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Industrial networks – Wireless communication network and communication profiles – WirelessHART™

Réseaux industriels – Réseau de communications sans fil et profils de communication – WirelessHART™

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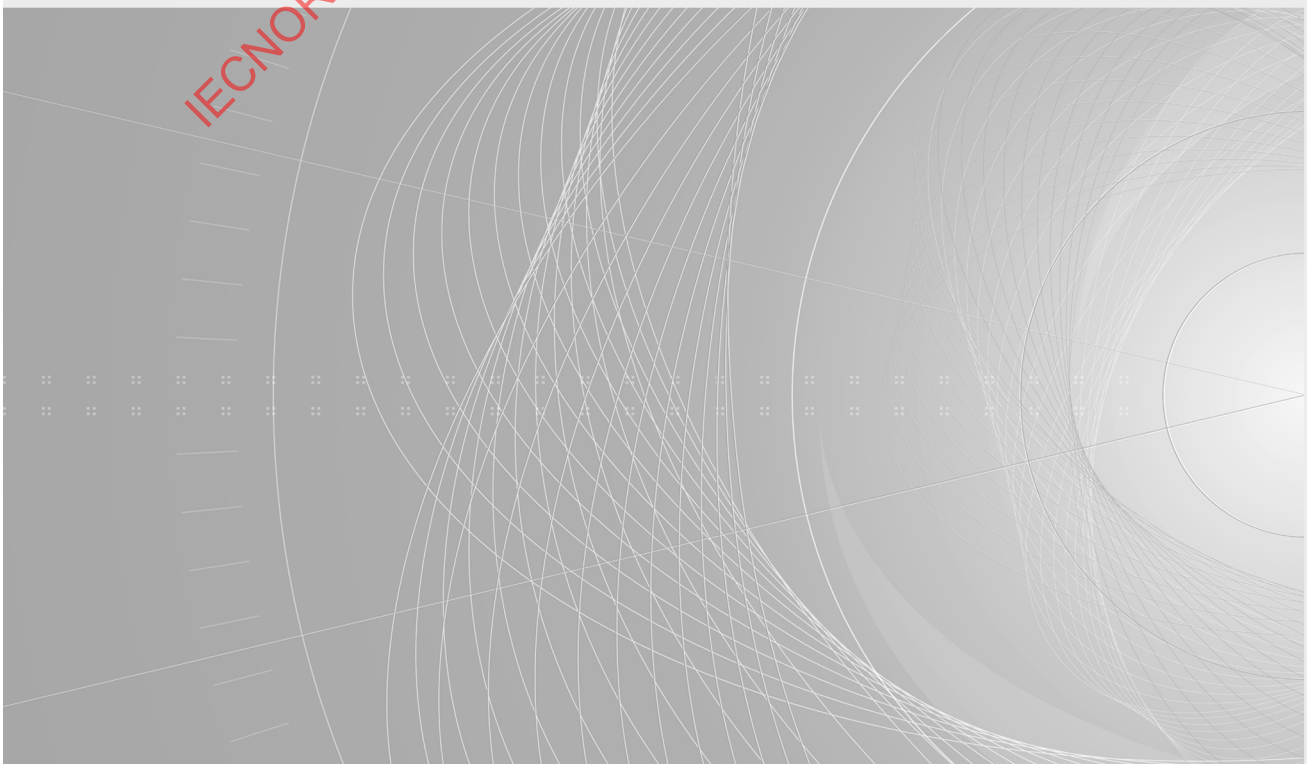

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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INDUSTRIAL NETWORKS – WIRELESS COMMUNICATION NETWORK AND COMMUNICATION PROFILES – WirelessHART™

FOREWORD

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International Standard IEC 62591 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial process measurement, control and automation.

This second edition cancels and replaces the first edition published in 2010. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- enhancements to the performance statistics using key performance indicators (KPI). These improvements result in expansion of statistics provided by Gateways. For example Read network device statistics service was expanded and Read network statistics service was added to provide a summary of network performance;
- "Stale Data" detection was added (see services Read stale data setpoints, Write stale data timer and Write stale data count setpoint). These standardize Gateway reporting should process data or events fail to arrive at the Gateway in a timely fashion. For

example, Host Applications will receive the "Update Failure" Response Code should the process data in the command response be stale;

- gateway commands were added;
- a Quarantined State was added;
- CCA Modes were extended to be more in-line with IEEE 802.15.4;
- clarifications on whitelist and blacklist management were added;
- clarifications on join (e.g. only require a single neighbor) were added;
- clarifications on use of join links, table management, and defaults were added;
- corrections and updates were made.

The reader's attention is drawn to the fact that Annex M lists all of the “in-some-country” clauses on differing practices of a less permanent nature relating to the subject of this standard.

The text of this standard is based on the following documents:

FDIS	Report on voting
65C/835/FDIS	65C/842/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

The contents of the corrigendum of March 2021 have been included in this copy.

INTRODUCTION

This International standard provides the specification, definitions, and profile for a Wireless communication network. It supplements IEC 61158-5-20, IEC 61158-6-20 where some services and commands are specified and it supplements IEC 61784-1 where a Communication Profile CP 9/1, universal command, is specified.

This document follows the structure and conventions of IEC 61158 series (for example separation of DL-service definitions and DL-protocol specification) and conventions of IEC 61784-1. IEC 61158 series specify different communication networks. These are structured in different Types. The Type 20 is assigned to technologies of Hart™[1] Communication Foundation (HCF). For other assignments of Type numbers see IEC 61158-1.

IEC 61784-1, and IEC 61784-2 provide Communication Profile Families (CPF), and, within a family, one to n Communication Profiles. The assigned CPF number for technologies of the HCF is CPF 9. For other assignments of CPF numbers see IEC 61158-1.

A new project number IEC 62591 was assigned to the Type 20 enhancements and the associated CP 9/2, so that this document contains the Type 20 specific equivalent to the IEC 61158 series and of CPF 9 specific profile using the same conventions as used in IEC 61784-1. The equivalent of 4 Type specific subparts and the profile are organized in this document in different clauses.

The Type 20 protocol supports two way digital communications for process measurement and control devices. Applications include remote process variable interrogation, cyclical access to process data, parameter setting and diagnostics. This document defines the specification that comprises the Type 20 field communications protocol for wireless devices. Specification of the Type 20 protocol is based largely on the OSI 7-layer Communication Model.

The International Electrotechnical Commission (IEC) draws attention to the fact that it is claimed that compliance with this document may involve the use of patents concerning the claims of the patents listed below given in the normative clauses.

US 8676219 [HCF]	Combined Wired and Wireless Communications with Field Devices in a Process Control Environment
US 8798084 [HCF]	Increasing Reliability and Reducing Latency in a Wireless Network
US 8325627 [HCF]	Adaptive Scheduling in a Wireless Network
US 8660108 [HCF]	Synchronizing Timeslots in a Wireless Communication Protocol
US 8169974 [HCF]	Suspending Transmissions in a Wireless Communication Network
US 8670746 [HCF]	Enhancing Security in a Wireless Network
US 8670749 [HCF]	Enhancing Security in a Wireless Network
US 8451809 [HCF]	Wireless Gateway in a Process Control Environment Supporting a Wireless Communication Protocol
US 8570922 [HCF]	Efficient Addressing in Wireless HART Protocol
US 8942219 [HCF]	Support for Network Management and Device Communications in a Wireless Network

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US 8406248 [HCF]	Priority Based Scheduling and Routing in a Wireless Network
US 8892769 [HCF]	Routing Packets on a Network Using Directed Graphs
US 8230108 [HCF]	Routing Packets on a Network Using Directed Graphs
US 8356431 [HCF]	Scheduling Communication Frames in a Wireless Network

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INDUSTRIAL NETWORKS – WIRELESS COMMUNICATION NETWORK AND COMMUNICATION PROFILES – WirelessHART™

1 Scope

This International Standard specifies a wireless communication network in addition to the Type 20 in IEC 61158-3-20, IEC 61158-4-20, IEC 61158-5-20, IEC 61158-6-20 and a Communication Profile CP 9/2 in addition to IEC 61784-1, CPF 9.

This standard specifies the following:

- Physical layer service definition and protocol specification,
- Data-link layer service and protocol,
- Application layer service and protocol,
- Network management,
- Security,
- Communication profile,
- Wireless procedures and
- Gateway.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61158-1:2014, *Industrial communication networks – Fieldbus specifications – Part 1: Overview and guidance for the IEC 61158 and IEC 61784 series*

IEC 61158-2, *Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition*

IEC 61158-3-20:2014, *Industrial communication networks – Fieldbus specifications – Part 3-20: Data-link layer service definition – Type 20 elements*

IEC 61158-4-20:2014, *Industrial communication networks – Fieldbus specifications – Part 4-20: Data-link layer protocol specification – Type 20 elements*

IEC 61158-5-20:2014, *Industrial communication networks – Fieldbus specifications – Part 5-20: Application layer service definition – Type 20 elements*

IEC 61158-6-20:2014, *Industrial communication networks – Fieldbus specifications – Part 6-20: Application layer protocol specification – Type 20 elements*

IEC 61784-1:2014, *Industrial Communication Networks – Profiles – Part 1: Fieldbus profiles*

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IEC 61784-2:2014, *Industrial Communication Networks – Profiles – Part 2: Part 2: Additional fieldbus profiles for real-time networks based on ISO/IEC 8802-3*

ISO/IEC 7498-1, *Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model*

ISO/IEC 7498-3, *Information technology – Open Systems Interconnection – Basic Reference Model: Naming and addressing*

ISO/IEC/IEEE 60559, *Information technology – Microprocessor Systems – Floating-Point arithmetic*

ISO/IEC 8824 (all parts), *Information Technology – Abstract Syntax Notation One (ASN.1)*

ISO/IEC 8859-1, *Information technology – 8-bit single-byte coded graphic character sets – Part 1: Latin alphabet No. 1*

ISO/IEC 9545, *Information technology – Open Systems Interconnection – Application Layer structure*

ISO/IEC 10731, *Information technology – Open Systems Interconnection – Basic Reference Model – Conventions for the definition of OSI services*

IEEE Std 802-2001, *IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture*

IEEE Std 802.15.4-2011, *IEEE Standard for Local and metropolitan area networks – Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)*

IEEE Std 802.15.4e:2012, *IEEE Standard for Local and metropolitan area networks – Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs) – Amendment 1: MAC sublayer*

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3 Terms, definitions, symbols, abbreviations and conventions

For the purposes of this document, the following terms as defined in these publications apply.

3.1 Reference model terms and definitions

3.1.1 Terms and definitions from ISO/IEC 7498-1 terms and ISO/IEC 7498-3 terms

This standard is based in part on the concepts developed in ISO/IEC 7498-1 and ISO/IEC 7498-3, and makes use of the following terms defined therein.

a) abstract syntax
b) application entity
c) application entity invocation
d) application process
e) application process invocation
f) application protocol data unit
g) application service element
h) application transaction
i) DL protocol-data-unit
j) DL service-data-unit

k) DL-entity (N=2)
l) DLS user-data
m) NL protocol-data-unit
n) NL service-data-unit
o) NL-entity (N=3)
p) NLS user-data
q) presentation context
r) real open system
s) TL protocol-data-unit
t) TL service-data-unit
u) TL-entity (N=4)
v) TLS user-data
w) transfer syntax

3.1.2 Terms and definitions from ISO/IEC 9545

a) application-association
b) application-context
c) application context name
d) application-entity-invocation
e) application-entity-type
f) application-process-invocation
g) application-process-type
h) application-service-element
i) application control service element

3.1.3 Terms and definitions from ISO/IEC 8824

a) object identifier
b) type
c) value
d) simple type
e) structured type
f) component type
g) tag
i) true
j) false
k) integer type
m) octet string type
n) null type
o) sequence type
p) sequence of type
q) choice type
r) tagged type
s) any type
t) module

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u) production

3.1.4 Terms and definitions from ISO/IEC 8825-1

a) encoding (of a data value)

b) data value

c) identifier octets (the singular form is used in this standard)

d) length octet(s) (both singular and plural forms are used in this standard)

e) contents octets

3.2 Specific terms and definitions

3.2.1
absolute slot number
count of all slots that have occurred since the network was formed

Note 1 to entry: This number always increments and is never reset to any fixed value or zero. Its current value is always the sequence number of the current slot. Its maximum value is $(2^{40} - 1)$ after that it rolls over to zero.

3.2.2
acknowledge
explicit data-link response to the successful reception of a directed, non-broadcast DLPDU from a DLE source device and the second DLPDU of a two-DLPDU transaction

3.2.3
adapter
network device that enables connection and communication with a field device which does not have a direct connection to a Type 20 network

3.2.4
Advertise DLPDU
DLPDU that invites new devices into the network

Note 1 to entry: When a device wishes to join a network, it listens for these DLPDUs and then uses the information in the DLPDU to synchronize with the network and initiate the join process.

3.2.5
analog channel
continuously varying electrical signal connecting a field device to the remainder of the data acquisition or control system

Note 1 to entry: Some field devices support multiple analog channels (input or output).

Note 2 to entry: Each analog channel transmits a single dynamic variable to or from the field device.

3.2.6
application
function or data structure for which data is consumed or produced

[SOURCE: IEC 61158-6-9:2014: 3.2.1]

3.2.7
application domain
classification of the application process based on communication priority and capacity requirement

3.2.8
application object
object class that manages and provides the run time exchange of messages across the network and within the network device

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Note 1 to entry: Multiple types of application object classes may be defined.

[SOURCE: IEC 61158-6-9:2014, 3.2.3]

3.2.9
application relationship
cooperative association between two or more application-entity-invocations for the purpose of exchange of information and coordination of their joint operation

Note 1 to entry: This relationship is activated either by the exchange of application-protocol-data-units or as a result of pre-configuration activities.

[SOURCE: IEC 61158-6-9:2014, 3.2.8]

3.2.10
application relationship endpoint
context and behavior of an application relationship as seen and maintained by one of the application processes involved in the application relationship

Note 1 to entry: Each application process involved in the application relationship maintains its own application relationship endpoint.

3.2.11
ASN time
time represented as absolute slot number; any instance in time is equal to absolute slot number at that instance

3.2.12
attribute
description of an externally visible characteristic or feature of an object

Note 1 to entry: The attributes of an object contain information about variable portions of an object. Typically, they provide status information or govern the operation of an object. Attributes may also affect the behavior of an object. Attributes are divided into class attributes and instance attributes.

3.2.13
availability
percentage of packets that arrive at the gateway within the burst period of the device

3.2.14
behavior
indication of how the object responds to particular events

Note 1 to entry: Its description includes the relationship between attribute values and services.

3.2.15
broadcast
process of sending a PDU to all devices that are connected to the network and are able to receive the transmission

3.2.16
broadcast address
address used by a master to send a command to all devices

3.2.17
busy
state of a device which is active on different tasks and cannot execute a command at the time

3.2.18
channel
RF frequency band used to transmit a modulated signal carrying packets

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3.2.19
channel blacklisting
method of eliminating an RF channel from usage

3.2.20
channel hopping
regular change of transmit or receive frequency to combat interference and fading

3.2.21
channel offset
link-specific value provided by the network manager that is used to calculate the channel to use when channel hopping

3.2.22
class
set of objects, all of which represent the same kind of system component

Note 1 to entry: A class is a generalization of the object; a template for defining variables and methods. All objects in a class are identical in form and behavior, but usually contain different data in their attributes.

3.2.23
class attributes
attribute that is shared by all objects within the same class

3.2.24
class code
unique identifier assigned to each object class

3.2.25
class specific service
service defined by a particular object class to perform a required function which is not performed by a common service

Note 1 to entry: A class specific object is unique to the object class which defines it.

3.2.26
clear channel assessment
testing while the RF channel is in use to avoid initiating a transaction

Note 1 to entry: It is performed by listening to the channel prior to sending the first DLPDU of a transaction. If signal is detected, then the transaction is deferred to a later TDMA slot.

3.2.27
client
a) object which uses the services of another (server) object to perform a task

b) initiator of a message to which a server reacts, such as the role of an AR endpoint in which it issues confirmed service request APDUs to a single AR endpoint acting as a server

[SOURCE: IEC 61158-6-9:2014, 3.2.17]

3.2.28
coexistence
state in which all wireless communication solutions of a plant using shared medium fulfill all their application communication requirements

Note 1 to entry: This is consistent with the definition of coexistence in IEEE 802.15.2-2003.

[SOURCE: IEC 62657-2:2013, 3.1.12]

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3.2.29
conformity, conform to
result of an systematic examination of the extent to which a product, process or service fulfils specified requirements

Note 1 to entry: EN: This term and its definition are derived from the term “conformity evaluation” defined in IEC 60050-151-16-14:2001.

3.2.30
connected
device has issued a join request

3.2.31
compliance, comply with
data or information belonging or pertaining to a standard, which match the requirements of another standard, law, or base document

3.2.32
conveyance path
unidirectional flow of APDUs across an application relationship

3.2.33
cyclic
term used to describe events which repeat in a regular and repetitive manner

3.2.34
device
any entity containing an implementation of Type 20 fieldbus

Note 1 to entry: The term device and WirelessHART device are synonyms of the term Radio and Telecommunications Terminal Equipment (R&TTE) and the term equipment used in some harmonized standards like EN 300 328.

3.2.35
device ID
serial number for a device that is unique among all instances of one type of device

3.2.36
device profile
collection of device dependent information and functionality providing consistency between similar devices of the same device type

3.2.37
expanded device type
manufacturer’s type of a device as specified in IEC 61158-6-20:2014, Table 6

3.2.38
device variable
uniquely defined data item within a Field Device that is always associated with cyclical process information

Note 1 to entry: A device variable's value varies in response to changes and variations in the process to which the device is connected.

3.2.39
discovery
process of finding a new neighbor by listening to the special DLPDU that indicates the presence of the device

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3.2.40
discovery link
link that is used for transmitting and receiving the special DLPDU that indicates the presence of the device

3.2.41
dynamic variable
connection between a process and an analog channel

Note 1 to entry: A device may contain primary, secondary, tertiary, and quaternary variables. These are collectively called the dynamic variables.

3.2.42
endpoint
one of the communicating entities involved in a connection

3.2.43
error
discrepancy between a computed, observed or measured value or condition and the specified or theoretically correct value or condition

3.2.44
error code
identification of a specific type of error within an error class

3.2.45
field device
network device that is connected to the process or to plant equipment

Note 1 to entry: It directly connects to the sensor or actuator or performs process control function and it is directly connected to the physical layer of Type 20.

3.2.46
frequency channel
allocation of the frequency spectrum in a given frequency range

3.2.47
gateway
network device containing at least one host interface such as serial or Ethernet, acting as ingress or an egress point enabling communication between host applications and field devices

3.2.48
graph
collection of directed paths among network devices such that more than one route is possible from a source device to destination device

3.2.49
Graph_ID
identifier used to indicate a specific graph entry

3.2.50
joined
device is in communication with the network manager and has received at least: the network key, its nickname, the unicast network manager session, a Superframe and links from the network manager, graph edges, a time-source neighbor, and a route to the network manager handheld host application residing on a portable device

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3.2.51
handheld superframe
specific superframe for diagnostics

3.2.52
Harmonized Standard
listed European standard in the official Journal of the European Commission (EC)

3.2.53
hop
movement of a packet directly between two adjacent neighbors in one network transaction without the participation of any other node in the network

3.2.54
hop to live
field in the network header of each packet that specifies how many more hops a packet can travel before being discarded

3.2.55
join
process by which a network device is authenticated and allowed to participate in the network

Note 1 to entry: A device is considered Joined when it has the network key, a network manager session and a normal (not join) superframe and links.

3.2.56
join_key
security key that is used to start the join process

3.2.57
latency
time it takes for a packet to cross a network connection, from sender to receiver

3.2.58
link
full communication specification between adjacent devices in a network and it includes the communication parameters necessary to move a DLPDU one hop

Note 1 to entry: A Link is a function of source and destination address pairing, slot and channel offset assignment, direction of communication, dedicated or shared communication, and type. Links are assigned to superframes as part of the scheduling process.

3.2.59
logical link control
higher of the two data-link layer sublayers and used for error detection, flow control, framing, and addressing

3.2.60
long_tag
32-character restricted ISO Latin-1 string used to identify a field device

3.2.61
loop current
value measured by a mA in series with the field device

Note 1 to entry: The loop current is a near DC analog 4 mA to 20 mA signal used to communicate a single value between the control system and the field device. Voltage mode devices use "Volts DC" as their engineering units where "loop current" values are used.

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3.2.62
maintenance port
interface in the network device that is used for provisioning

Note 1 to entry: This interface is used to write the Join_key and network identifier, and to monitor the join process.

3.2.63
management information
network-accessible information that supports managing the operation of the fieldbus system, including the application layer

Note 1 to entry: Managing includes functions such as controlling, monitoring, and diagnosing.

3.2.64
manufacturer ID
2 octet enumeration identifying the manufacturer that produced a device

Note 1 to entry: A manufacturer is required to use the value assigned to it and is not permitted to use the value assigned to another manufacturer.

3.2.65
master
device that initiates communication activity by sending request APDU to a device and expecting a response PDU

3.2.66
medium access control
lower of the two data-link sublayers and used for controlling the access to the communication channel

3.2.67
multicast
sending of one packet to more than one device in the network using only one transmission

3.2.68
neighbor
adjacent node in the network such that the received signal level (RSL) from it suggests that the communication is possible in at least one direction

3.2.69
neighbor table
list of all devices that the device considers as neighbor

Note 1 to entry: It also stores the attributes of the neighbor.

3.2.70
network
series of nodes connected by some type of communication medium

Note 1 to entry: The connection paths between any pair of nodes can include repeaters, routers and gateways.

3.2.71
network device
device with a direct physical layer connection to the network

Note 1 to entry: Each network device has a unique address that is used in communication with the device. Network devices include field device, access point (i.e. gateway), adapter and handheld.

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3.2.72
network_ID
identifier used to indicate a network to which all inter-communicating devices are connected

3.2.73
network manager
entity that is responsible for configuration of the network, scheduling communication between network devices, management of the routing tables and monitoring and reporting the health of the network

3.2.74
nickname
identifier assigned to a device such that it is unique within the network to which the device is connected

3.2.75
node
addressable logical or physical device attached to the network

3.2.76
nonce
non-repeating number constructed so as to be unique to the current packet and to ensure that old communications cannot be reused in replay attacks

Note 1 to entry: Nonce is necessary for maintaining packet secrecy and providing sender authenticity and packet integrity.

3.2.77
packet
formatted, aggregated bits that are transmitted together in time across the physical medium

3.2.78
packet error rate
percentage of failed transmits to a device that is given on a neighbor-by-neighbor basis

3.2.79
packets late or lost
number of late or lost packets reported by each device

3.2.80
parameterization
configuring a field device for proper operation in a given plant installation

3.2.81
portal
combination of Gateway, Network Manager, and Access Point(s)

3.2.82
provisioning
configuring a field device for integration into the network

3.2.83
path
direct communication link between two neighbor devices in the mesh

3.2.84
payload data
contents of a data message that is being transmitted

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3.2.85
pipe
secure, bi-directional, virtual communication connection between peer devices

3.2.86
polling address
integer used to identify a device

Note 1 to entry: The polling address is used to construct a one-octet address.

3.2.87
pre-defined AR endpoint
AR endpoint that is defined locally within a device without use of the create service

Note 1 to entry: Pre-defined ARs that are not pre-established are established before being used.

3.2.88
pre-established AR endpoint
AR endpoint that is placed in an established state during configuration of the AEs that control its endpoints

3.2.89
route
one sequence of unidirectional paths from one device to another connecting a source device to a destination device

3.2.90
route ID
identifier used to indicate a specific route

3.2.91
server
<communication> role of an AREP in which it returns a confirmed service response APDU to the client that initiated the request

3.2.92
server
<system> object which provides services to another (client) object

3.2.93
service
operation or function than an object and/or object class performs upon request from another object and/or object class

Note 1 to entry: A set of common services is defined and provisions for the definition of object-specific services are provided. Object-specific services are those which are defined by a particular object class to perform a required function which is not performed by a common service.

3.2.94
session ID
identifier used to indicate a specific session entry

3.2.95
slave
device that initiates communication activity only after it receives a request PDU from a master device and it is required to send a response to that request

3.2.96
slot
fixed time interval that may be used for communication between neighbors

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3.2.97
superframe
collection of slots repeating at a constant rate, each slot having a link associated with it

3.2.98
Superframe_ID
identifier used to indicate a specific superframe entry

3.2.99
tag
8-character ASCII string used to identify a field device

3.2.100
time division multiple access
medium access control technique that uses time slots where communications between devices can occur

Note 1 to entry: It provides collision free, deterministic communications.

3.2.101
transaction
exchange of related, consecutive frames between two peer medium access control entities, required for a successful transmission

Note 1 to entry: A transaction consists of either (a) a single PhPDU transmission from a source device, or (b) one PhPDU from the source device followed by a second, link-level acknowledgement PhPDU from the destination device.

3.2.102
throughput
average number of packets per second transmitted or received by the combination of the Network Manager and Gateway

3.2.103
transmission time
time for a packet to traverse from the source to the destination at the DLL

3.2.104
unicast
sending of a packet to a single device in the network

3.2.105
Unique ID
identifier assigned to a device which is unique among all instances of the devices compliant to this standard and compliant to Communication Profile CP 9/2 using identical organization name as specified in 9.3.1

3.2.106
utilization
percentage of recommended capacity currently consumed

3.3 Abbreviations

ACK	Acknowledge
AE	Application entity
AL	Application layer
AP	Application process
APDU	Application protocol data unit

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APO	Application Object
AR	Application relationship
AREP	Application relationship endpoint
ARPM	Application Relationship Protocol Machine
ASCII	American Standard Code for Information Interchange
ASE	Application Service Element
ASN	Absolute Slot Number
BACK	Burst acknowledge
CCA	Clear channel assessment
Cnf	Confirmation
CP	Communication Profile
CPF	Communication Profile Family
CRC	Cyclic redundancy check
dBm	Power ratio in decibels (dB) of the measured power, referenced to one mW (1 mW), 0 dBm =1 mW,10 dBm= 10 mW, 20 dBm= 100 mW, 30 dBm= 1 W
DL-	Data-link layer (as a prefix)
DLE	DL-entity (the local active instance of the data-link layer)
DLL	Data-link layer
DLM	DL-management
DLMS	DL-management service
DLPDU	Data-link protocol data unit
DLS	DL-service
DLSDU	DL-service-data-unit
DR	Delayed response
DRM	Delayed response mechanism
DSSS	Direct sequence spread spectrum
DUT	Device under test
EUI-64	Extended unique identifier (64 bits long)
FAL	Fieldbus application layer
FSMP	FAL Service Protocol Machine
HCF	HART™ Communication Foundation
HTL	Hop to live
ID	Identifier
IEC	International Electrotechnical Commission
Ind	Indication
ISM	Industrial, scientific and medical
ITU-T	International Telecommunication Union – Telecommunication Standardization Sector
KPI	Key Performance Indicators
LLC	Logical link control
LSB	Least significant byte
MAC	Medium access control
MIC	Message integrity code
MSB	Most significant byte
NL	Network layer
NL-	Network layer (as a prefix)
NLE	NL-entity (the local active instance of the network layer)
NLM	NL-management

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NLMS	NL-management service	
NLS	NL-service	
NLSDU	NL-service-data-unit	
NPDU	NL-protocol-data-unit	
NSDU	NL-service-data-unit	
O-QPSK	Offset Quadrature Phase-Shift Keying	
OSI	Open Systems Interconnect	
OUI	Organizationally Unique Identifier	
PER	Packet Error Rate	
PDU	Protocol data unit	
PhE	PhL-entity (the local active instance of the physical layer)	
PhL-	Physical layer (as a prefix)	
PhPDU	PhL-protocol-data-unit	[ISO/IEC 7498-1]
PhS	Physical layer service	[ISO/IEC 7498-1]
PHY	Physical layer [IEEE 802.15.4]	
QoS	Quality-of-service	
Req	Request	
RF	Radio Frequency	
RSL	Received signal level	
Rsp	Response	
RSV	Reserved	
SAP	Service access point	
SN	Sign bit	
SOM	Start of message	
STX	Start of a transaction	
TDMA	Time Division Multiple Access	
TL	Transport layer	
TL-	Transport layer (as a prefix)	
TLE	TL-entity (the local active instance of the transport layer)	
TLM	TL-management	
TLMS	TL-management service	
TLS	TL-service	
TMPM	Transport layer Mapping Protocol Machine	
TPDU	TL-protocol-data-unit	
TSDU	TL-service-data-unit	
VFD	Virtual field device	

3.4 Conventions

3.4.1 Conventions used for DL-services

This standard uses the descriptive conventions given in ISO/IEC 10731.

The service model, service primitives, and time-sequence diagrams used are entirely abstract descriptions; they do not represent a specification for implementation.

Service primitives, used to represent service user/service provider interactions (see ISO/IEC 10731), convey parameters that indicate information available in the user/provider interaction.

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This standard uses a tabular format to describe the component parameters of the Physical, Data Link, Network, Transport and Application layer service primitives. The parameters that apply to each group of primitives are set out in tables throughout the remainder of this standard. Each table consists of up to six columns, containing the name of the service parameter, and a column each for those primitives and parameter-transfer directions used by the service:

– the request primitive's input parameters;
– the request primitive's output parameters;
– the indication primitive's output parameters;
– the response primitive's input parameters; and
– the confirm primitive's output parameters.

One parameter (or part of it) is listed in each row of each table. For local services, only request primitive with input and output parameters is used. Under the appropriate service primitive columns, a code is used to specify the type of usage of the parameter on the primitive and parameter direction specified in the column:

M parameter is mandatory for the primitive.

U parameter is a user option and may or may not be provided depending on the dynamic usage of the DLS-user. When not provided, a default value for the parameter is assumed.

S only one parameter in a group of parameters using this code is required.

C parameter is conditional upon other parameters or upon the environment of the DLS-user.

CU parameter is a conditional user option, and may or may not be permitted depending upon other parameters or upon the environment of the DLS-user. When permitted, it may or may not be provided depending on the dynamic usage of the DLS-user. When permitted and not provided, a default value for the parameter is assumed.

(blank) parameter is never present.

Some entries are further qualified by items in brackets. These may be:

a) a parameter-specific constraint

(=) indicates that the parameter is semantically equivalent to the parameter in the service primitive to its immediate left in the table;

(≤) indicates that the set of parameter values has an implicit order and that the parameter's value is less than or equal to that of the parameter in the service primitive to its immediate left in the table (that is, left by one or two columns);

(≥) indicates that the set of parameter values has an implicit order and that the parameter's value is greater than, or equal to, that of the parameter in the service primitive to its immediate left in the table (that is, left by one or two columns).

b) an indication that some note applies to the entry

(n) indicates that the following note n contains additional information pertaining to the parameter and its use.

3.4.2 Conventions used for DL-protocol (state machine)

This standard uses a diagram to represent a state machine. The following convention is used.

- The labeled rectangles represent states that a component can be in.
- State transitions are directed lines. They show which state a component leaves and which state it transitions to.

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- A transition is labeled with the events that caused it and the corresponding actions (this may be empty). The events (above the line) causing the transition is separated from the resulting actions (below the line) by a horizontal line.
- A tilde (" ~ ") means the one's complement or negation.

3.4.3 Conventions for Application Layer service

3.4.3.1 Overview

The Fieldbus Application Layer (FAL) is defined as a set of object-oriented Application Service Elements (ASE). Each ASE is specified in a separate subclause. Each ASE specification is composed of two parts, its class specification, and its service specification.

The class specification defines the attributes of the class. The service specification defines the services that are provided by the ASE.

3.4.3.2 Conventions for class definitions

Class definitions are described using templates. Each template consists of a list of attributes for the class. An example of the template is shown below:

FAL ASE:			**ASE Name**
CLASS:		Class Name	
CLASS ID:			#
PARENT CLASS:			Parent Class Name
ATTRIBUTES:			
1	(o)	Key Attribute:	numeric identifier
2	(o)	Key Attribute:	name
3	(m)	Attribute:	attribute name(values)
4	(m)	Attribute:	attribute name(values)
4.1	(s)	Attribute:	attribute name(values)
4.2	(s)	Attribute:	attribute name(values)
4.3	(s)	Attribute:	attribute name(values)
5.	(c)	Constraint:	constraint expression
5.1	(m)	Attribute:	attribute name(values)
5.2	(o)	Attribute:	attribute name(values)
6	(m)	Attribute:	attribute name(values)
6.1	(s)	Attribute:	attribute name(values)
6.2	(s)	Attribute:	attribute name(values)
SERVICES:			
1	(o)	OpsService:	service name
2.	(c)	Constraint:	constraint expression
2.1	(o)	OpsService:	service name
3	(m)	MgtService:	service name

(1) The "FAL ASE:" entry is the name of the FAL ASE that provides the services for the class being specified.

(2) The "CLASS:" entry is the name of the class being specified. All objects defined using this template will be an instance of this class. The class may be specified by this standard, or by a user of this standard.

(3) The "CLASS ID:" entry is a number that identifies the class being specified. This number is unique within the FAL ASE that will provide the services for this class. When qualified by the identity of its FAL ASE, it unambiguously identifies the class within the scope of the FAL. The value "NULL" indicates that the class cannot be instantiated. Class IDs between 1 and 255 are reserved by this standard to identify standardized classes. They have been assigned to maintain compatibility with existing national standards. CLASS IDs between 256 and 2048 are allocated for identifying user defined classes.

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(4) The "PARENT CLASS:" entry is the name of the parent class for the class being specified. All attributes defined for the parent class and inherited by it are inherited for the class being defined, and therefore do not have to be redefined in the template for this class.

NOTE The parent-class "TOP" indicates that the class being defined is an initial class definition. The parent class TOP is used as a starting point from which all other classes are defined. The use of TOP is reserved for classes defined by this standard.

(5) The "ATTRIBUTES" label indicate that the following entries are attributes defined for the class.

a) Each of the attribute entries contains a line number in column 1, a mandatory (m) / optional (o) / conditional (c) / selector (s) indicator in column 2, an attribute type label in column 3, a name or a conditional expression in column 4, and optionally a list of enumerated values in column 5. In the column following the list of values, the default value for the attribute may be specified.

b) Objects are normally identified by a numeric identifier or by an object name, or by both. In the class templates, these key attributes are defined under the key attribute.

c) The line number defines the sequence and the level of nesting of the line. Each nesting level is identified by period. Nesting is used to specify

i) fields of a structured attribute (4.1, 4.2, 4.3),

ii) attributes conditional on a constraint statement (5). Attributes may be mandatory (5.1) or optional (5.2) if the constraint is true. Not all optional attributes require constraint statements as does the attribute defined in (5.2),

iii) the selection fields of a choice type attribute (6.1 and 6.2).

(6) The "SERVICES" label indicates that the following entries are services defined for the class.

a) An (m) in column 2 indicates that the service is mandatory for the class, while an (o) indicates that it is optional. A (c) in this column indicates that the service is conditional. When all services defined for a class are defined as optional, at least one has to be selected when an instance of the class is defined.

b) The label "OpsService" designates an operational service (1).

c) The label "MgtService" designates a management service (2).

d) The line number defines the sequence and the level of nesting of the line. Each nesting level is identified by period. Nesting within the list of services is used to specify services conditional on a constraint statement.

3.4.3.3 Conventions for service definitions

3.4.3.3.1 General

This standard uses the descriptive conventions given in ISO/IEC 10731.

The service model, service primitives, and time-sequence diagrams used are entirely abstract descriptions; they do not represent a specification for implementation.

3.4.3.3.2 Service parameters

Service primitives are used to represent service user/service provider interactions (ISO/IEC 10731). They convey parameters which indicate information available in the user/provider interaction.

NOTE 1 See the Note under 3.4.3.3.3 relative to the non-inclusion of service parameters that are appropriate to a protocol specification or programming interface specification or implementation specification, but not to an abstract service definition.

This standard uses a tabular format to describe the component parameters of the service primitives. The parameters that apply to each group of service primitives are set out in tables

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throughout the remainder of this standard. Each table consists of up to six columns: a column for the name of the service parameter, and a column each for those primitives and parameter-transfer directions used by the service. The possible six columns are

1) the parameter name;
2) the request primitive's input parameters;
3) the request primitive's output parameters;

NOTE 2 This is a seldom-used capability. Unless otherwise specified, request primitive parameters are input parameters.

4) the indication primitive's output parameters;
5) the response primitive's input parameters; and
6) the confirm primitive's output parameters.

NOTE 3 The request, indication, response and confirm primitives are also known as requestor.submit, acceptor.deliver, acceptor.submit, and requestor.deliver primitives, respectively (see ISO/IEC 10731).

One parameter (or component of it) is listed in each row of each table. Under the appropriate service primitive columns, a code is used to specify the type of usage of the parameter on the primitive specified in the column:

M parameter is mandatory for the primitive

U parameter is a User option, and may or may not be provided depending on dynamic usage of the service user. When not provided, a default value for the parameter is assumed.

C parameter is conditional upon other parameters or upon the environment of the service user.

– (blank) parameter is never present.

S parameter is a selected item.

Some entries are further qualified by items in brackets. These may be

a) a parameter-specific constraint:

"(=)" indicates that the parameter is semantically equivalent to the parameter in the service primitive to its immediate left in the table,

b) an indication that some note applies to the entry:

"(n)" indicates that the following note "n" contains additional information pertaining to the parameter and its use.

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3.4.3.3.3 Service procedures

The procedures are defined in terms of

- the interactions between application entities through the exchange of fieldbus Application Protocol Data Units, and
- the interactions between an application layer service provider and an application layer service user in the same system through the invocation of application layer service primitives.

These procedures are applicable to instances of communication between systems which support time-constrained communications services within the fieldbus application layer.

NOTE The Data-link layer services define sets of abstract services. They are neither protocol specifications nor implementation specifications nor concrete programming interface specifications. Therefore there are restrictions

on the extent to which service procedures can be mandated defined in Clause 5. Protocol aspects that can vary among different protocol specifications or different implementations that instantiate the same abstract services are unsuitable for inclusion in these service definitions, except at the level of abstraction that is necessarily common to all such expressions. In this document, Clause 7 is the equivalent of the IEC 61158-5 subseries.

For example the means by which service providers pair request and reply Protocol data units (PDU) is appropriate for specification in an IEC 61158-6 subseries protocol specification standard but not in an IEC 61158-5 subseries abstract service definition standard. Similarly, local implementation methods by which a service provider or service user pairs request and confirm(-action) primitives, or indication and response primitives, is appropriate for an implementation specification or for a programming interface specification, but not for an abstract service standard or for a protocol standard, except at a level of abstraction that is necessarily common to all embodiments of the specifying standard. In all cases, the abstract definition is not permitted to over-specify the more concrete instantiating realization.

Further information on the conceptual service procedures of an implementation of a protocol that realizes the services of one of the IEC 61158-5 subseries abstract service definitions can be found in IEC 61158-1:2014, Clause 9.

3.4.4 Conventions for the AL-protocol

3.4.4.1 General concept

The FAL is defined as a set of object-oriented ASEs. Each ASE is specified in a separate subclause. Each ASE specification is composed of three parts: its class definitions, its services, and its protocol specification. The first two are contained in Clause 7 and IEC 61158-5 subseries. The protocol specification for each of the ASEs is defined in Clause 8 and IEC 61158-6 subseries.

The class definitions define the attributes of the classes supported by each ASE. The attributes are accessible from instances of the class using the Management ASE services specified in Clause 7 and IEC 61158-5 subseries. The service specification defines the services that are provided by the ASE.

This standard uses the descriptive conventions given in ISO/IEC 10731.

3.4.4.2 Conventions for class definitions

The data-link layer mapping definitions are described using templates. Each template consists of a list of attributes for the class. The general form of the template is defined in IEC 61158-5-20:2014, 3.5.2.

3.4.4.3 Conventions used in state machines

The conventions used in state machines are described in Table 1.

Table 1 – Conventions used for state machines

#	Current state	Event / condition => action	Next state
Name of this transition	The current state to which this state transition applies	Events or conditions that trigger this state transaction => The actions that are taken when the above events or conditions are met. The actions are always indented below events or conditions	The next state after the actions in this transition is taken

The conventions used in the state machines are as follows:

:= Value of an item on the left is replaced by value of an item on the right. If an item on the right is a parameter, it comes from the primitive shown as an input event.

xxx A parameter name.

Example:

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Identifier:= reason

means value of a 'reason' parameter is assigned to a parameter called 'Identifier.'

"xxx" Indicates fixed value.

Example:

Identifier:= "abc"

means value "abc" is assigned to a parameter named 'Identifier.'

= A logical condition to indicate an item on the left is equal to an item on the right.

< A logical condition to indicate an item on the left is less than the item on the right.

> A logical condition to indicate an item on the left is greater than the item on the right.

<> A logical condition to indicate an item on the left is not equal to an item on the right.

&& Logical "AND"

|| Logical "OR"

This construct allows the execution of a sequence of actions in a loop within one transition. The loop is executed for all values from start_value to end_value.

Example:

```
for (Identifier:= start_value to end_value)
    actions
    endfor
```

This construct allows the execution of alternative actions depending on some condition (which might be the value of some identifier or the outcome of a previous action) within one transition.

Example:

```
If (condition)
    actions
else
    actions
endif
```

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Readers are strongly recommended to refer to the subclauses for the Application relationship endpoint (AREP) attribute definitions, the local functions, and the FAL-PDU definitions to understand protocol machines. It is assumed that readers have sufficient knowledge of these definitions, and they are used without further explanations.

3.4.4.4 Class diagram

3.4.4.4.1 General

UML is used in this document to show class diagram. The purpose of a class diagram is to show the objects and their relationships within a system. In a class diagram objects are classes (as opposed to an instance diagram where the objects are instances of classes). There are several forms of relationships including associations, generalization/specialization, aggregation, and dependency.

3.4.4.4.2 Classes

Classes contain three compartments arranged vertically. The top compartment is the class name. The middle compartment lists the class's attributes. The bottom compartment lists the class's operations. When drawing a class element on a class diagram, the top compartment is mandatory, and the bottom two compartments are optional. The bottom compartment is not required in a diagram in which the purpose is to show only the relationship between classes. It is not necessary to show all attributes in all drawings where the class is used. Figure 1 shows a Superframe class with operations suppressed. In Figure 1, the class name is 'Superframe'. The class is illustrated with three attributes, Superframe_ID, NumSlots, and Active.

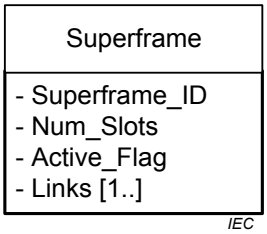
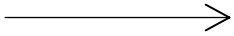
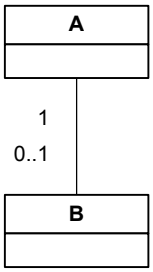
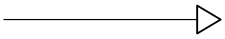


Figure 1 – Superframe class example

3.4.4.4.3 Relationships

The forms of relations used in this document are summarized in Table 2.

Table 2 – Class relationship notation

Relationship	Function	Notation
Bi-directional association	A bi-directional association is indicated by a solid line between the two classes.	
Uni-directional association	In a uni-directional association, two classes are related, but only one class knows that the relationship exists. It is indicated by a line with one arrow between the two classes.	
Association showing multiplicity	Multiplicity specifies how many instances of one class can be related to one instance of another class. In this example the 0..1 means that when an instance of a 'A' exists, it can either have zero or one instance of a 'B' associated with it (B may not have yet been created).	
Generalization	A relationship more specific and more general description, used for inheritance.	
Basic aggregation	Part-whole relationship – the lifecycle of a part class is independent from the whole class's lifecycle.	

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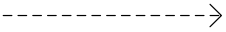
Relationship	Function	Notation
Composite aggregation	Part-whole relationship – the lifecycle of a part class is dependent on the containing object.	
Dependency	Shows a relationship between two model elements; it indicates that one object depends on another object for some behavior.	

3.4.4.4.4 Inheritance

An important concept in object-oriented design is inheritance. Inheritance refers to the ability of one class (child class) to inherit the identical functionality of another class (super class), and then add new functionality of its own. To model inheritance on a class diagram, a solid line is drawn from the child class (the class inheriting the behavior) with a closed, arrowhead (or triangle) pointing to the super class. Figure 2 shows a Superframe class modeled as a specialized type of Graph.

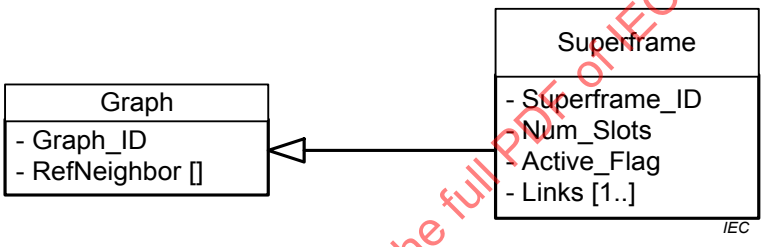


Figure 2 – Inheritance example

3.4.4.4.5 Basic aggregation

Another important concept in object-oriented design is aggregation. Aggregation is used to model a "whole to its parts" relationship. There are two forms of aggregation; basic aggregation and composition aggregation. In basic aggregation relationships, the lifecycle of a part class is independent from the whole class's lifecycle. As shown in Figure 3, Car is a whole entity and Wheel is part of the overall Car. The Wheel can be created ahead of time, and it can sit in a warehouse before being placed on a car during assembly.

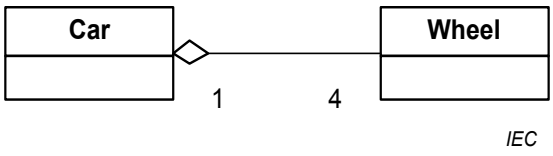


Figure 3 – Basic aggregation example

3.4.4.4.6 Composition aggregation

The other form of aggregation is composition aggregation, usually simply referred to as composition. Figure 4 shows the relationship of a superframe and its links. In this case a link cannot exist without the superframe. Composition is drawn with a filled diamond shape.

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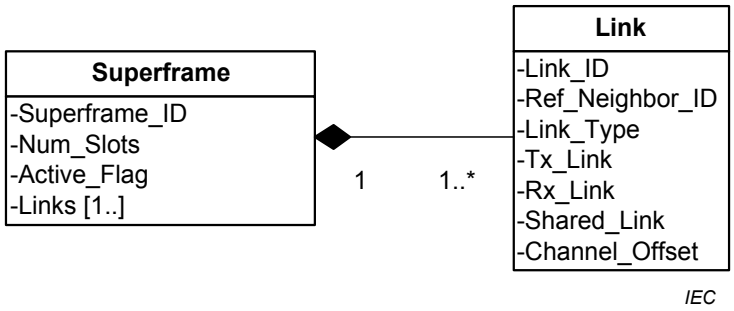

Figure 4 – Composition aggregation example

3.4.4.4.7 Multiplicity

Multiplicity shows how many instances of one class can be related to one instance of another class. Table 3 lists the examples of multiplicity indicators along with their meanings.

Table 3 – Multiplicity notation

Potential Multiplicity Values	
Indicator	**Meaning**
0..1	Zero or one
1	Only one
0..*	Zero or more
*	Zero or more
1..*	One or more
1..2	One or Two
4	Only four
0..5	Zero to Five

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4 Physical layer specification and service definition

4.1 General

This document specifies the wireless physical layer (PhL) of Type 20 in addition to the wired PhL of Type 20 specified in IEC 61158-2.

4.2 Physical layer service definition

4.2.1 General overview

Type 20 devices use Radio Frequencies (RF) to communicate between devices. The distance between two devices can be 100 meters or more depending upon the transmitter power, antenna type and lack of obstruction between two devices. Devices complying with Type 20 can be powered either by mains power, battery, energy harvesting devices (for example solar, vibration, etc.), or a combination there of.

This standard defines the Type 20 PhL. It is used for devices implementing wireless mesh network communication as defined by this standard. The PhL is responsible for the signaling method, signal strength, device sensitivity, and environment for sending bits across the network media. This wireless PhL specification is based on the 2 450 MHz DSSS physical layer and the employing offset quadrature phase-shift keying (O-QPSK) modulation according to IEEE Std 802.15.4-2011. This standard defines the services that the physical layer

provides to higher layers of this standard to send and receive data on the media. It also defines the local management parameters used to control the operation of the PhL.

The PhL of this standard deals with radio characteristics making a network connection. It associates with any part of the network structure that doesn't process information in any way. It is responsible for sending the bits across the network media. It does not define what a bit is or how it is used, merely how it's sent. The PhL is responsible for transmitting and receiving the data.

4.2.2 Physical layer services

4.2.2.1 Facilities of the physical layer services

The PhL provides following services:

- Control service – it supports enabling or disabling of the PhL entity (PhE) and to do clear channel assessment of the underlying medium,
- Message service – it supports the transfer of Physical layer service (PhS) -user-data from a source PhS-user to a destination PhS-user, and
- PhL-management services – it supports configuration of the PhL.

4.2.2.2 Sequence of primitives

The relations of primitives of each type at the interface of PhS-user and one PhE to primitives at the PhS-user and the other PhEs for error-free cases are summarized in the diagrams of Figure 5.

Before using the PhE, the PhS-user has to enable it as shown in the sequence a). The sequence c) shows the transmission of PhPDU from the source PhL-entity (PhE) to the destination PhE. The transmission starts with clear channel assessment as shown in the sequence b). At the destination, the reception starts with PH-RECV-SD indication after the start delimiter has been received by the PhE. The error free reception ends with PH-DATA indication. If there is any error in the reception then the PhE at the destination indicates it by a status parameter and does not deliver any Physical layer service (PhS) user-data.

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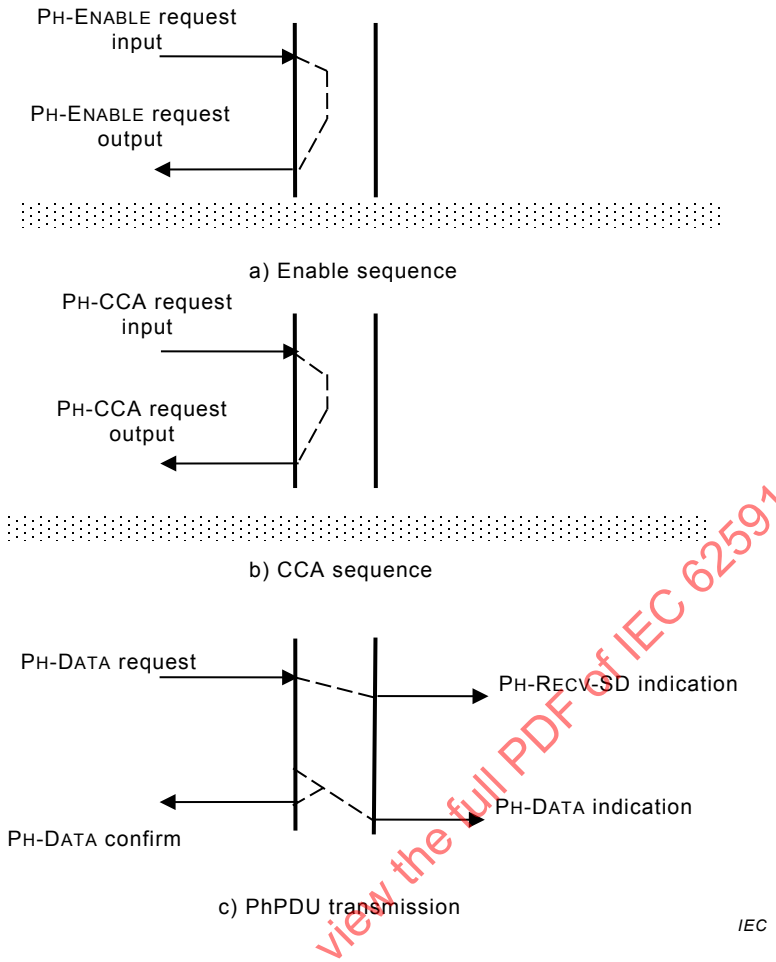

Figure 5 – Physical layer service sequences

4.2.2.3 PH-ENABLE service

4.2.2.3.1 Types of primitives and parameters

Table 4 indicates the types of primitives and the parameters needed for the PhL-Enable service. This service is used to enable or to disable the PhE and to place it in transmit or receive mode on the specified frequency channel. The request service is successful only if the channel is in idle state.

Table 4 – PH-ENABLE primitives and parameters

	Request	
Parameter name	Input	Output
Channel	M	M
State	M	M

4.2.2.3.2 Parameters

4.2.2.3.2.1 Channel

It specifies one of the available channels for which this service is used.

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4.2.2.3.2.2 State

In the request primitive, it specifies the state in which the channel should be, when this service is completed. In the confirm primitive, it specifies the current state of the channel after the service is completed. Its value can be either Enable or Disable.

4.2.2.4 PH-CCA service

4.2.2.4.1 Types of primitives and parameters

Table 5 indicates the types of primitives and the parameters needed for the PH-CCA service. This service is used to check the state of the channel. The request service is successful only if the channel is enabled in receive mode.

Table 5 – PH-CCA primitives and parameters

	Request	
Parameter name	Input	Output
State		M
NOTE The request primitive does not require any parameter.		

4.2.2.4.2 Parameter – state

This parameter shows the result of clear channel assessment. The values of this parameter are:

– Channel Idle;
– Channel busy;
– Transceiver off and unable to perform assessment.

4.2.2.5 PH-RECV-SD service

The only primitive of this service is indication and it has no parameter. This primitive is used by the PhE at the end of reception of the start delimiter in receive mode.

4.2.2.6 PH-DATA service

4.2.2.6.1 Types of primitives and parameters

Table 6 indicates the types of primitives and the parameters needed for the PH-DATA service.

Table 6 – PH-DATA primitives and parameters

Parameter name	Request	Indication	Confirm
PhS-user-data	M	C(=)	
Received signal level		C	
Status		M	M

4.2.2.6.2 Parameters

4.2.2.6.2.1 PhS-user-data

This parameter allows the transmission of data between PhS-users without alteration by the PhS-provider. If there is any error in reception then this parameter is absent in the indication primitive. Else, its value is identical to the value in the request primitive.

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4.2.2.6.2.2 Received signal level

This parameter indicates the estimated received signal level for this PhPDU. It is present only if there is no reception error.

4.2.2.6.2.3 Status

In the indication primitive, this parameter indicates either success or one of the following reasons for error:

- Receive buffer overflow,
- Incomplete packet.

In the Confirm primitive, this parameter indicates either success or one of the following reasons for error:

- Transceiver off,
- Receiver on,
- Transmitter busy.

If the Receiver is on, then the PhE cannot transmit.

4.2.2.7 PHM-SET service

4.2.2.7.1 Types of primitives and parameters

Table 7 indicates the primitive and parameters of this service.

Table 7 – PHM-SET primitive and parameters

	Request	
Parameter name	Input	Output
PHM-object-identifier	M	
Desired-value	M	
Status		M

4.2.2.7.2 Parameters

4.2.2.7.2.1 PHM-object-identifier

This parameter specifies the object within the PhE whose value is to be altered. The naming-domain of the PHM-object-identifier is the local-view.

4.2.2.7.2.2 Desired-value

This parameter specifies the desired value for the object specified by the associated PHM-object-identifier. Its type is identical to that of the specified object.

4.2.2.7.2.3 Status

This parameter allows the PhS-user to determine whether the requested service was provided successfully, or failed.

The failure reason may also be provided.

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4.2.2.8 PHM-GET service

4.2.2.8.1 Types of primitives and parameters

Table 8 indicates the primitive and parameters of this service.

Table 8 – PHM-GET primitive and parameters

	Request	
Parameter name	Input	Output
PHM-object-identifier	M	
Status		M
Current-value		C

4.2.2.8.2 Parameters

4.2.2.8.2.1 PHM-object-identifier

This parameter specifies the object within the PhE whose value is being requested. The naming-domain of the PHM-object-identifier is the local-view.

4.2.2.8.2.2 Status

This parameter allows the PhS-user to determine whether the requested service was provided successfully, or failed.

The failure reason may also be provided.

4.2.2.8.2.3 Current-value

This parameter is present when the status parameter indicates that the requested service was performed successfully. This parameter specifies the current value for the object specified by the associated PHM-object-identifier. Its type is identical to that of the specified object.

4.3 Physical layer protocol specification

The physical layer protocol is specified in IEEE Std 802.15.4-2011. The profile for this standard is specified in 9.3.4.

5 Data-link layer service definition – Type 20 elements

5.1 General

This document defines the wireless Data-link layer service of Type 20 in addition to the wired Data-link layer service of Type 20 specified in IEC 61158-3-20.

5.2 Data-link layer services

5.2.1 Facilities of the data-link layer services

5.2.1.1 Data transfer service

The Message services support the transfer of DL-service-data-unit (DLSDU) from a source DLS-user to a destination DLS-user. The data-link layer supports automatic retransmission to ensure error-free data transfer.

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5.2.1.2 Data receive service

This service supports reception only of a DL-service-data-unit (DLSDU) without sending any acknowledgement.

5.2.1.3 Event service

These services indicate events on the link:

- reception of a DLPDU from a DLE indicating that it is disconnecting from the link and provide an indication of this event to the DLS-user,
- detection of the failure of the path to another DLE and provide an indication of this event to the DLS-user,
- reception of a DLPDU that invites new DLE to connect to the link and provide an indication of this event to the DLS-user, and
- reception of a DLPDU from a DLE that is not in the neighbor table of the receiving DLE and provide an indication of this event to the DLS-user.

5.2.1.4 Local DL-management service

This service supports configuration of the DLL and access to DLL statistics. DL-management facilities provide a means for

- writing DLE configuration parameters,
- reading DLE configuration parameters, operational parameters and statistics,
- commanding major DLE actions, and
- receiving notification of significant DLE events.

Together these facilities constitute the DL-management-service (DLMS).

5.2.1.5 Security function

The DL provides security function for communications between pairs of communicating devices on one link. A key is used to ensure that the DLPDU is originated from an approved, authenticated device.

There is no explicit user service for security. The security parameters are written by using DL-management service.

5.2.2 QoS for message service

5.2.2.1 Priority

The message service primitives specify the priority of the transferred DLSDU. The four priorities from highest priority to lowest priority are defined below.

- Command – this priority should be used by the DLS-user to send network-related diagnostics, configuration, or control information DLSDU.
- Process-Data – this priority should be used by the DLS-user to send DLSDU that contains measurements from process transmitters or setpoints to control devices or any other process related data or network statistics data.
- Normal – this priority should be used by the DLS-user to send DLSDU that contains any other data not meeting the criteria for "Command", "Process-Data", or "Alarm" priority.
- Alarm – this priority should be used by the DLS-user to send DLSDU that contains only alarm or event DLSDU.

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5.2.2.2 Timeout

Each message request specifies upper bounds on the maximum time duration permitted for the completion of each related instance of a sequence of message primitives.

5.2.3 Sequence of primitives

The relations of primitives of each type at the interface of DLS-user and one DLE to primitives at the DLS-user and the other DLEs for error-free cases are summarized in the diagrams of Figure 6.

Sequence a) shows an error-free single unicast transaction. In this sequence the DL-TRANSMIT request at the source DLE inserts the message into that DLE's transmit queue. Sometime later, when a slot, supporting scheduled communication to the destination DLE occurs, the DLPDU carrying the message DLSDU is transmitted. When a non-broadcast DLPDU is received and validated, the receiving DLE transmits an acknowledgement and generates a DL-TRANSMIT indication to its user. Upon reception of the acknowledgement, the source DLE generates a DL-TRANSMIT confirm to the requesting user.

Sequence b) shows an error-free multiple unicast transactions. In this sequence the DL-TRANSMIT request at the source DLE inserts the message into that DLE's transmit queue. Before the DLPDU carrying this message DLSDU is transmitted, the DLE receives another DL-TRANSMIT request to be sent to a DLE different than the previous request. Sometime later, when a slot, supporting scheduled communication to the destination DLE occurs, the DLPDU carrying the second message DLSDU is transmitted. When a non-broadcast DLPDU is received and validated, the receiving DLE transmits an acknowledgement and generates a DL-TRANSMIT indication to its user. Therefore, the DLSDU may not be transmitted in the same order as they were issued at the source DLE.

Sequence c) shows an error-free single multicast transaction. In this sequence the DL-TRANSMIT request at the source DLE inserts the message into that DLE's transmit queue. Sometime later, when a slot, supporting scheduled communication to the destination DLE occurs, the DLPDU carrying the message DLSDU is transmitted. When a DLPDU destined to several DLEs is received and validated, the receiving DLE generates a DL-TRANSMIT indication to its user. Upon transmission of the DLPDU, the source DLE generates a DL-TRANSMIT confirm to the requesting user.

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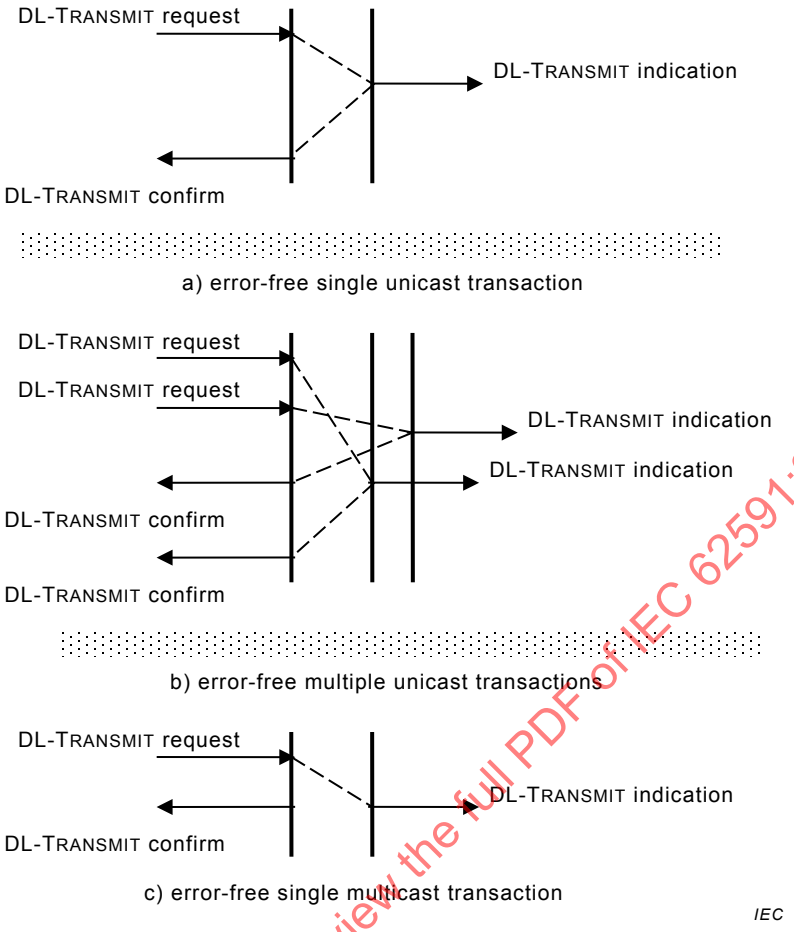

Figure 6 – Message service error-free sequences

The relations of primitives of each type at the interface of DLS-user and one DLE to primitives at the DLS-user and the other DLEs for error cases are summarized in the diagrams of Figure 7.

The sequence a) shows the DLPDU lost in the transmission. The sequence b) shows that the receiving DLE discarded the DLPDU due to lack of buffer resource and sends an acknowledgment with a response code of "Error". As shown, the source DLE retransmits the message until either an acknowledgement with a response code of "Success" is received, or a limit on maximum number of retries is reached. If the packet resides in the source DLE without an acknowledgement from the destination DLE, for a duration which is greater than the specified timeout value, then the DLE stops retrying.

The sequence c) shows that the destination DLE received the DLPDU with either an invalid message integrity code or a destination address that does not match. The receiving DLE discards the DLPDU and does not send any acknowledgment.

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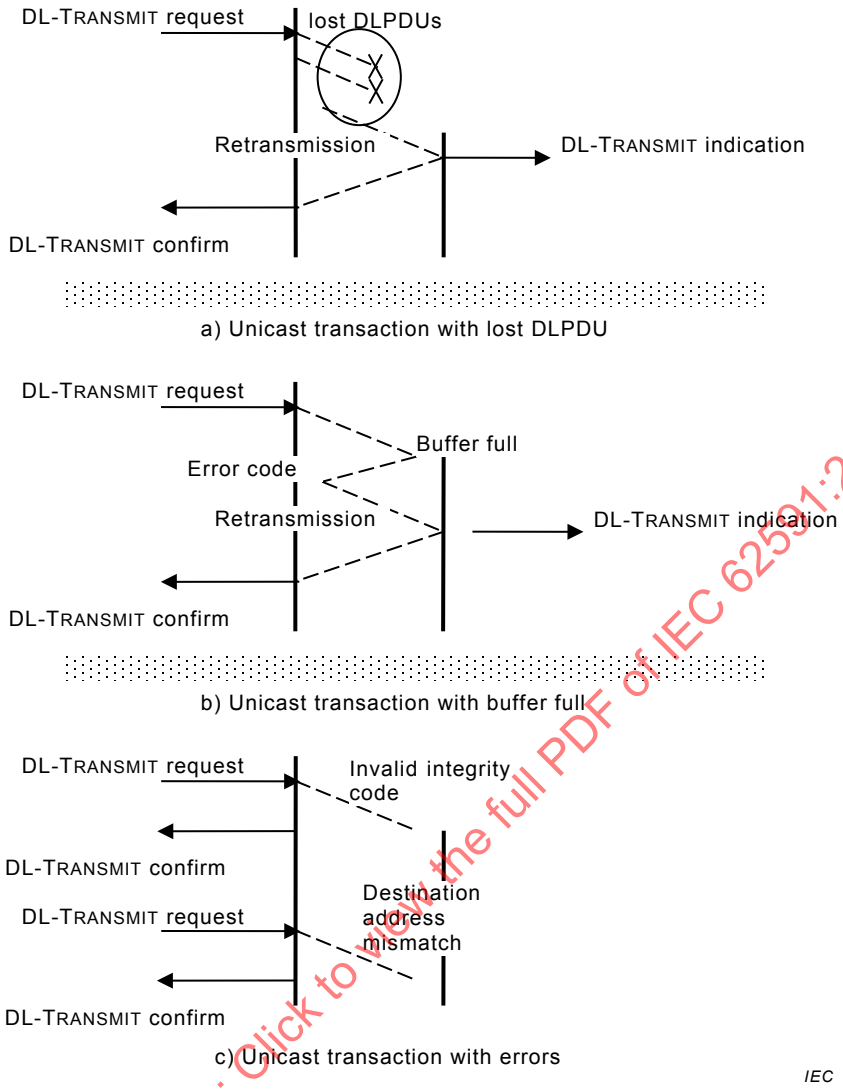

Figure 7 – Message service sequences with errors

Figure 8 shows the receive-only primitive. This is available in a DLE that supports a promiscuous operating mode where communications from other DLEs are captured.

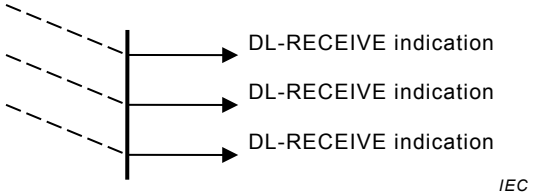

Figure 8 – Receive only message service

5.2.4 DL-TRANSMIT service

5.2.4.1 Function

It can be used to transmit an independent, self-contained DLSDU from one DLE to another DLE in a single service access, and to return the status of that delivery to the originating DLS-user.

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5.2.4.2 Types of primitives and parameters

Table 9 indicates the types of primitives and the parameters needed for the DL-Transmit service.

Table 9 – DL-Transmit primitives and parameters

Parameter name	Request	Indication	Confirm
Handle	M		M(=)[a]
Broadcast	M	M	
Source address		M	
Destination address			
Short address	S		
Long address	S		
Superframe_ID	C		
Graph	C		
Priority	M	M(=)	
Timeout	M		
DLS-user-data	M	M(=)	
Status		M	M
[a] The value of this parameter is equal to the value in the request primitive.			

5.2.4.3 Parameters

5.2.4.3.1 Handle

This parameter is supported for the convenience of the DLS-user. Its value in confirm primitive is identical to the value in the corresponding request primitive.

5.2.4.3.2 Broadcast

If the value of this parameter is TRUE, then the DLSDU is broadcast in the superframe specified in the request primitive.

5.2.4.3.3 Source address

This parameter identifies the source of the DLSDU conveyed in the indication primitive.

5.2.4.3.4 Destination address

5.2.4.3.4.1 Short address

This parameter is present only if Broadcast is FALSE. It is the nickname of the destination DLE that is used for the next hop.

5.2.4.3.4.2 Long address

This parameter is present only if Broadcast is FALSE. It is the Unique ID of the destination DLE that is used for the next hop.

5.2.4.3.5 Superframe_ID

This parameter is present only if Broadcast is TRUE. It specifies the superframe whose broadcast links has to be used to transmit the DLSDU.

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5.2.4.3.6 Graph

This parameter is present only if graph routing is to be used. When used, the graph indicates the neighbors that can be used as the destination for the next hop.

5.2.4.3.7 Priority

This parameter specifies the priority for the transmission. Its value is any one member of the set: {command, process-data, normal, alarm}.

5.2.4.3.8 Timeout

This is the maximum time duration for the completion of each related instance of a sequence of DL-TRANSMIT primitives.

5.2.4.3.9 DLS-user-data

This parameter allows the transmission of data between DLS-users without alteration by the DLS-provider.

5.2.4.3.10 Status

In indication primitive, this parameter indicates the data-link key used to authenticate the DLPDU and whether the DLPDU was a broadcast.

In confirm primitive, this parameter indicates that the service was provided successfully, or failed for the reason specified.

5.2.5 DL-RECEIVE service

5.2.5.1 Function

It can be used by a DLE to receive any DLPDU and provide the DLSDU in that DLPDU to it DLS-user. This service is also called "promiscuous operating mode" and can be used for network troubleshooting.

5.2.5.2 Type of primitive and parameters

Table 10 indicates the type of primitive and the parameters needed for the Receive service.

Table 10 – DL-RECEIVE primitive and parameters

Parameter name	Indication
Packet RSL	M
DLS-user-data	M

5.2.5.3 Parameters

5.2.5.3.1 Packet RSL

This parameter is RSL of the just received DLPDU.

5.2.5.3.2 DLS-user-data

This parameter conveys the data received by the DLE.

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5.2.6 DL-DISCONNECT service

5.2.6.1 Function

This service notifies that another DLE is disconnecting from the link. A DLPDU has been received from that DLE indicating that it is disconnecting from the link.

NOTE The Disconnect DLPDU is expected only from a device that is a neighbor. It is possible that the receiving device does not know all of its neighbors. Therefore it always receives Disconnect DLPDU and provides an indication, even if it is from a device that is not known as neighbor.

5.2.6.2 Type of primitive and parameters

5.2.6.2.1 General

Table 11 indicates the type of primitive and the parameters needed for the Disconnect service.

Table 11 – DL-DISCONNECT primitive and parameters

Parameter name	Indication
Source address	M

5.2.6.2.2 Source address

This parameter identifies the address of the DLE that just disconnected.

5.2.7 DL-PATH-FAILURE service

5.2.7.1 Function

This service notifies that the path to a DLE with which this DLE is connected has failed. The communications with the indicated DLE has timed out unexpectedly and the DLE appears to be unavailable.

5.2.7.2 Type of primitive and parameters

5.2.7.2.1 General

Table 12 indicates the type of primitive and the parameters needed for PATH-FAILURE service.

Table 12 – DL-PATH-FAILURE primitive and parameters

Parameter name	Indication
Source address	M

5.2.7.2.2 Source address

This parameter identifies the address of the DLE to which the path has just failed.

5.2.8 DL-ADVERTISE service

5.2.8.1 Function

This service notifies that the DLE has received Advertise DLPDU. The DLS-user should use the information provided in this service before joining the network.

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5.2.8.2 Type of primitive and parameters

5.2.8.2.1 General

Table 13 indicates the type of primitive and the parameters needed for the Advertise service.

Table 13 – DL-ADVERTISE primitive and parameters

Parameter name	Indication
DLS-user-data	M

5.2.8.2.2 DLS-user-data

This parameter conveys the data received by the DLE in the Advertise DLPDU.

5.2.9 DL-NEIGHBOR service

5.2.9.1 Function

This service notifies that the DLE has received a DLPDU from a DLE that is not listed in its neighbor table (see 6.4.3.4).

5.2.9.2 Type of primitive and parameters

Table 14 indicates the type of primitive and the parameters needed for the neighbor service.

Table 14 – DL-NEIGHBOR primitive and parameters

Parameter name	Indication
Source address	M
Packet RSL	M

5.2.9.3 Parameters

5.2.9.3.1 Source address

This parameter identifies the address of the DLE that is not in its neighbor table.

5.2.9.3.2 Packet RSL

This primitive indicates the RSL of the received DLPDU.

5.2.10 DLM-SET

5.2.10.1 Function

This primitive can be used to set (write) the value of a DLE configuration parameter.

5.2.10.2 Types of parameters

Table 15 indicates the primitive and parameters of the Set service.

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Table 15 – DLM-SET primitive and parameters

	Request	
Parameter name	Input	Output
DLM-object-identifier	M	
Desired-value	M	
Status		M

5.2.10.3 Parameters

5.2.10.3.1 DLM-object-identifier

This parameter specifies the primitive or composite object within the DLE whose value is to be altered. The naming-domain of the DL-management (DLM) object-identifier is the DLM local-view.

5.2.10.3.2 Desired-value

This parameter specifies the desired value for the DLM object specified by the associated DLM-object-identifier. Its type is identical to that of the specified DLM object.

5.2.10.3.3 Status

This parameter allows the DLM service (DLMS) user to determine whether the requested DLMS was provided successfully, or failed.

The failure reason may also be provided.

5.2.11 DLM-GET

5.2.11.1 Function

This primitive can be used to get (read) the value of a DLE configuration parameter, operational parameter or statistics.

5.2.11.2 Types of parameters

Table 16 indicates the primitive and parameters of the GET service.

Table 16 – DLM-GET primitive and parameters

	Request	
Parameter name	Input	Output
DLM-object-identifier	M	
Status		M
Current-value		C

5.2.11.3 Parameters

5.2.11.3.1 DLM object-identifier

This parameter specifies the primitive or composite object within the DLE whose value is being requested. The naming-domain of the DLM-object-identifier is the DLM local-view.

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5.2.11.3.2 Status

This parameter allows the DLMS-user to determine whether the requested DLMS was provided successfully, or failed.

The failure reason may also be provided.

5.2.11.3.3 Current-value

This parameter is present when the status parameter indicates that the requested service was performed successfully. It specifies the current value for the DLM-object specified by the associated DLM-object-identifier. Its type is identical to that of the specified DLM-object.

5.2.12 DLM-ACTION

5.2.12.1 Function

This primitive can be used to command a specified action of the DLE.

5.2.12.2 Types of parameters

Table 17 indicates the primitives and parameters of the ACTION service.

Table 17 – DLM-ACTION primitive and parameters

	Request	Confirm
Parameter name	Input	Output
Desired-action	M	
Action-qualifiers	C	
Status		M
Additional-information		C

5.2.12.3 Parameters

5.2.12.3.1 Desired-action

This parameter specifies the desired action which the DLE is to take. The possible values for this parameter are listed in Table 47.

5.2.12.3.2 Action-qualifiers

This parameter specifies additional action-specific parameters which serve to qualify the commanded action.

NOTE Some of the actions require additional parameters, such as DELETE-SUPERFRAME requires Superframe_ID.

5.2.12.3.3 Status

This parameter allows the DLMS-user to determine whether the requested DLMS was provided successfully, or failed.

The failure reason may also be provided.

5.2.12.3.4 Additional-information

This optional parameter provides action-specific additional information which augments the returned status.

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5.2.13 DLM-EVENT

5.2.13.1 Function

This primitive is used to report the occurrence of a DL-event which could be of significance to DL-management.

5.2.13.2 Types of parameters

No parameters defined.

5.3 Network layer services

5.3.1 Facilities of the network layer services

5.3.1.1 Data transfer service

The network layer provides service to transmit Network layer (NL) service-data-unit (NSDU) from source NL-entity (NLE) to destination NLE. It may require routing an NL-protocol-data-unit (NPDU) through intermediate NLEs. The route for a NPDU is setup using NL-management services (NLMS).

5.3.1.2 Local NL-management service

This service supports configuration of the NL and access to NL statistics. NL-management facilities provide a means for

- writing NLE configuration parameters,
- reading NLE configuration parameters, operational parameters and statistics,
- commanding major NLE actions, and
- receiving notification of significant NLE events.

Together these facilities constitute the NLMS.

5.3.1.3 Security function

The NL provides security function for end to end communications between pairs of communicating devices. NL is session oriented for security purpose. A session enables private and secure communication between a pair of network addresses. The following types of security keys are supported.

- Join

  This key is used when the device tries to join the network.
- Network manager

  This key is for communication between network manager and a network device.
- Gateway

  This key is for communication between gateway and a network device.

There is no explicit user service for security. The security parameters are written by using NL-management service.

5.3.2 QoS for message service

The data transfer service primitives specify the priority of the transferred NSDU. The four priorities are, from highest priority to lowest priority:

- Command

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This priority should be used by the NLS-user to send network-related diagnostics, configuration, or control information data.

- Process-Data

  This priority should be used by the NLS-user to send data that contains measurements from process transmitters or set-points to control devices or any other process related data or network statistics data.

- Normal

  This priority should be used by the NLS-user to send data that contains any other data not meeting the criteria for "Command", "Process-Data", or "Alarm" priority.

- Alarm

  This priority should be used by the NLS-user to send data that contains only alarm or event information.

5.3.3 Sequence of primitives

The relations of primitives at the end-points of message service of each type at the interface of NLS-user and one NLE to primitives at the NLS-user and the other NLEs are summarized in the diagrams of Figure 9. After the DLE provides the confirmation of transmission, the NLE generates a NL-Transmit confirm to its requesting user. There is no confirmation of delivery from the remote NLE.

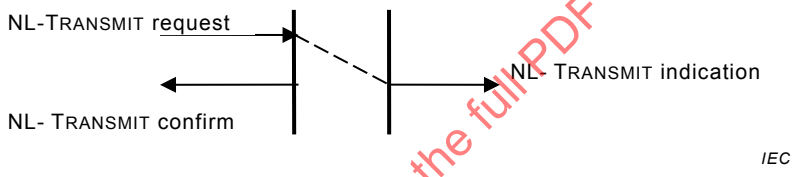

Figure 9 – NLL Data transfer service sequences

5.3.4 NL-TRANSMIT Service

5.3.4.1 Function

It can be used to transmit an independent, self-contained NSDU from one NLE to another NLE in a single service access and to return the status of that delivery to the originating NLS-user.

5.3.4.2 Types of primitives and parameters

Table 18 indicates the types of primitives and the parameters needed for the Transmit service.

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Table 18 – NL-TRANSMIT primitives and parameters

Parameter name	Request	Indication	Confirm
Handle	M		M(=)[a]
Sequence_number		M	
Source address		M	
Destination address			
Short address	S		
Long address	S		
Broadcast	S		
Priority	M	M(=)	
Timetable_ID	C		
transport_type	M	M(=)	
NLS-user-data	M	M(=)	
Status			M

[a] The value of this parameter is equal to the value in the request primitive.

5.3.4.3 Parameters

5.3.4.3.1 Handle

In the request, this parameter is supported for the convenience of the NLS-user. Its value in confirm primitive is identical to the value in the corresponding request primitive.

5.3.4.3.2 Sequence_number

This parameter sequence_number is used to uniquely identify the TPDU.

5.3.4.3.3 Source address

This parameter identifies the source of the NSDU conveyed in the indication primitive.

5.3.4.3.4 Destination address

5.3.4.3.4.1 Short address

It is the nickname of the destination NLE.

5.3.4.3.4.2 Long address

It is the Unique ID of the destination NLE.

5.3.4.3.4.3 Broadcast

All NLEs in the network are the destinations.

5.3.4.3.5 Priority

This parameter specifies the priority for the transmission. Its value is any one member of the set: {command, process-data, normal, alarm}.

5.3.4.3.6 Timetable_ID

This parameter specifies the Timetable that was used to allocate the network communication bandwidth for this service primitive. This parameter is present only if the destination address

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is not that of the network manager and if this request is required to use the allocated bandwidth. If there is insufficient remaining bandwidth for the NL-TRANSMIT.request then an error shall be returned and the NLS-user-data shall not be transmitted. The network manager shall not be restrained by the Timetable.

5.3.4.3.7 transport_type

The transport_type indicates the type of transport service used (refer to 5.4.4.3.2).

5.3.4.3.8 NLS-user-data

This parameter allows the transmission of data between NLS-users without alteration by the NLS-provider.

5.3.4.3.9 Source address

This parameter identifies the source of the NSDU conveyed in the indication primitive.

5.3.4.3.10 Status

In confirm primitive, this parameter indicates success, warning or failure of the service. For warning and failure, it also indicates the cause of the warning or error.

5.3.5 NLM-SET

5.3.5.1 Function

This primitive can be used to set (write) the value of a NLE configuration parameter.

5.3.5.2 Types of parameters

Table 19 indicates the primitive and parameters of the SET service.

Table 19 – NLM-SET primitive and parameters

	Request	
Parameter name	Input	Output
NLM-object-identifier	M	
Desired-value	M	
Status		M

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5.3.5.3 Parameters

5.3.5.3.1 NLM-object-identifier

This parameter specifies the primitive or composite object within the NLE whose value is to be altered. The naming-domain of the NLM-object-identifier is the NLM local-view.

5.3.5.3.2 Desired-value

This parameter specifies the desired value for the NLM object specified by the associated NLM-object-identifier. Its type is identical to that of the specified NLM object.

5.3.5.3.3 Status

This parameter allows the NLMS-user to determine whether the requested NLMS was provided successfully, or failed.

The failure reason may also be provided.

5.3.6 NLM-GET

5.3.6.1 Function

This primitive can be used to get (read) the value of a NLE configuration parameter, operational parameter or statistics.

5.3.6.2 Types of parameters

Table 20 indicates the primitive and parameters of the GET service.

Table 20 – NLM-GET primitive and parameters

	Request	
Parameter name	Input	Output
NLM-object-identifier	M	
Status		M
Current-value		C

5.3.6.3 Parameters

5.3.6.3.1 NLM-object-identifier

This parameter specifies the primitive or composite object within the NLE whose value is being requested. The naming-domain of the NLM-object-identifier is the NLM local-view.

5.3.6.3.2 Status

This parameter allows the NLMS-user to determine whether the requested NLMS was provided successfully, or failed.

The failure reason may also be provided.

5.3.6.3.3 Current-value

This parameter is present when the status parameter indicates that the requested service was performed successfully. This parameter specifies the current value for the NLM-object specified by the associated NLM-object-identifier. Its type is identical to that of the specified NLM-object.

5.3.7 NLM-ACTION

5.3.7.1 Function

This primitive can be used to command a specified action of the NLE.

5.3.7.2 Types of parameters

Table 21 indicates the primitives and parameters of the Action service.

Table 21 – NLM-ACTION primitive and parameters

	Request	Confirm
Parameter name	Input	Output
Desired-action	M	

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	Request	Confirm
Action-qualifiers	C	
Status		M
Additional-information		C

5.3.7.3 Parameters

5.3.7.3.1 Desired-action

This parameter specifies the desired action which the NLE is to take. The possible values for this parameter are listed in Table 59.

5.3.7.3.2 Action-qualifiers

This parameter specifies additional action-specific parameters which serve to qualify the commanded action. Some of the actions require additional parameters, such as DELETE-SESSION requires Session ID.

5.3.7.3.3 Status

This parameter allows the NLMS-user to determine whether the requested NLMS was provided successfully, or failed.

The failure reason may also be provided.

5.3.7.3.4 Additional-information

This optional parameter provides action-specific additional information which augments the returned status.

5.4 Transport layer services

5.4.1 Facilities of the transport layer services

5.4.1.1 Data transfer service

The transport layer (TL) supports both acknowledged and unacknowledged services.

The unacknowledged service allows devices to send packets without requiring acknowledgement from the receiving end. The packets may be delivered at the destination device in a different order than the order in which it was originally sent from the source device. This service is useful for publishing the process data. Since process data is propagated periodically, end to end acknowledgement and retries have limited utility considering a new data point will be generated on a regular basis.

The acknowledged service is used to construct a synchronous transport pipe across the network connecting two devices. This pipe allows devices to send packets and confirm their delivery. The TL-service (TLS) user can send packet which will be delivered without loss, duplication or misordering to the receiving TLS-user. This service is suited for user request and response traffic and event notifications. When the acknowledged service is used, the communication is synchronous. Only one outstanding transaction across the network for that transport pipe is permitted at a time.

Using acknowledged service allows the client layer to ensure retries are automatically performed, if communication latency becomes excessive. Statistically, communication reliability for a well-formed Type 20 mesh network is greater than 3 σ (3-sigma = 99,730 020 4 %) and normally greater than 4 σ (99,993 7%). The primary benefit provided by the acknowledged service is that the client layer will receive positive acknowledgement after

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TL-protocol-data-unit (TPDU) arrival at the destination. This allows synchronous operation across the network as well as assuring the client layer that the TPDU was delivered and acknowledged.

5.4.1.2 Local TL-management service

This service supports configuration of the TL and access to TL statistics. TL-management facilities provide a means for

- writing TL-entity (TLE) configuration parameters, and
- reading TLE configuration parameters, operational parameters and statistics.

Together these facilities constitute the NL-management-service (NLMS).

5.4.2 QoS for message service

5.4.2.1 Priority

The data transfer service primitives specify the priority of the transferred data. The four priorities are, from highest priority to lowest priority:

- Command

  This priority should be used by the TLS-user to send network-related diagnostics, configuration, or control information data.

- Process-Data

  This priority should be used by the TLS-user to send data that contains measurements from process transmitters or set-points to control devices or any other process related data or network statistics data.

- Normal

  This priority should be used by the TLS-user to send data that contains any other data not meeting the criteria for "Command", "Process-Data", or "Alarm" priority.

- Alarm

  This priority should be used by the TLS-user to send data that contains only alarm and event information.

5.4.2.2 Retry

The TL-management specifies upper bounds on the maximum time duration permitted for the completion of each related instance of a sequence of data transfer primitives. It also specifies the maximum number of retries to send request and receive response primitive.

5.4.3 Sequence of primitives

Subclause 5.4.3 specifies relation of primitives at the end-points of data transfer service.

The relations of primitives of each type at the interface of TLS-user and one TLE to primitives at the TLS-user and the other TLEs for error-free cases are summarized in the diagrams of Figure 10.

Sequence a) shows an error-free unidirectional transfer of data without acknowledgment from the destination TLE. After the NLE provides the confirmation of transmission, the TLE generates a TL-DATA-TRANSFER confirm to its requesting user.

Sequence b) shows an error-free bidirectional acknowledged exchange of data. In this sequence, TL-DATA-EXCHANGE request at the source TLE inserts the message into transmit queue of the TLE. When a TPDU is received and validated, the destination TLE generates a TL-DATA-EXCHANGE indication. The TLS-user at that destination is expected to provide

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response data. The TLE transmits this response to the source TLE. Upon reception of the response, the source TLE generates a TL-DATA-EXCHANGE confirm to its user.

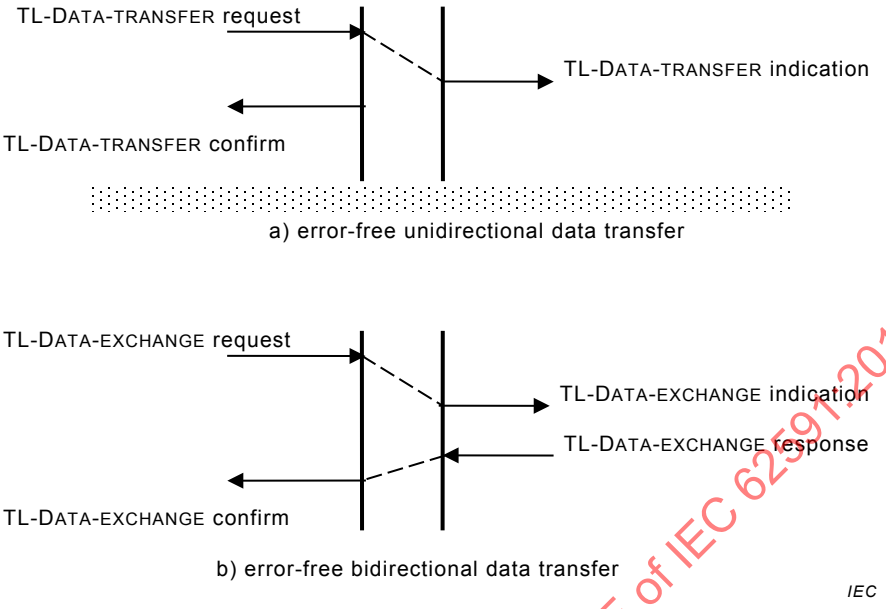

Figure 10 – Data transfer service error-free sequences

The relations of primitives of each type at the interface of TLS-user and one TLE to primitives at the TLS-user and the other TLEs for error cases are summarized in the diagram of Figure 11. The sequence shows the TL-protocol-data-unit (TPDU) lost in the transmission. As shown, the source TLE retransmits the TPDU until either a response TPDU is received, or a limit on maximum number of retries is reached. If the packet resides in the source TLE without a response from the destination TLE, for a duration which is greater than the timeout value, then the TLE stops retrying.

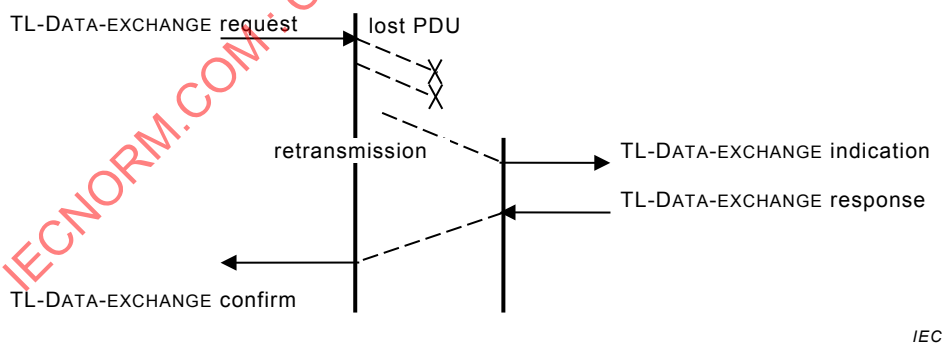

Figure 11 – Data transfer service sequences with errors

5.4.4 TL-DATA-TRANSFER Service

5.4.4.1 Function

It can be used to transmit an independent, self-contained request TL-service-data-unit (TSDU) from one TLE to another TLE in a single service access without any delivery confirmation.

5.4.4.2 Types of primitives and parameters

Table 22 indicates the types of primitives and the parameters needed for the Data-transfer service.

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Table 22 – TL-DATA-TRANSFER primitives and parameters

Parameter name	Request	Indication	Confirm
Handle	M	M(=)[a]	M(=)[b]
Transport type	M	M	
Source address		M	
Destination address			
Short address	S		
Long address	S		
Broadcast	S		
Priority	M	M(=)	
Timetable_ID	C		
TLS-user-data	M	M(=)	
Status			M

[a] This parameter in indication is considered as the sequence number.

[b] The value of this parameter is equal to the value in the request primitive.

5.4.4.3 Parameters

5.4.4.3.1 Handle

In the request, this parameter is supported for the convenience of the DLS-user. Its value in confirm primitive is identical to the value in the corresponding request primitive. In the indication primitive this parameter is used to provide a sequence number.

5.4.4.3.2 Transport type

In the request primitive, this parameter indicates the type of service requested. Its value is one of the following.

- Block-transfer request
- Block-transfer response
- Search-broadcast
- Publish-broadcast
- Response-broadcast
- Publish-unicast

5.4.4.3.3 Source address

This parameter identifies the source of the TSDU conveyed in the indication primitive.

5.4.4.3.4 Destination address

5.4.4.3.4.1 Short address

It is the nickname of the destination TLE.

5.4.4.3.4.2 Long address

It is the Unique ID of the destination TLE.

5.4.4.3.4.3 Broadcast

All TLEs in the network are the destinations.

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5.4.4.3.5 Priority

This parameter specifies the priority for the transmission. Its value is any one member of the set: {command, process-data, normal, alarm}.

5.4.4.3.6 Timetable_ID

This parameter specifies the Timetable that was used to allocate the network communication bandwidth for this service primitive. This parameter is present only if the destination address is not that of the network manager.

5.4.4.3.7 TLS-user-data

This parameter allows the transmission of data between TLS-users without alteration by the TLS-provider.

5.4.4.3.8 Source address

This parameter identifies the source of the TSDU conveyed in the indication primitive.

5.4.4.3.9 Status

In confirm primitive, this parameter indicates success, warning or failure of the service. For warning and failure, it also indicates the cause of the warning or error.

5.4.5 TL-DATA-EXCHANGE Service

5.4.5.1 Function

It can be used to transmit an independent, self-contained request TSDU from one TLE to another TLE in a single service access, to receive response TSDU from the destination TLE and to return the status of that exchange to the originating TLS-user.

5.4.5.2 Types of primitives and parameters

Table 23 indicates the types of primitives and the parameters needed for the TL-DATA-EXCHANGE service.

Table 23 – TL-DATA-EXCHANGE primitives and parameters

Parameter name	Request	Indication	Response	Confirm
Handle	M	M(=)[a]	M(=)	M(=)[b]
Transport type	M	M(=)		
Source address		M		
Destination address				
Short address	S			
Long address	S			
Broadcast	S			
Priority	M	M(=)		
Timetable_ID	C			
TLS-user-data	M	M(=)	M	C(=)
Status				M

[a] This parameter in indication is considered as the sequence number.

[b] This parameter is equal to the value in the request primitive.

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5.4.5.3 Parameters

5.4.5.3.1 Handle

In the request, this parameter is supported for the convenience of the DLS-user. Its value in confirm primitive is identical to the value in the corresponding request primitive. In the indication primitive this parameter is used to associate the request with the response.

5.4.5.3.2 Transport type

In the request primitive, this parameter indicates the type of service requested by master. Its value is one of the following.

- Request-unicast
- Request-broadcast

In the response primitive, this parameter indicates the type of service requested by slave. Its value is – Response-unicast.

5.4.5.3.3 Source address

This parameter identifies the source of the TSDU conveyed in the indication primitive.

5.4.5.3.4 Destination address

5.4.5.3.4.1 Short address

It is the nickname of the destination TLE.

5.4.5.3.4.2 Long address

It is the Unique ID of the destination TLE.

5.4.5.3.4.3 Broadcast

All TLEs in the network are the destinations.

5.4.5.3.5 Priority

This parameter specifies the priority for the transmission. Its value is any one member of the set: {command, process-data, normal, alarm}.

5.4.5.3.6 Timetable_ID

This parameter specifies the Timetable that was used to allocate the network communication bandwidth for this service primitive. This parameter is present only if the destination address is not that of the network manager.

The communication bandwidth allocation is requested by the transaction initiator and the response is not included in the allocation for any Timetables in the device. Therefore, Timetable_ID is not included in the response primitive.

5.4.5.3.7 TLS-user-data

This parameter allows the transmission of data between TLS-users without alteration by the TLS-provider.

5.4.5.3.8 Source address

This parameter identifies the source of the TSDU conveyed in the indication primitive.

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5.4.5.3.9 Status

In confirm primitive, this parameter indicates success, warning or failure of the service. For warning and failure, it also indicates the cause of the warning or error.

5.4.6 TLM-SET

5.4.6.1 Function

This primitive can be used to set (write) the value of a TLE configuration parameter.

5.4.6.2 Types of parameters

Table 24 indicates the primitive and parameters of the SET service.

Table 24 – TLM-Set primitive and parameters

	Request	
Parameter name	Input	Output
TLM-object-identifier	M	
Desired-value	M	
Status		M

5.4.6.3 Parameters

5.4.6.3.1 TLM-object-identifier

This parameter specifies the primitive or composite object within the TLE whose value is to be altered. The naming-domain of the TLM-object-identifier is the TLM local-view.

5.4.6.3.2 Desired-value

This parameter specifies the desired value for the TLM object specified by the associated TLM object-identifier. Its type is identical to that of the specified TLM object.

5.4.6.3.3 Status

This parameter allows the TL-management service (TLMS) user to determine whether the requested TLMS was provided successfully, or failed.

The failure reason may also be provided.

5.4.7 TLM-GET

5.4.7.1 Function

This primitive can be used to get (read) the value of a TLE configuration parameter, operational parameter or statistic.

5.4.7.2 Types of parameters

Table 25 indicates the primitive and parameters of the GET service.

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Table 25 – TLM-Get primitive and parameters

	Request	
Parameter name	Input	Output
TLM-object-identifier	M	
Status		M
Current-value		C

5.4.7.3 Parameters

5.4.7.3.1 TLM-object-identifier

This parameter specifies the primitive or composite object within the TLE whose value is being requested. The naming-domain of the TLM-object-identifier is the TLM local-view.

5.4.7.3.2 Status

This parameter allows the TLMS-user to determine whether the requested TLMS was provided successfully, or failed.

The failure reason may also be provided.

5.4.7.3.3 Current-value

This parameter is present when the status parameter indicates that the requested service was performed successfully. This parameter specifies the current value for the TLM-object specified by the associated TLM-object-identifier. Its type is identical to that of the specified TLM-object.

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6 Data-link layer protocol specification – Type 20 elements

6.1 General

This document specifies the wireless Data-link layer protocol of Type 20 in addition to the wired Data-link layer protocol of Type 20 specified in IEC 61158-4-20.

6.2 Overview

6.2.1 Data-link layer operation

6.2.1.1 Two sublayer model of DLL

The DLL is modeled as a

- higher sublayer logical link control (LLC), and
- lower sublayer medium access control (MAC).

Interoperating with all sublayers are DL-management functions.

6.2.1.2 Logical link control

The LLC sublayer provides the higher-level functionality of

- managing all DLE interactions with the DLS-user, converting all DLS-user request and response primitives into the necessary sequence of DLE operations, and generating DLS-user indication and confirm primitives where appropriate,
- preparation of the DLPDU for transmission,

- parsing of the received DLPDU,
- flow control,
- error detection,
- maintenance of the neighbor table, and
- security at the data-link layer.

6.2.1.3 Medium access control

The Type 20 data-link layer uses Time Division Multiple Access (TDMA) and channel hopping to control access to the link. This Medium access control (MAC) technique provides collision free, deterministic communication between two devices. The communication between two devices occurs during one time slot. A TDMA superframe consists of a series of time slots. The basic structure of TDMA time slots and the superframe are shown in Figure 12. Slot sizes and the superframe length in number of slots are fixed and form a link cycle. All devices support multiple superframes, starting with superframe number zero (0). At least one superframe is always enabled while additional superframes can be enabled or disabled. The length of a superframe can be changed only while it is inactive. Superframe may have lengths that differ from each other. Superframes are repeated continuously with a fixed repetition rate.

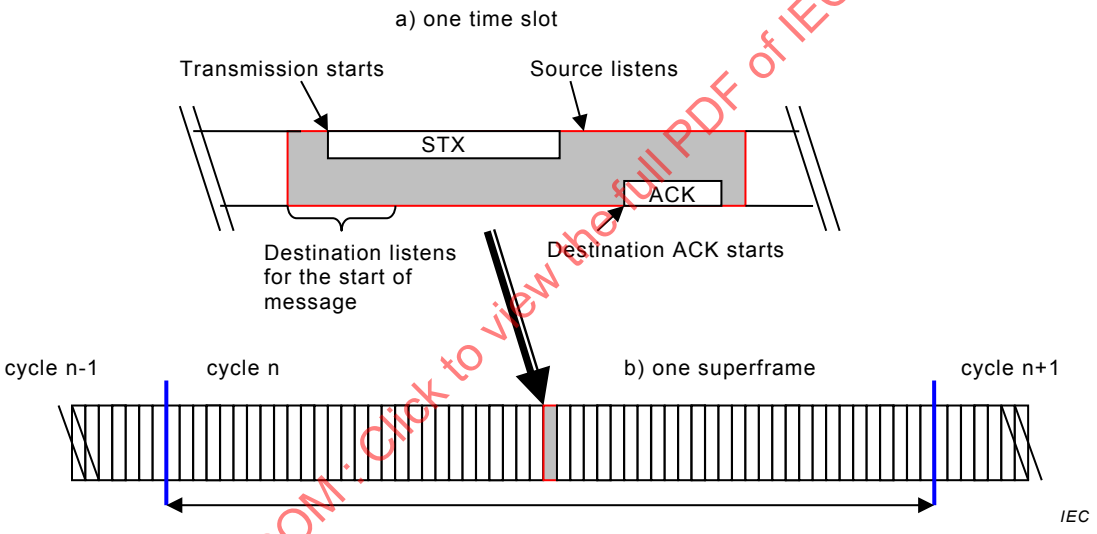

Figure 12 – A TDMA slot and superframe

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Typically, two devices are assigned to one time slot. One is designated as the source and the other as the destination. A link transaction within a slot supports the transmission of one DLPDU from a source device and if required it is followed immediately by the transmission of an acknowledgement (ACK) DLPDU by the destination device. The ACK DLPDU contains either "Success" response code indicating the initial DLPDU was successfully received and handled, or an error response code. An error response code indicates that the initial DLPDU was successfully received, but that further processing failed, for example there were no buffers available in the receiving device.

A broadcast message, using the Data-Link destination address as the broadcast address, is never acknowledged. In this case, multiple receivers are assigned to the same slot.

For successful and efficient TDMA communications, it is imperative that devices know when the start of a time slot occurs. This requires synchronization of clocks among all devices in the network. To ensure network-wide device clock synchronization, the tolerances on time keeping and time synchronization mechanisms are specified in this protocol.

Within a time slot, transmission of the source DLPDU starts at a specified offset from the start of the time slot. This offset allows the source and destination to set their frequency channel

and allows the receiver to begin listening on the specified channel. Since there is a tolerance on clocks, the receiver starts to listen before the ideal transmission start time and continues to listen after that ideal time. Once the transmission is complete, the communication direction is reversed and the destination device indicates, by transmitting an ACK, whether it received the source device's DLPDU successfully or with a specific class of detected errors. If the destination did not hear any transmission or if there was an error in reception which is not included in this class of errors, then the destination device does not transmit ACK DLPDU.

6.2.1.4 Channel hopping

To enhance reliability, channel hopping is combined with TDMA as shown in Figure 13. Channel hopping provides frequency diversity, which can avoid interferers and reduce multi-path fading effects. TDMA enables efficient, low-power and reliable channel hopping communication because the synchronization of the slot and channel used by the communicating devices allows them to rendez vous in time and frequency, thus promoting successful communications.

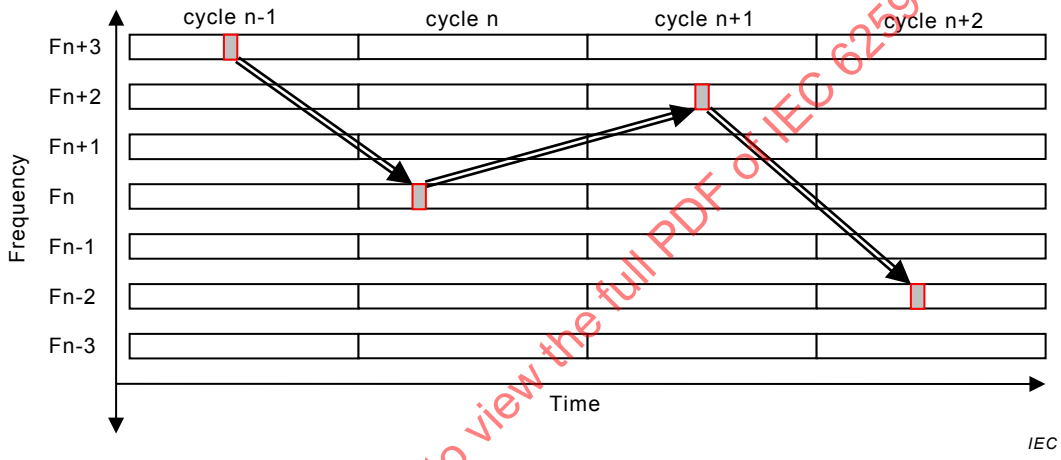

Figure 13 – Channel hopping

Communicating devices are assigned to a superframe, a slot within that superframe and a channel offset. This trio forms a communications link between two communicating devices. All devices support multiple links. The number of possible links is, typically, equal to the number of channels utilized by a network times the number of slots in the superframe. For example using 15 channels and 9 000 slots per superframe results in 135 000 possible links.

Channel hopping provides channel diversity, so each slot is used on multiple channels at the same time by different nodes. This can be achieved by creating links on the same slot, but with different channel offsets. Each device maintains a list of channels in use and the specification (for example the frequency) for that channel. All devices in a network have identical channel lists determined by the network manager. Assignment of links and the devices in a link is the responsibility of the network manager.

Channel blacklisting is a feature of this protocol that allows the network administrator to restrict the channel hopping by the devices to selected channels in the available RF band. For example network administrators can blacklist certain channels in order to protect a wireless service that uses a fixed portion of the RF band that could have been shared by the devices in this network. In practice, communication in the available bandwidth by the devices using other protocols is very random and uses a tiny amount of the total available bandwidth. Consequently, blacklisting seldom provides tangible benefits.

6.2.1.5 Network maintenance

Time and channel are the first two dimensions of a Type 20 network. The third dimension is space (distance). Network devices are installed at various locations in a plant and a given

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device has a set of other devices with which it can communicate directly. This set of devices is defined as neighborhood. Since the RF environment is subject to change, a device keeps its list of neighbor current. Maintenance activities include discovering potential neighbors, gathering statistics about the communication channel to each neighbor, and maintaining time synchronization with neighbors.

Two special DLPDUs assist in building and maintaining a device's list of neighbors. These are Advertise DLPDU and Keep-alive DLPDU. These DLPDUs contain sufficient information to allow new neighbors to be discovered or to allow a newly installed device to request admission to the network. If accepted, the new device can become a neighbor of the advertising device.

NOTE The network manager can schedule transmission of these DLPDUs.

Every successful communication with a neighbor confirms the neighbor's presence and allows the quality of the communication link to be assessed. Since communications only occurs when the device has a DLPDU for the neighbor, there can be long intervals during which the link is not exercised. Keep-alive DLPDUs are used to probe quiescent links and to maintain time synchronization.

6.2.1.6 Time keeping

Time synchronization across the network is essential for TDMA communications. Irrespective of the choice of device hardware time source (for example crystals, ceramic resonators, etc.), some skew between devices (for example due to temperature or voltage variations or ageing) is inevitable. Consequently, Type 20 data-link layer has several mechanisms to synchronize network-wide time.

When a device receives a DLPDU destined to it, its time of arrival is noted. Using this information the destination calculates the difference between the actual time of arrival and the expected time of arrival for that DLPDU. This delta-t (Δt) is communicated in every ACK reply DLPDU sent to the source device. Thus, every acknowledged transaction measures the alignment of network time between the devices.

Within the neighbor list, selected neighbors, specified by the network manager, are used as time synchronization sources. When a DLPDU from a time synchronization neighbor is received, the network time of the receiving device is adjusted. Time synchronization is based on either the DLPDU arrival time or the delta-t in the ACK DLPDU, depending on which device initiated the transaction.

In addition, device designers should understand the time drift characteristics of their products. When the device's time source drifts, the device transmits Keep-alive DLPDU, as needed, to its time-synch neighbors to maintain time synchronization. Device should be built such that it does not require a Keep-alive DLPDU more often than once per 30 s while temperature is varying 2 °C per minute or less. Furthermore, device designs should tolerate one retry in case of packet loss (i.e. a 10 s safety margin). This corresponds to approximately a compensated clock accuracy of 10 parts per million or better.

6.2.2 Network layer operation

6.2.2.1 General

The Type 20 network is a sensor and actuator mesh communication system that simplifies network and device installation and allows the end user to tailor the installation and its topology to satisfy specific application requirements. The basic elements of this network include field devices, gateway and network manager. Every network includes at least one gateway. While redundant network managers are supported, there is only one active network manager per network. Gateways may include one or more access points.

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6.2.2.2 Mesh network

Figure 14 shows an example of network with the field devices deployed in a mesh topology. In this example network, there is one gateway, one network manager and thirteen field devices (labeled a to n). All communication occurs by moving packets from the gateway, through the intermediate devices, to the packet's destination field device. Each movement of a packet from one device to another along the route to the packet's final destination is called a hop.

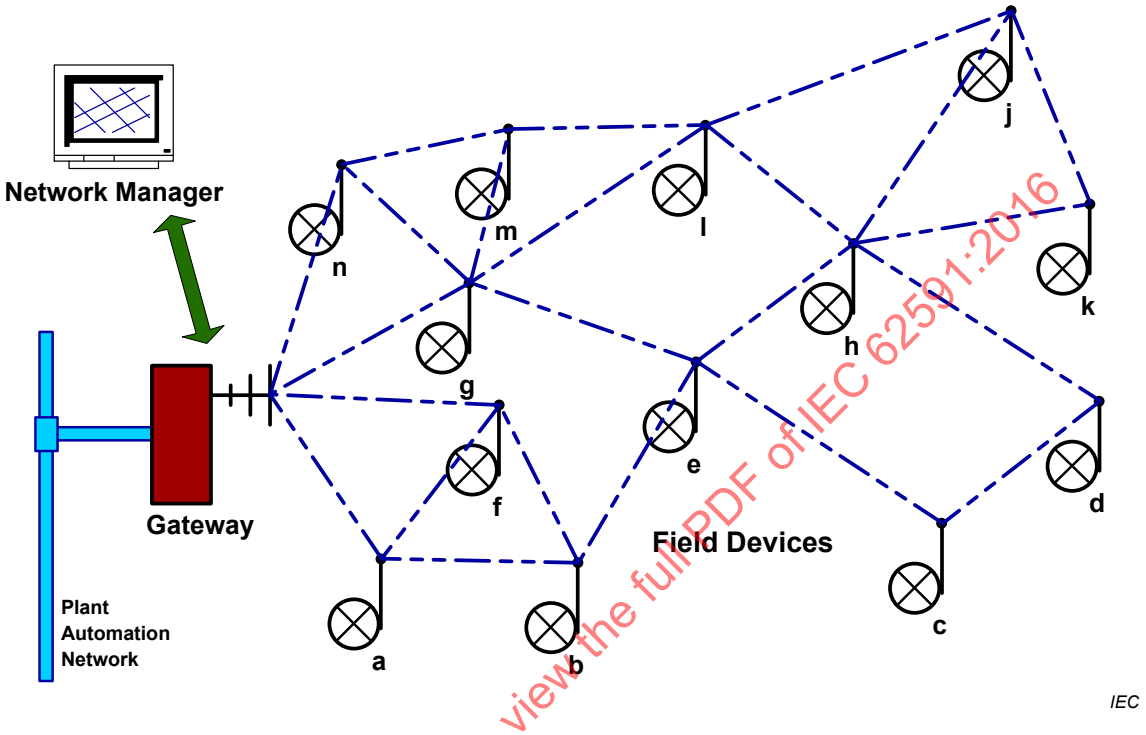

Figure 14 – Wireless network

All devices are able to source and sink packets and are capable of routing packets received from other devices in the network. The routing of packets from their initial source to their final destination may take several hops. The routing of packets is the responsibility of the network layer.

Within this network, nodes ‘a’, ‘f’, ‘g’, and ‘n’ are one hop from the gateway. Since these devices can pass packets directly to the gateway, communication with these devices has the lowest latency. However, since this network uses mesh topology, redundant links are included to improve system reliability by allowing packets to be routed around interference. In Figure 14, node ‘a’ can communicate directly to the gateway but can also communicate via node f to the gateway, if the direct route becomes blocked.

Nodes ‘c’, ‘d’, ‘j’ and ‘k’ are several hops away from the gateway. All intermediate devices (for example field devices ‘g’ and ‘e’) are capable of receiving and forwarding packets to and from these devices. Since the packets shall make several hops to and from nodes ‘c’, ‘d’, ‘j’ and ‘k’, the communication latency to these devices is larger than the devices that are one hop away. However, the mesh topology allows the physical size of the network to become larger and allows communication around obstructions. Furthermore the number of the devices that can be supported in a single mesh network can be larger than that can be supported by single star network.

The protocol for mesh topology can also be used in a star topology i.e. all devices are only one hop from the gateway to support a high performance application. It can also be used in a multi-hop overly-connected mesh topology for a less demanding (for example monitoring) application, or any topology in between. This protocol is flexible enough that a variety of applications (both high and low performance) can operate in the same network.

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The wireless network maintains very high reliability using several mechanisms including multiple paths to network devices, multiple frequencies, and retries. If improved reliability is required, more paths can be inserted by adding additional field devices. The gateway uses access point to connect with the network and it can have more than one access points (see Annex D). Additional network access points can be used to increase throughput and reduce latency.

6.2.3 Device procedures

Several device level procedures are specified in Annex B.

6.3 Logical link control

6.3.1 General DLPDU structure

6.3.1.1 Overview

Figure 15 shows the common DLPDU structure. The DLE shall provide the octets to the physical layer in the same sequence as shown in this figure. The most significant octet of a multiple octet field shall be transmitted first, except as specified otherwise.

Each DLPDU shall consist of the fields in a sequence described below.

a) A single octet set to 0x41 (That means data mode enabled according to IEEE Std 802.15.4-2011, Table 120 and security enabled according to IEEE Std 802.15.4-2011, 5.2.1.1.2).

b) A 1-octet address specifier.

c) The 1-octet Sequence Number.

d) The 2-octet network_ID.

e) Destination and Source Addresses either of which can be 2 or 8-octets long.

f) A 1-octet DLPDU specifier.

g) The DLL payload.

h) A 4-octet keyed Message Integrity Code (MIC).

i) A 2-octet ITU-T CRC16.

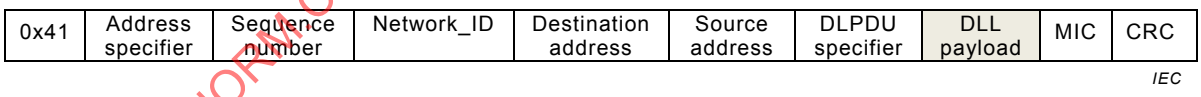

Figure 15 – DLPDU Structure

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6.3.1.2 DLPDU structure fields

6.3.1.2.1 Address specifier

This field specifies the length and type of destination and source addresses as shown in Figure 16. The bit-6 specifies the source address type; the bit-2 specifies the destination address type. If the value of any of these two bits is ‘1’, then the address in the DLPDU, corresponding to that bit is EUI-64, else it is nickname (see 6.3.1.2.4). Any combination of address lengths can be used in a DLPDU.

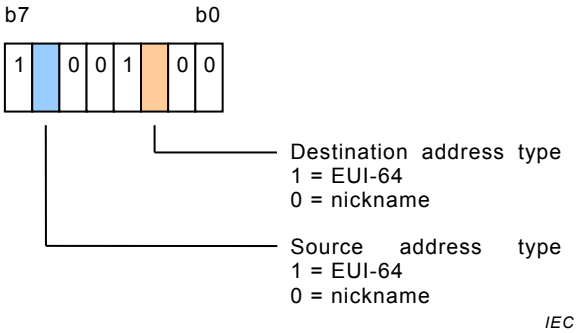

Figure 16 – Address specifier

The other bits in this field shall be set as indicated in the Figure 16.

6.3.1.2.2 Sequence number

The Sequence Number shall be set equal to the least significant octet of the Absolute Slot Number (ASN).

6.3.1.2.3 Network_ID

All networks are identified using a 2-octet number. A device connected to one network shall not send a PDU directly to another device connected to a different network.

This 2-octet value is transmitted, least significant octet (LSB) first, in all DLPDUs. If the network_ID does not match that of the network the device is a member of, then the packet shall be discarded. The ranges of network ID values and their application are shown in Table 26.

Unless specifically noted the most significant octet of the DLPDU shall be transmitted first. The network_ID shall be transmitted with the least significant octet first.

Table 26 – Network_ID Allocation

Network_ID range	Application of network_ID
00 000-32 767 (0x0000-0x7FFF)	Permanent user defined networks (critical networks)
32 768-36 863 (0x8000-0x8FFF)	Temporary user defined networks (demos, trade shows, field trials, etc.)
36 864-57 343 (0x9000-0xDFFF)	Reserved
57 344-61 439 (0xE000-0xEFFF)	Manufacturing networks (non-public used by device manufacturers)
61 440-65 535 (0xF000-0xFFFF)	Reserved

6.3.1.2.4 Destination and source addresses

The DLL supports two types of addresses: a 2-octet nickname and an 8-octet IEEE EUI-64 address.

The 2-octet nickname is an address assigned to a specific network device (see 3.2.74). It needs to be unique only within the network to which the device is connected. The value 0xFFFF is reserved as broadcast address.

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The EUI-64 shall be a concatenation of the 3-octet Organizationally unique identifier (OUI) value as defined by IEEE 802, and a 5-octet Unique ID (see 3.2.105) as shown in Figure 17. The Unique ID shall be a concatenation of the 2-octet Expanded Device type code and the 3-octet Device ID.

No two devices compliant to this standard shall have identical EUI-64 addresses.

NOTE The value of OUI is given by the IEEE Registration Authority Committee – see http://standards.ieee.org/regauth/tutorials.html.

The Expanded Device Type code shall be uniquely assigned for devices within a network and devices in range of other networks. Each device manufactured with the identical Expanded Device type code shall be assigned a Device ID that is unique among all instances of that type of device.

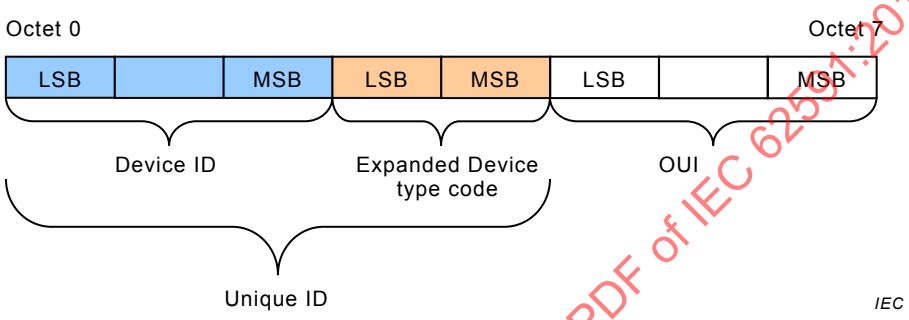

Figure 17 – Construction of 8-octet EUI-64 Address

IEEE STD 802.15.4-2011, 10.1 requires multiple octet fields to be transmitted LSB first. Therefore, the EUI-64 address in the DLPDU shall be transmitted in the sequence shown in Figure 17 i.e. starting with the LSB of the Device ID and ending with the MSB of the OUI. The nickname shall also be transmitted starting with the LSB.

6.3.1.2.5 DLPDU specifier

This field is shown in Figure 18. The most significant two bits are reserved for future use. The DLE shall set the value of these bits to '00' before transmission. The DLE shall ignore any value of these two bits.

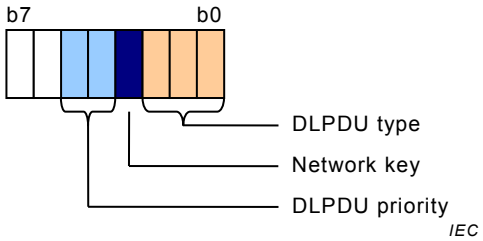

Figure 18 – DLPDU specifier

The bits 5 and 4 indicate the priority of the DLSDU contained in the DLPDU. Its encoding is:

00: Alarm (lowest) priority;

01: Normal priority;

10: Process data priority;

11: Command (highest) priority.

Bit 3 indicates the type of network key being used in the DLPDU. Its encoding is:

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0: the well known key from this specification, used only by the unauthenticated device;

1: the confidential network-key, used by the authenticated device.

It indicates the key being used to authenticate the DLPDU. For all communications within the network between authenticated devices, the DLE shall set this bit to '1' and use the confidential network-key when generating the DLPDU MIC (see 6.3.4.2). This bit shall be reset to '0' during the joining process while the device is unauthenticated. DLPDUs passed between the unauthenticated device and its neighbors shall use the well known key (see 6.3.4.2.3).

The bits 2, 1 and 0 of the DLPDU specifier indicate the DLPDU type. Its encoding is:

000: ACK;

001: Advertise;

010: Keep-alive;

011: Disconnect;

111: Data.

The ACK, Advertise, Keep-alive and Disconnect DLPDUs shall use Command (highest) priority.

Other encodings of this field are reserved for future use.

6.3.1.2.6 DLL payload

The DLL payload depends on the DLPDU type. Data DLPDUs contain a DLSDU. Other types of DLPDU have DLE maintenance data that depends upon the type of DLPDU. For example ACK DLPDU has a payload that consists of a time adjustment as measured by the destination device specified in the immediately prior DLPDU.

6.3.1.2.7 Keyed message integrity code

A keyed message integrity code (MIC) is used for link-layer authentication of the received DLPDU. The receiving devices shall reply only to unicast, non-acknowledgement DLPDU that has been successfully authenticated.

6.3.1.2.8 Cyclic Redundancy Check

The Cyclic Redundancy Check (CRC) field is based on the 16 bit ITU-T CRC polynomial, also known as a CRC16. The CRC is calculated over the entire frame using the following generator polynomial of degree 16:

$$G_{16}(x) = x^{16} + x^{12} + x^5 + 1$$

For more information see IEEE 802.15.4-2011, 5.2.1.9. The CRC should be calculated in the device hardware.

At receivers, the received octet stream is subjected to a similar calculation. When a receiver may predict the octets that will contain a CRC, it may omit those octets from the calculation and check that the received CRC matches those octets. Alternatively, the receiver may compute a CRC over all the octets of the message and check that the result matches an expected residual value of zero.

The CRC is used to detect bit errors and devices shall reply only to non-acknowledgement DLPDU with a CRC matching that calculated by the receiving device, or whose residual value after processing the entire DLPDU, including received CRC octets, matches the expected residual of zero.

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6.3.2 DLPDU-specific structure, encoding and elements of procedure

6.3.2.1 General

There are five DLPDU types.

- Data DLPDU – contains DLSDU in transit to their final destination device. The source and sink for Data DLPDUs is the network layer.
- ACK DLPDU – is the immediate link level response to receipt of the source device's transmission DLPDU.
- Keep-alive DLPDU – facilitates connection maintenance between neighboring devices.
- Advertise DLPDU – provides information to neighboring devices trying to join the network.
- Disconnect DLPDU – are used to advise neighboring devices that the device is leaving the network.
- Devices receiving a DLPDU with any type other than the above listed types shall discard it and shall not acknowledge the received DLPDU.
- ACK, Advertise, Keep-Alive and Disconnect DLPDUs are generated and consumed by peer DLEs. These DLPDUs are not propagated to the network layer or onward through the network.

6.3.2.2 Data DLPDU

6.3.2.2.1 Purpose of Data DLPDU

The Data DLPDU is used to send DLS-user data from the source DLE to the destination DLE. It is also used by network layer to forward its user data from an intermediate DLE to another DLE.

6.3.2.2.2 Contents of the Data DLPDU payload

The DLL payload in this DLPDU originates from the network layer of this hop's source device and is passed to the destination device's network layer. It is then forwarded by the peer network layer to its final destination.

6.3.2.3 ACK DLPDU

6.3.2.3.1 Purpose of ACK DLPDU

It is used to send an immediate response to the just received non-ACK DLPDU.

6.3.2.3.2 Contents of the ACK DLPDU payload

The structure of the DLL payload for ACK DLPDU is shown in Table 27.

Table 27 – Contents of the ACK DLPDU payload

Offset from the start of the payload	Length in octets	Description
0	1	Response-code
1	2	Time-adjustment in μs. The value of the Time adjustment is positive (negative) if the DLPDU was received earlier (later) than expected.

The Response-code shall specify either the successful reception or the error in reception of the immediately prior DLPDU as shown in Table 28.

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Table 28 – ACK response-code

Code	Class	Description
0	Success	DLPDU was received without error and was accepted by destination device.
61	Error	No buffer was available to store the DLPDU of priority other than 'Alarm'; DLPDU was discarded.
62	Error	No buffer was available to store the DLPDU of 'alarm' priority; DLPDU was discarded.
63	Error	Priority of the received DLPDU was lower than Priority_threshold (see 6.5.2); DLPDU was discarded.

The Time-adjustment is the difference between the expected time of reception of the complete start delimiter that frames a non-ACK DLPDU and the actual reception of that complete start delimiter, measured in μs. The Time-adjustment is a 2-octet, two's-complement integer.

6.3.2.3.3 Contents of the ACK MIC

The MIC field of ACK DLPDU shall be computed using the same key as the key in the just received DLPDU. See 6.3.4.2 for generating MIC.

6.3.2.3.4 Sending the ACK DLPDU

The ACK DLPDU shall be sent on the link when the sending DLE has just received any DLPDU except ACK DLPDU and there was no reception error and the destination address in the just received DLPDU is not a broadcast address. The DLE shall check the priority of the received DLPDU and availability of the local storage buffer and either accept or discard the received DLPDU as specified in 6.3.3.

6.3.2.3.5 Receiving the ACK DLPDU

The received DLPDU shall be processed as specified in 6.4.5.2.4.

6.3.2.4 Keep-alive DLPDU

6.3.2.4.1 Purpose of keep-alive DLPDU

Keep-alive DLPDUs is used:

- for network time synchronization. Time synchronization is updated based on the Time adjustment value returned in the ACK DLPDU;
- to confirm connectivity with a neighbor;
- to allow the device to be detected by others.

6.3.2.4.2 Contents of the keep-alive DLPDU payload

This field shall be null.

6.3.2.4.3 Sending the keep-alive DLPDU

This DLPDU is sent as specified in 6.4.3.4.

6.3.2.4.4 Receiving the keep-alive DLPDU

The received DLPDU shall be used to update the neighbor table as specified in 6.4.3.4.

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6.3.2.5 Advertise DLPDU

6.3.2.5.1 Purpose of Advertise DLPDU

Advertise DLPDU is used to invite new devices into the network.

6.3.2.5.2 Contents of Destination Addresses

The destination address shall be the broadcast address. The broadcast address shall have be five octets long and shall have all zeros as the value.

6.3.2.5.3 Contents of the Advertise DLPDU payload

The DLL payload includes network information. The structure of the DLL payload for Advertise DLPDU is shown in Table 29.

Table 29 – Contents of the Advertise DLPDU payload

Offset from the start of the payload	Length in octets	Description
0	5	Absolute slot number – the number of slots since the start of the network to the slot used for transmission of this DLPDU.
5	1	Join-control
6	1	The Size of channel map array in number of bits. Maximum size of the channel map array is 256 bits.
7	Variable	Channel-map-array – this is an array of bits starting with the least significant bit (bit 0 of octet 0) and adding octets as necessary until all bits are accounted for. Each bit corresponds to one channel. If the bit is set to '1', then the corresponding channel is in use.
n+1	2	Graph_ID
n+3	1	Number of superframes

The Join-control field specifies security level and join-priority as shown below:

Bits 7 – 4: Security level supported by the network;

Bits 3 – 0: Join_priority – an unsigned integer indicating the ability of the advertising device to support another child device. The lower the value the better this advertising device is for joining.

The content of Table 30, Table 31, and Table 32 are repeated for each superframe.

Table 30 – Beginning of the superframe

Offset from the start of the payload	Length in octets	Description
Variable	1	Superframe_ID
Variable	2	Superframe size i.e. the number of slots in this superframe.

Table 31 – The next field after the last superframe size

Offset from the start of the payload	Length in octets	Description
Variable	1	Number of Links

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Table 32 – Repeated for each link

Offset from the start of the payload	Length in octets	Description
Variable	2	Join-slot – the specific slot within the superframe for this link
Variable	1	Join-slot-channel-offset

The Join-slot-channel-offset field specifies:

Bit 7: Reserved for future use; the sending DLE shall set it to '0';

Bit 6: If the link is for DLPDU transmission by the joining device, then the sending DLE shall set it to '1';

Bits 5 – 0: Channel offset – the frequency channel offset for this slot. This value is used to calculate the link frequency/channel number.

The size of Channel-map-array depends on the underlying physical layer. The IEEE 802.15.4-2011, 2 450 MHz physical layer provides 16 channels. The channel-map-array is two octets long. The least significant octet contains channels 11 – 18 and the most-significant octet contains channels 19-25 as shown in Table 33. The channel 26 is not used and thus bit 15 is always '0'.

Table 33 – Channel and frequency assignments

Index	Channel number
0	11
1	12
2	13
3	14
4	15
5	16
6	17
7	18
8	19
9	20
10	21
11	22
12	23
13	24
14	25
15	26

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The absolute slot number and the channel map allows the current channel offset to be identified when issuing a packet to petition the network manager for admission to the network.

6.3.2.5.4 Contents of the Advertise MIC

The MIC field of Advertise DLPDU shall be computed using the well-known key. See 6.3.4.2 for generating MIC.

6.3.2.5.5 Sending the Advertise DLPDU

An Advertise packet can be sent on any transmit link that is available for transmission by the advertising device. On the joining device, when the DL-management requests that the DLE join a network, the DLE listens for the Advertise DLPDUs sent by other DLEs. It then uses the information in the received DLPDUs to synchronize with the network and to initiate the join process by sending its Join Request DLPDU. The joining device is limited to these links until it is authenticated by the network manager, and has received its network key. By limiting communication to only the join links, the network manager can quarantine the device until it is ready for the device to fully participate in the network.

All other DLPDUs have a higher priority than Advertise DLPDU.

6.3.2.5.6 Receiving the Advertise DLPDU

The DLE that has not joined the network shall receive all Advertise DLPDUs. It shall learn the network parameters included as the DLL payload of Advertise DLPDU. The reception of this DLPDU shall generate DL-Advertise indication primitive to the DLM-user.

6.3.2.6 Disconnect DLPDU

6.3.2.6.1 Purpose of Disconnect DLPDU

Disconnect DLPDU is used by a device that is leaving the network. It is sent to every neighbor known to the device.

6.3.2.6.2 Contents of Destination Addresses

The destination address shall be the neighbor's address.

6.3.2.6.3 Contents of the Disconnect DLPDU payload

This field shall be null, which means no octets shall be used in the payload.

6.3.2.6.4 Contents of the Disconnect MIC

The MIC field of ACK DLPDU shall be computed using the network key. See 6.3.4.2 for generating MIC.

6.3.2.6.5 Sending the Disconnect DLPDU

When the DL-management requests that the DLE leave the network, it shall send Disconnect DLPDU at the first opportunity.

6.3.2.6.6 Receiving the Disconnect DLPDU

The receiving DLE shall remove the sending DLE from its neighbor list, and shall delete all links connecting to the sending DLE. The reception of this DLPDU shall generate DL-DISCONNECT indication primitive to the DLM-user.

6.3.3 DLPDU Priority and Flow Control

The DLPDU priority is used for flow control, to mitigate the network congestion and ensure that the network manager retains control of the network during a process upset or when an adverse RF event occurs. For example the network manager can raise the Priority_threshold to reduce packet flow through the device by changing the value of Priority_threshold (see 6.5.2).

The DLE is required have at least one storage buffer reserved to receive "Alarm" priority DLPDU and at least one storage buffer reserved to receive "Command" priority DLPDU and

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these reserved buffers shall not be used to store the received DLPDU of any other priority. The receiving DLE shall check the priority of the received DLPDU, the current Priority_threshold and availability of the local storage buffer to determine whether the DLPDU is accepted or discarded as follows.

If the final destination of the just received DLPDU is not the DLE itself and the priority level of the received DLPDU is lower than the Priority_threshold, then the DLE shall discard the received DLPDU and the response code in the ACK DLPDU shall be set to 63.

NOTE 1 To manage DLPDU flow through the network, the network manager can raise or lower the priority level of DLPDUs that a DLE is allowed to accept.

Else if the priority level is “Alarm” then

1) if one and only one buffer dedicated to store this priority level is not available, then the DLE shall discard the received DLPDU and response code in the ACK DLPDU shall be set to 62;

   NOTE 2 Only one buffer for “Alarm” priority is allowed to reduce the flood of alarms. The alarms are not lost, because these are time stamped and the PDU containing alarm information is sent again after a timeout.

2) Else the DLE shall accept the received DLPDU and response code in the ACK DLPDU shall be set to Success.

Else the priority level is not “Alarm” and

1) if a buffer dedicated to store priority level of the received DLPDU is not available, then the DLE shall discard the received DLPDU and response code in the ACK DLPDU shall be set to 61;
2) Else the DLE shall accept the received DLPDU and response code in the ACK DLPDU shall be set to “Success”.
3) If the received DLPDU is Keep-alive or Advertise or Disconnect, then the DLE shall always accept it and response code in the ACK DLPDU shall be set to “Success”.

If a storage buffer is available, the DLE always accepts the “Command” priority DLPDU, because it is the highest priority. The DLE should allocate enough buffers, so that it can receive almost all of the received “Command” priority DLPDUs.

In summary, network management DLPDUs always propagate through the network allowing the network manager to keep the network operational. Alarms flow through the network is restricted ensuring alarm floods do not disrupt network operation. Since alarms are always time-stamped, no information regarding failure sequences is lost.

All other network traffic flows through the network as buffer space and network capacity allows. Within this network traffic, process data has the highest priority. Operation and control of the process is lower priority to prevent network communication disruption.

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6.3.4 Error detection and security

6.3.4.1 General

To perform error detection this standard includes a frame check sequence at the end of every DLPDU. The check (CRC) is used to detect communications errors. The CRC is calculated across the entire DLPDU using the 16-bit ITU-T algorithm.

For security, every DLPDU includes a MIC in every DLPDU.

6.3.4.2 MIC computation

6.3.4.2.1 General

A keyed MIC is used to ensure that the DLPDU is originated from an approved, authenticated device. The DLPDU itself is not enciphered; rather its contents are authenticated using the

four-octet MIC. The MIC is generated and confirmed using CCM* mode (combined counter with CBC-MAC (corrected)) in conjunction with the AES-128 block cipher to provide authentication as specified in NIST Pub 800-38C. This cipher requires four octet-strings as parameters:

- 'a', the additional data to be authenticated but not enciphered;
- 'm', is the message to be enciphered;
- 'N', the 13-octet nonce; and
- 'K', the 128-bit AES Key.

The parts of a DLPDU, from the 0x41 octet through the end of the payload, is the octet-string 'a'. Since the DLPDU is not enciphered, the octet-string 'm' is empty.

6.3.4.2.2 DLL nonce

The 'N' shall be exactly 13 octets long and is the concatenation of the ASN and the source address in the DLPDU.

The ASN always contains the number of the current slot. The ASN is 5-octets long and is copied into N[0] to N[4], where N[0] is the most significant octet MSB of the ASN.

If the DLPDU has the EUI-64 address then it is copied (MSB to LSB) into N[5] through N[12]. In other words, the OUI is copied into N[5] through N[7]. The Expanded device type code and Device ID are copied (MSB to LSB) into N[8] through N[9] and N[10] through N[12], respectively.

If the DLPDU has the 2-octet nickname then it is copied (MSB to LSB) into N[11] through N[12]. The N[5] through N[10] are set to 0x00.

6.3.4.2.3 DLL key

The key shall be 128-bits (16 octets) long as required by the CCM Mode. It is copied into the 'K' octet-string in most significant octet first. The K[0] and K[15] are the most significant and least significant octet of the key, respectively.

There are two DLL keys:

- the well-known key, which is used in Advertise DLPDU; and
- the network key, which is used for all other DLPDUs.

The well-known key shall be identical for all devices and has a value of 7777 772E 6861 7274 636F 6D6D 2E6F 7267 hexadecimal. It is used for DLPDUs passed between the joining device and devices already part of the network.

NOTE The well-known key is randomly chosen.

This network key is supplied by the network manager to a device, when it joins the network. The device shall not change the value of this key.

The network manager may change the network key any time.

6.3.4.3 Error detection

When the DLE receives a DLPDU, it checks the CRC in the received DLPDU. If the CRC in the DLPDU does not match the expected CRC, then the DLE shall discard the received DLPDU and shall not send ACK DLPDU in response.

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If the CRC in the received DLPDU is correct, then the DLE shall compute the expected MIC. It shall then compare it with the MIC in the received DLPDU. If these two are not identical, then the DLE shall discard the received DLPDU and shall not send ACK DLPDU in response.

6.4 Medium Access Control

6.4.1 Function

The Medium Access Control (MAC) sublayer provides basic communication from one DLE to another. The timing of such communication is regulated by slot synchronization across the network. To accomplish this, the DLE includes:

- Neighbor table, superframes, links, and graphs that configure the communication between the device and its neighbors (see 6.4.3). These tables are prepared by the network manager. In addition the neighbor table is updated by the DLE, as it discovers addition of a new neighbor to the network or disconnection of an existing neighbor from the network.
- A link scheduler (see 6.4.4) that evaluates the device's tables and chooses the next slot to be serviced by listening for a DLPDU or by sending a DLPDU. In general the link scheduler walks the tables to identify the next slot in which to send a DLPDU and the next slot in which to listen. The slot scheduled is the next of these two slots to occur.
- State machines that control the propagation of DLPDUs through the MAC sublayer. MAC operation (see 6.4.5) consists of schedule maintenance and service slots. MAC operation is event driven and responds to service primitive invocations and the start of a slot needing servicing.

The MAC sublayer sends the DLPDU queued in the device's buffers and it receives DLPDU sent by a neighbor DLE. Both of these operations are performed one slot at a time. Successful communication depends on slot time synchronization between neighbors and the compliant timing of the transaction within the slot.

6.4.2 Slot timing

6.4.2.1 General

Figure 19 shows one slot and provides an overview of single transaction timings according to IEEE 802.15.4e:2012, Figure 22b. The diagram (a) shows the operation at the source neighbor and the diagram (b) shows the operation at the destination neighbor. The details of slot time parameters are defined in Table 34; it also shows the values required for the physical layer supported by this standard and specified in IEEE 802.15.4e:2012, Table 52e, 2 450 MHz physical layer. All transactions are required to comply with these timing parameters.

The slot start time at the source and destination can be different due to different amount of clock drift. This diagram shows that the slot starts at a later time at the destination device.

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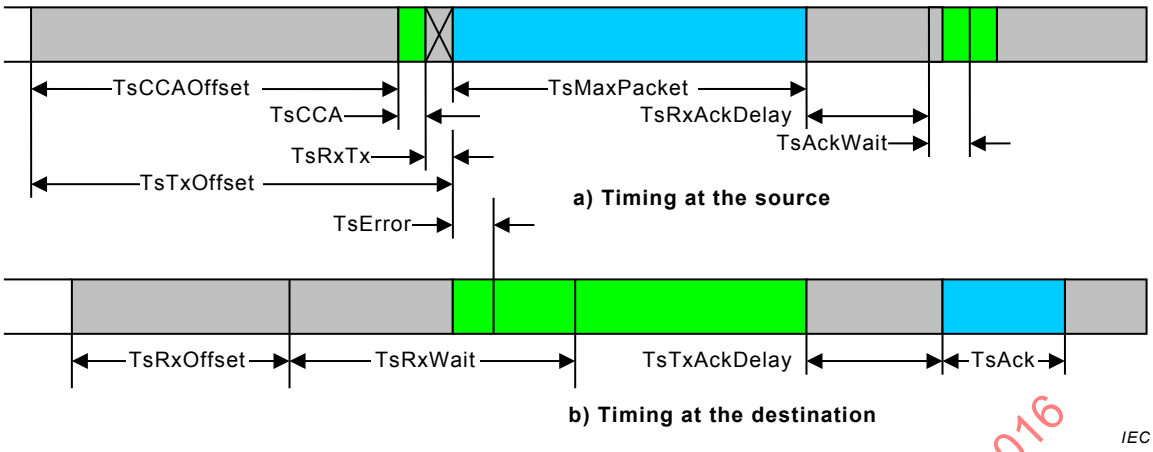

Figure 19 – Slot timing details

Table 34 – Slot timing definitions and values

Symbol	Definition	Required value
TsTxOffset	Start of the slot to start of preamble transmission	2 120 µs
TsRxOffset	Start of the slot to when transceiver shall be listening	1 120 µs
TsRxWait	The minimum time to wait for start of message; this correlates to the amount of drift between the neighbors that can be tolerated to maintain communications.	2 200 µs ±100 µs
TsMaxPacket	The amount of time it takes to transmit the longest possible packet that includes PhL preamble, delimiter, length and DLPDU	4 256 µs
TsTxAckDelay	End of message to start of ACK; the destination device shall validate the STX, and generate an ACK, if required, during this interval.	1 000 µs ±100 µs
TsRxAckDelay	End of transmit PhPDU to when transceiver shall be listening for ACK	800 µs ±100 µs
TsAckWait	The minimum time to wait for the start of an ACK	560 µs
TsAck	Time to transmit an ACK (25 octets[a])	800 µs
TsCCAOffset	Start of slot to beginning of CCA	1 800 µs ±100 µs
TsCCA	Time to perform CCA (8 symbols)	128 µs
TsRxTx	The longer of the time it takes to switch from reception to transmission or vice versa (12 symbols)	192 µs
TsError	This is the difference between the actual start of message and the ideal start of message time as perceived by the receiving device. In other words, this is how much the receiving device perceives the transmitting device to be out of sync.	

[a] ACK is longer when long (8 octet) addresses are used.

A time slot period shall be 10 ms.

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If a device has a packet ready for transmission and it is scheduled to transmit in a slot, then that slot begins by allowing a time interval to prepare the PhPDU for transmission. The source shall perform the clear channel assessment (CCA) and transmit the packet. If the received DLPDU requires an acknowledgement, then the destination DLE shall transmit the PhPDU conveying ACK DLPDU.

If a device is scheduled to receive in a slot, then that device shall enter receive mode. The device shall start to listen to the medium after TsRxOffset delay from the start of the slot. The receive window specified by TsRxWait permits device time to drift, while still allowing devices to communicate and resynchronize their slot timers.

If the destination device detects a PhPDU, it shall capture the end of reception of the physical layer Delimiter start time. It shall calculate TsError as the difference between the expected start time and the actual start time of the physical layer Delimiter.

Time is allocated towards the end of the slot for processing the received packet and preparing for the next slot, (for example assessing and prioritizing the packets now queued up in each device). If one of the neighbors was the time source for the other, then the end of the slot time shall be aligned after successful communication.

6.4.2.2 Transmission of a packet

The source device shall wait for TsCCAOffset duration after the start of a slot and then it shall perform CCA for TsCCA duration. If the channel is occupied, the transaction attempt is rescheduled for a later slot. Else, if the channel is clear, then the device shall switch the transceiver from reception to transmission. After that, the device shall begin its transmission such that the start of message (SOM) occurs exactly TsTxOffset duration from the start of the slot.

6.4.2.3 Reception of a packet

The destination device shall enter the receive mode at the start of the slot. It shall start to listen to the medium TsRxOffset delay from the start of the slot. The destination device shall continue to check for SOM. If the SOM is not detected within (TsRxOffset + TsRxWait) duration from the start of the slot, then it shall stop listening. Else, if the SOM is detected, then it shall receive and validate the received packet.

6.4.2.4 Acknowledged transaction

Most communications consist of the source device propagating a message by transmitting a packet and the destination device acknowledging the reception of that packet. For acknowledged communication the source and destination address in the DLPDU shall contain individual device address.

If the received packet is valid, then the destination device shall inspect the destination address in the DLPDU. If the destination address is not a broadcast address, and there are no reception error then the device shall switch from reception to transmission and shall transmit PhPDU containing ACK DLPDU, such that the SOM of this PhPDU occurs exactly TsTxAckDelay after the end of the transmitted source device's packet.

Meanwhile the source device shall switch from transmission to reception. After TsRxAckDelay duration from the end of its transmission, the source device shall listen to the medium. It shall check for SOM for the duration of TsAckWait.

6.4.2.5 Broadcast transaction

Broadcast transmissions are also supported. The DLPDU source address is individual device address and the destination address is the broadcast address. Broadcast messages are not acknowledged by the receiving device. The broadcast address shall be five octets long and shall have all zeros as the value.

If the received packet is valid, then the destination device shall inspect the destination address in the DLPDU. If the destination address is a broadcast address then the receiving device shall not transmit any response.

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6.4.3 Communication tables and buffers

6.4.3.1 General

All devices shall maintain a series of tables that control the communications performed by the device and collect statistics on those communications. In addition, the device shall buffer the received packets, process these and forward, if required.

The tables controlling communication activities are:

- Superframe table – it stores the attributes of a superframe;
- Link table – these are used to store the attributes of a link;
- Neighbor table – it stores the list of all devices that the device may be able to directly communicate with;
- Graph table – it stores the next hop destinations legal for propagating the packet onward toward its destination.

Some of the information in these tables is shared between the NLE and DLE. The relationship among these tables is shown in Figure 20. Within the device the neighbor table is central. This table contains a list of all devices that have been identified by the device.

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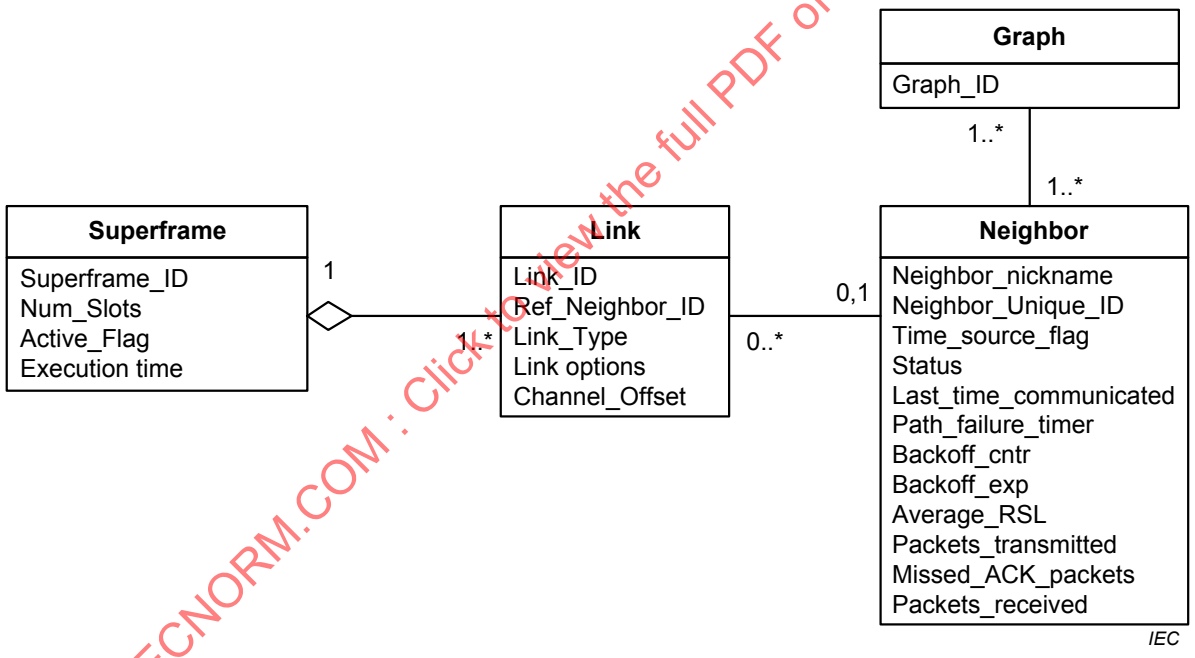

Figure 20 – DLE tables and relationship

A superframe contains 1 or more links. A link is associated with 0 (broadcast link) or 1 neighbor (specific network device). A neighbor can be associated with multiple links. Neighbors can also be associated with 0 or more graphs and graphs can be associated with 1 or more neighbors.

In addition to these tables, there are buffers to store the packets. Table 35 shows the minimum number of table entries and buffer space that every network device shall support.

Table 35 – Minimum DLE Table and buffer space requirement

Table name	Required minimum entries
Superframe	16

Link	64
Neighbor	32
Graph	32
Total Number of Graph-Neighbor Connections	128
Packet buffers	16

Some of the attributes of these tables described in this standard may be calculated or derived from other information, and it is not necessarily to store these separately.

NOTE Although specific implementation of data and configuration storage is left up to the designers of the device, general description of the fields contained in the data structures is important to overall operation.

Each superframe has one or more links. The links specify the slot and associated information required to forward or accept a packet.

Each link defines a communications opportunity. A link can belong to one and only one superframe. Links specify a neighbor that is the partner in any communication using the link. A link is either directed to a neighbor or is a broadcast link. For a link, packets are either propagated to or from the neighbor. Broadcast links always propagate packets from the device.

A graph may specify more than one neighbor, any of which may be used for the next hop for packets following the route designated by the Graph_ID. When forwarding a packet using graph routing, the device can propagate it to any of the neighbors associated with that packet's Graph_ID. For more information see 6.4.3.5.

6.4.3.2 Superframe table

The superframe attributes are shown in Table 36. Superframe consists of a fixed number of slots, and initially contains no links. Superframes are created and maintained by the network manager. Once a superframe is created the network manager can add, delete or modify links within the superframe, thus identifying opportunities for device to device communications. Once configured with links, the superframe can be enabled to allow the link scheduler to begin identifying transmit and receive slots. When Joining, the advertised Superframe is immediately activated. When a Superframe is created using Write superframe service, the Superframe Mode Flags determine whether the Superframe is active or not.

Table 36 – Superframe attributes

Attribute name	Range of values	Definition
Superframe_ID	0 to 255	Unique identifier of the superframe, supplied by the network manager
Num_Slots	0 to 65 535	Number of slots in this superframe i.e. size of superframe
Active_Flag	TRUE, FALSE	Flag indicating if the superframe is currently activated
Links [1..]	Link_ID	List of links in this superframe

6.4.3.3 Link table

6.4.3.3.1 General

The link attributes are shown in Table 37. The link includes a reference to neighbor that is permitted to communicate with the device. This reference can be to a single neighbor or it can be unspecified group of neighbors (for broadcast link). The Network Manager may specify multiple links in the same slot. The slot number within the superframe, direction of the communication, link characteristics – shared or dedicated, and the initial communication

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channel are specified. The link is uniquely identified by the combination of following key parameters:

Superframe_ID, Slot number and neighbor address.

When the Network Manager deletes all the links in the device, the device shall rejoin the network.

Table 37 – Link attributes

Attribute name	Range of values	Definition
Link_ID	See Note	Identifier of the link
Ref_Neighbor_ID	See Note	Reference to a neighbor table entry
Link_type	NORMAL, BROADCAST, JOIN, DISCOVERY	Indicates the type of link
Tx_Link	TRUE, FALSE	When TRUE, indicates the link shall be used for transmission
Rx_Link	TRUE, FALSE	When TRUE, indicates the link shall be used for reception
Shared_Link	TRUE, FALSE	When TRUE, indicates the link is shared by multiple devices
Slot	0 to 65 535	Slot number in superframe assigned to this link
Channel_Offset	11 – 25	Initial frequency hopping channel offset (see Table 33)
NOTE The range of values is not specified by this standard; it is implementation dependent.		

NOTE The network manager does not delete or suspend any link of JOIN type, while there is any outstanding request join request.

Links are allocated to a superframe by the network manager. When the network manager designates a link as being shared, contention-based, multiple-sender access is performed within the corresponding link. For these links, messages that are not acknowledged result in a random back-off algorithm being applied (see 6.4.4.4).

6.4.3.3.2 Link channel calculation

The link also specifies the Channel_Offset and thus implicitly the order in which the channels are hopped. The remainder of this operation indexes the channel table to obtain the actual channel used for communication in the active slot. The channel table contents and length depends upon the underlying physical layer. In the preferred physical layer specified in IEEE 802.15.4-2011 (2 450 MHz), the number of available channels is 16.

NOTE This standard uses only first 15 out of available 16 channels.

The DLE shall contain a 64-bit ChannelMap variable that tracks the device's active channels. Each bit (bit 0 through bit 63) that is TRUE identifies an active channel. The ChannelMap is initialized to all TRUE (i.e., all channels are active by default). Only bits corresponding to available channels for the physical layer are significant and considered in any calculations.

The DLE shall have a variable ActiveChannelArray to store the ordered set of active bit numbers in ChannelMap. The bit number of the least significant active channel shall be stored at index zero in the array. The bit number corresponds to the index into the Physical Channel Table for the Physical Layer in use.

The DLE shall compute the value of the variable ActiveChannel by dividing the sum of the Channel_Offset and absolute slot number by the number of channels currently active.

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ActiveChannel = (Channel_Offset + absolute slot number) % number of active channels.

It shall use ActiveChannel value to index into the ActiveChannelArray. The value stored at that index shall be used as the channel to be used for the link in that absolute slot number.

Channel = ActiveChannelArray [ActiveChannel].

The ActiveChannelArray shall be an ordered list beginning with the smallest active channel index (at ActiveChannelArray [0]) through the largest.

6.4.3.4 Neighbor table

The device shall maintain a list of neighbors it has knowledge of. These are the companion devices that share a link with this device or neighbors whose communications have been overheard. Within this list, all linked neighbors shall reside in the list before (i.e., at the beginning of the list) the unlinked neighbors.

As shown in Figure 20, the neighbor table is central to driving device communications:

- Each link has a reference to one neighbor, or it is broadcast link.
- Graphs may have references to several neighbors. When a graph is used for routing, the neighbors for that graph are all valid recipients of the packet being propagated.

The neighbor table collects a variety of attributes and statistics pertaining to the neighbor as shown in Table 38 including:

- Basic neighbor identity information;
- Performance and historical statistics; and
- Shared slot attributes.

Basic identity information includes the neighbor's Unique ID, 2-octet nickname address and whether the device is a time source. To support contention-based access in shared slots, the neighbor table also contains the parameters necessary to support the back-off algorithm (see 6.4.4.4).

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Table 38 – Neighbor attributes and variables

Attribute name	Range of values	Definition
Neighbor_Unique_ID	see 6.3.1.2.4	Unique ID of the neighbor device (i.e. the long address)
Neighbor_nickname	see 6.3.1.2.4	The short address of the neighbor as defined in 3.2.74
Join_priority	0 to 15	Join_priority at which the neighbor advertises
Time_source_flag	TRUE, FALSE	Flag indicating if device should take time synchronization from this neighbor
Status	Bit Field	Status information regarding this neighbor (for example path failure) as specified in Table F.34
Backoff_exp	0 to 7	Back-off exponent in collision avoidance algorithm for shared links[b]
Backoff_cntr	0 to 511	Back-off counter in collision avoidance algorithm for shared links[b]
Last_time_communicated	0 to 2^{32}-1 in units of ms	Time when last communicated with this neighbor
Path_failure_timer	0 to 2^{32}-1	Cyclical timer in ms to detect failure of the path to the neighbor
Average_RSL	-128 to 127	Average received signal level in dBm for packets received from this neighbor
Packets_transmitted	0 to 65 535[a]	Number of non-broadcast packets transmitted to this neighbor

Attribute name	Range of values	Definition
Missed_ACK_packets	0 to 65 535[a]	Number of packets for which an expected ACK was not received from this neighbor
Packets_received	0 to 65 535[a]	Number of good non-broadcast packets received from this neighbor
Broadcasts_received	0 to 65 535[a]	Number of good broadcast packets received from this neighbor
[a] The value of packet counters rolls over from 65 535 to 0.		
[b] See 6.4.4.4 for the algorithm.		

The device's ability to communicate with a neighbor is a key metric in forming and grooming the mesh network. The statistics are maintained for each neighbor. These include Average_RSL; statistics on the packets transmitted and received and the timestamp of the last communication with the neighbor. For linked neighbors, Average_RSL is calculated using an IIR filter with the following equation:

Average_RSL = Average_RSL – (Average_RSL / RSL_damp) + (MeasuredRSL / RSL_damp)

where

MeasuredRSL is the RSL for the current packet;

RSL_damp is the damping factor.

RSL_damp shall be a power of 2 and defaults to 4. For discovered neighbors (i.e., neighbors the device does not communicate with) the highest RSL value is returned.

If a link to a neighbor exists, the Last_time_communicated is used to trigger transmission of Keep-alive DLPDU. A Keep-alive DLPDU shall be transmitted to the neighbor, whenever the Last_time_communicated time value plus the Keep_alive_time (see Table 46) is greater than the current time. Keep-alive DLPDU transmission shall be repeated until a new DLPDU is received from that neighbor.

The Path_failure_timer shall also be maintained for each neighbor. Whenever a DLPDU from the neighbor is received, the timer shall be initialized to Path_fail_time (see Table 46). When this timer reaches zero, the DLM-event indication with PATH_FAILURE event shall be invoked. When this occurs, the timer shall be re-initialized to Path_fail_time and restarted. The device shall keep trying to use the failed path until the neighbor or its links are removed from the table.

Every received packet is used to update the corresponding neighbor attributes or it creates a new neighbor table. If a device shares links with a neighbor, then that neighbor shall be retained in the table. When the neighbor table is full and a new neighbor is detected, the neighbor with the oldest value of Last_time_communicated shall be deleted and the new neighbor shall be added to the table.

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6.4.3.5 Graph table

The graph provides the routing information to guide the delivery of a packet to its final destination. A graph is a directed list of paths that connect two devices within the network. Both upstream (toward the gateway) and downstream graphs are used. The network manager is responsible for correctly configuring each graph. Table 39 shows graph attributes. Graphs have an identifier; a list of neighbors and the destination's long and short address. When the Graph_ID value is less than 0x0100 it indicates a Superframe_ID, and when equal to 0xFFFF it indicates the graph is invalid.

Table 39 – Graph attributes

Attribute name	Range of values	Definition
Graph_ID	256 to 65 534	Unique graph identifier as defined in 3.2.49
RefNeighbor [ ]	Neighbor_Unique_ID or Neighbor_nickname	List of references to neighbors that are the next hop toward the destination

At the original source device for a packet the upper layers identify the packet's final destination and the graph to use when routing the packet.

NOTE The device uses the route information to select the Graph_ID.

RefNeighbor identifies those devices that are permissible data-link destinations for the packet's next-hop toward its final destination. Since it is a possible for a graph to specify multiple next hops, redundancy and reliability is built into graph routing. Individual neighbor references are also called a "connection".

The destination addresses are required by all devices sourcing data to a specific final destination. However, the addresses are optional since intermediate devices may be merely forwarding the packet along its route and not sourcing data to the same final destination.

6.4.3.6 Packet buffer list

6.4.3.6.1 General

All devices shall maintain a list of packet buffers. These buffers are used to receive, to process and to transmit packets. The record associated with a packet is shown in Table 40. The Packet_ID is used to reference the packet and is created when the packet is added via the DL-TRANSMIT request service primitive.

Table 40 – Packet record

Record member	Definition
Packet_ID	Unique packet identifier
Payload	The DLL payload i.e. the NPDU
Priority	Transmit priority of the packet
Destination	Graph, source or proxy routing information or broadcast destination
PacketBirthASN	The PacketBirthASN is assigned when the NPDU is first created. This value is used in conjunction with the current ASN value to determine the age of the packet
Packet_time_stamp	The ASN time when a packet was added to the transmit list

The Packet_time_stamp shall be set when the packet is added to the transmit list. This time stamp shall be used to select the packet to transmit when either of two equal priority packets can be propagated in the same absolute slot. In this case the older packet shall be sent first. Also, in worst case scenarios after a long time elapses, by comparing against MaxPacketAge, the Packet_time_stamp is used to automatically flush a very old packet. The record contains the packet's priority and the specification of the packet's destination.

6.4.3.6.2 Packet Priorities

Since the device shall be able to store multiple packets, pending their propagation, it is possible that multiple packets could be candidates for transmission in the same slot. When that happens, priority and the age of the packet shall be used to select the packet to be transmitted in that slot. When there are multiple packets that can be transmitted in the slot the highest priority packet shall be chosen for transmission (see 6.3.3). If multiple packets are tied for the highest priority then the oldest packet shall be transmitted first.

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6.4.3.6.3 Destinations

The destination of a DLPDU can be specified as one of the following types:

- Graph route – the network layer specifies a Graph_ID as the destination. The DLE can send the packet to any of the devices associated with that graph.
- Source route – the network layer specifies a specific device address as the destination. The DLE shall transmit the packet on a link to that neighbor. If the device does not have a link to that neighbor then the network manager shall be notified that a source route error has occurred.
- Broadcast – the destination address is broadcast. The DLE shall transmitted using a broadcast link from the designated superframe.
- Proxy Route – the network layer indicates the destination address is that of a joining device. The DLE shall transmit the packet using a join link.

The destination type determines the Link_type that can be used and ultimately the slot the in which the DLPDU can be transmitted.

6.4.4 Link scheduling

6.4.4.1 General

All devices shall maintain a link schedule that identifies the next slot that shall be serviced. All communications are scheduled to occur within a superframe during specific slots in that superframe. Servicing a slot consists of either listening for a new packet or transmitting a packet. When a slot has both a packet waiting to be transmitted and it is also has a receive link, transmitting the packet shall have priority over attempting to listen for a new packet.

Preparing the link schedule consists of:

- to evaluate the packets pending transmission and to determine the first ASN that can be used to transmit a packet; and
- to determine the first ASN that can be used in attempting to receive a new packet.

The events external to DLE and internal events can affect the link schedule. Therefore, the DLE has to reassess the schedule whenever such event occurs. An example of the internal event is the failure of high priority transmission transaction. An example of the external event is that the network manager disables a superframe.

6.4.4.2 Servicing transmit link

Figure 21 summarizes the relationships that affect the calculation of the next transmit slot to be serviced. Packets received from the NLE are scheduled for a slot based on the graph, the destination address and whether or not the device is acting as a proxy for a device joining the network. Each packet has a destination and a priority. As specified in 6.4.3.6.3, there are several types of destinations, each of which affects slot selection. For each type of destination the set of transmit links shall be determined.

- For a graph-routed destination, the set of links shall be all transmit links for all neighbors in the graph.
- For a broadcast destination address, the set of links shall be all broadcast links for the designated superframe.
- For a single neighbor destination address, the set of links shall be all transmit links to that single neighbor.
- For a proxy destination address, the set of links shall be all transmit links of type Join.

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Once the set of links suitable for transmitting the packet are determined, the set of upcoming slots shall be determined. The intersection of the upcoming slots and the links with a pending packet determines the next slot to be scheduled to propagating that packet.

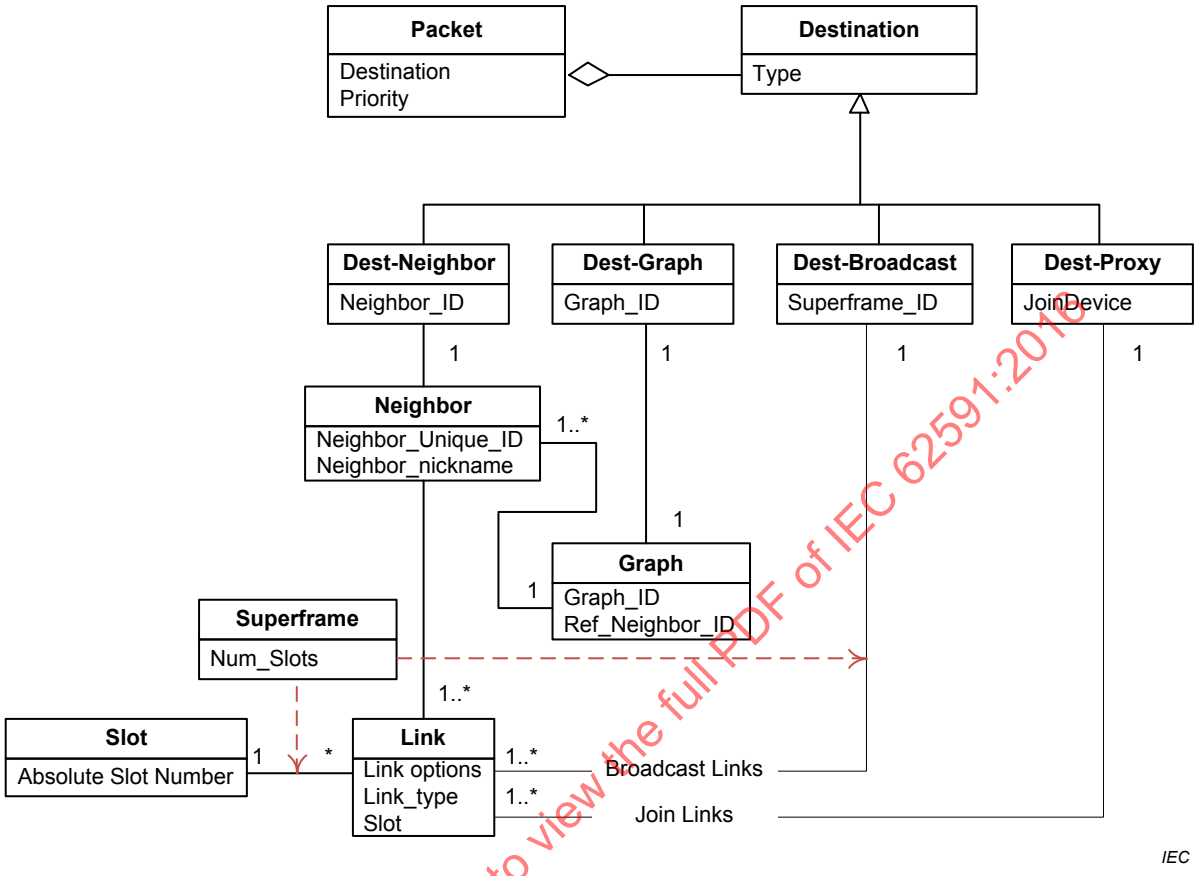

Figure 21 – Relationships used for link scheduling

The figure illustrates the static rules used at the DLL for determining what link will be used for transmission. A new object 'Airtime Slot' is introduced to model the fact that a fully specified link will be associated with an airtime slot.

A packet contains a destination. Destination can be further specialized by the destination type – a specific neighbor, a graph, a broadcast, or a proxy. If proxy address is being used then link shall be a join link. If the address is a broadcast address then a broadcast link shall be used. If the address is a specific neighbor, a specific link associated with a neighbor shall be used. If the destination is a graph then any neighbor on the graph may be used.

The ASN shall be used to track the occurrence of each slot. An ordered list of the links that are soon to occur within a superframe shall be identified using following equation:

Superframe slot = ASN % (Num_Slots of superframe).

Links may be shared (see 6.4.4.4), used to advertise (see 6.4.4.5) the device's presence to new devices attempting to join the network or used to discover neighbors (see 6.4.4.6)

The back-off algorithm in shared slots shall be employed to determine when a transmission in a shared slot is allowed. Advertise packets (see 6.4.4.5) are transmitted periodically as specified by the network manager.

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Links that cannot be used to propagate a pending packet are ignored. From the resulting set of links, the first potential link and its associated slot can be identified. When there are multiple packets that can be propagated in that slot, the rules specified below shall be used. The following rules shall be applied from a) to f) until a single packet has been identified:

- Find the packets with the highest priority;
- Choose the oldest packet based on the Packet_time_stamp;
- Find the packet destined to those neighbors with which there has not been any communication for the longest time;
- If the Keep_alive_time has expired with a neighbor, then prepare Keep-alive DLPDU for transmission to those neighbors with which there has not been any communication for the longest time;
- If an Advertise time has elapsed then prepare Advertise DLPDU for transmission.
- If there is a discovery link in this slot and the Discovery_time has elapsed then a Keep_alive_time packet is generated.

6.4.4.3 Servicing receive link

For each active superframe, all receive links shall be scheduled. The set of upcoming receive links can be calculated in the same way as with transmit links (see 6.4.4.2). If there is no need to propagate a packet, then all receive links shall be serviced. Once the ordered list of links is created, the earliest slot is selected and the link within that slot with the lowest superframe identifier number shall be the candidate for servicing. If there are no other receive links to be serviced, then the device shall service the discovery receive link. In any case, this receive link will be serviced if there are no pending packets to be transmitted on or before this slot.

6.4.4.4 Shared slots

Shared slots are assigned to more than one source device. One or more of these devices may attempt to convey a packet within that slot and channel. Therefore, collisions may occur within a shared slot. If a collision occurs, the destination device will not be able to successfully receive any source's transmission and will not produce an acknowledgement to any of them. To reduce the probability of repeated collisions, source devices shall use random back-off delay when their transmission in a shared slot is not acknowledged (i.e. no ACK is received by the source device).

A device shall maintain two variables for each neighbor: Back-off exponent (Backoff_exp) and Back-off counter (Backoff_cntr). Both of these variables shall be initialized to 0. When a transaction in a shared slot fails, the random back-off period shall be calculated based on the Backoff_exp. For each unsuccessful attempt by the source device in a shared slot, the Backoff_exp shall be incremented and a sequential set of numbers calculated. The value of Backoff_exp shall not exceed that of Max_backoff_exp. The set of numbers consists of the whole numbers {0, 1, ... L} where L = ((2 to the power Backoff_exp) – 1).

Table 41 shows the back-off sets for Backoff_exp values of one (1) to seven (7).

Table 41 – Example Backoff_cntr selection sets

Backoff_exp	Set of possible values for Backoff_cntr
1	{0, 1}
2	{0, 1, 2, 3}
3	{0, 1, 2, 3, 4, 5, 6, 7}
4	{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15}
5	{0, 1, 2, 3, 4, 5, …, 28, 29, 30, 31}
6	{0, 1, 2, 3, 4, 5, …, 60, 61, 62, 63}

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Backoff_exp	Set of possible values for Backoff_cntr
7	{0, 1, 2, 3, 4, 5, …, 124, 125, 126, 127}

From this set calculated based on the Backoff_exp, a random value for the Backoff_cntr shall be selected. For each subsequent shared link to that neighbor, the Backoff_cntr shall be decremented. When the corresponding Backoff_cntr is zero, then only the source device shall attempt a transmission in that shared slot.

Since it is also possible that interference can cause packet loss, the back-off exponent and counter shall be maintained separately for each neighbor. If communication with that neighbor fails on a dedicated link then the device shall assume channel degradation, rather than a collision as the cause of the failure in the shared slot and the Backoff_exp and the Backoff_cntr shall both be reset to zero.

Broadcast messages shall not be transmitted on shared slots.

6.4.4.5 Advertising

Nodes that are already part of the network may be configured by the network manager to advertise to the network and facilitate joining by new devices. The Advertise_time (see 6.5.2) attribute sets the interval at which Advertise packets are generated. Whenever the Advertise_time interval elapses, an Advertise packet shall be transmitted on the first available non-shared transmit link. When Advertise_time is set to zero then an Advertise packet shall be generated whenever a non-shared transmit link is available.

An Advertise packet may be sent on any non-shared transmit link that is not in use. All other traffic has higher priority than advertising.

6.4.4.6 Neighbor Discovery

Devices shall continuously listen for communications from their existing neighbor and for communications from new neighbors. Continuous monitoring of neighbors and the discovery of new neighbors is critical to the maintenance of the mesh and the enhancement of communications reliability.

Upon receiving any DLPDU, from a new neighbor, the device shall invoke the DLM-event indication along with that neighbor's address and the RSL for that DLPDU. Periodically the NLE communicates the list of new neighbors to the network manager. The device may receive a DLPDU, addressed to the device, from a new device attempting to join the network. When this happens the device shall add the device to the neighbor table. Then the device shall duplicate the join links and insert the joining device as the link neighbor. These neighbors are perishable and may be deleted based on the Last_time_communicated to make room for new neighbors (see 6.4.3.4). When a neighbor is deleted, the auto-created join links connecting the device to the joining device shall be deleted.

To aid in the discovery of new neighbors, the device listens whenever possible on discovery links. Discovery links are shared by all devices in the network. In addition to listening, a device shall also randomly transmit a Keep-alive DLPDU in a transmit discovery link. This allows other devices listening on the discovery link, the opportunity to discover the device.

The slowest rate at which the device transmits on the discovery link is bounded by the Discovery_time (see 6.5.2). To schedule the discovery transmission, the device shall select a random time period between 0 and Discovery_time and use this to initialize the discovery timer. When that timer expires, the device shall set a TimeToDiscover flag to TRUE and schedule the next randomly timed discovery transmission. If the value of Discovery_time is '-1' (i.e., 0xFFFFFFFF), then the DLE shall not serve discovery link.

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Once the TimeToDiscover flag is set, link scheduling will transmit the Keep-alive packet at the first available discovery transmit link. The Keep-alive packet shall be addressed to the linked neighbor with the oldest Last_time_communicated value.

6.4.5 MAC operation

6.4.5.1 General

This Subclause 6.4.5 decomposes the MAC sublayer into three primary components as shown in Figure 22. The components are the

- TDMA machine that specifies the overall operation of the MAC sublayer,
- transmitter that sends a DLPDU – XMIT machine, and
- receiver that listens to a link and receives a DLPDU – RECV machine.

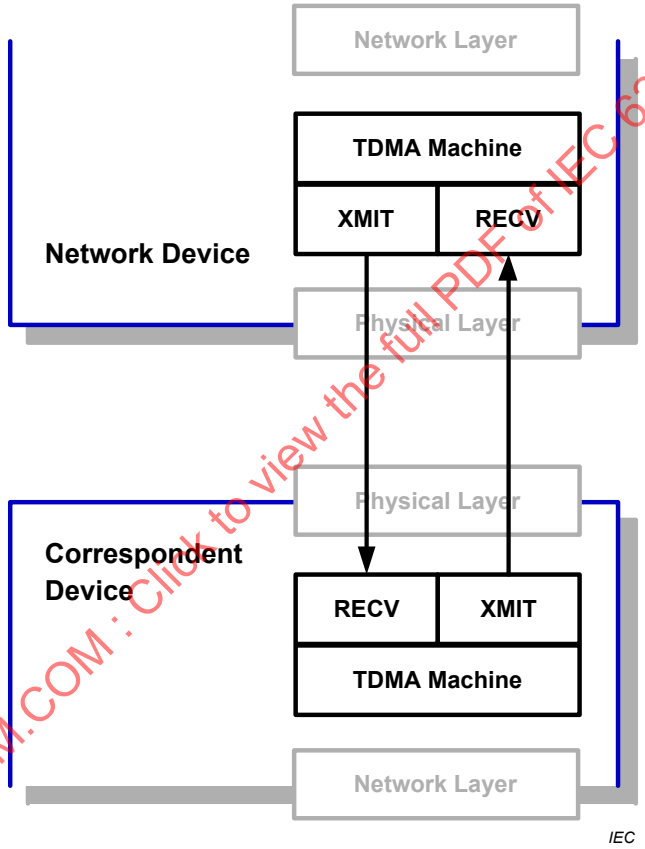

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Figure 22 – MAC components

6.4.5.2 TDMA machine

6.4.5.2.1 General

The operation of the TDMA Machine is shown in Figure 23. The state transitions are shown in Table 42. Operation of the TDMA Machine begins in “Idle” state, when the device joins a network; is configured with a list of superframes, graphs and links; and begins receiving DLPDUs from other devices or transmission request from the NLE. Normal operation can be divided into four responsibilities:

- to manage schedule;
- to transmit DLPDUs to other devices;
- to receive DLPDUs from other devices; and

- to maintain time synchronization.

Managing schedule includes creation and maintenance of superframes, links, and neighbor statistics. As DLPDUs are acquired and propagated, the schedules shall be updated. Link scheduling consists of evaluating the active superframes, links, DLPDUs waiting for transmission and to identify the next slot that needs servicing.

The schedule determines the dispatching of DLPDUs. All receive links shall be serviced by attempting DLPDU reception. Since links shall be allocated to support possible retries, often there are more receive links than transmission links. Since transmission is often successful, many of the receive links will be unused, not containing a corresponding transmission. Most received DLPDUs contain DLPDUs destined for the NLE.

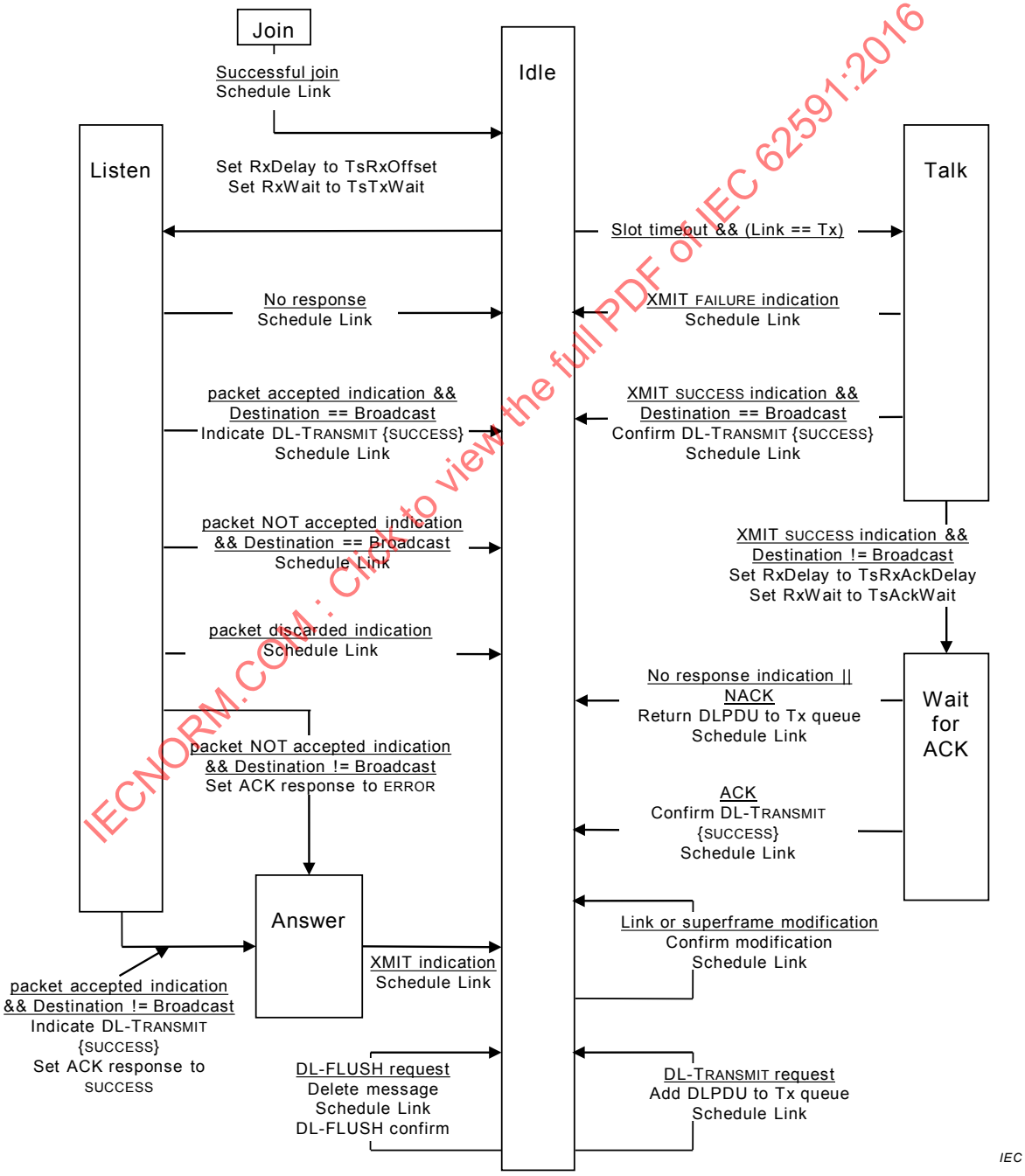

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Figure 23 – TDMA state machine

Table 42 – TDMA state machine

Current state	Event or condition => action	Next state
Idle	Slot timeout && (Link == Tx)	Talk
Idle	Slot timeout && (Link != Tx) && (Link == Rx) => Set RxDelay to TsRxOffset; Set RxWait to TsTxWait	Listen
Idle	Link or superframe modification => Confirm modification; Schedule Link	Idle
Idle	DL-TRANSMIT request => Add DLPDU to Tx queue; Schedule Link	Idle
Talk	XMIT FAILURE indication => Schedule Link	Idle
Talk	XMIT SUCCESS_indication && Destination == Broadcast => Confirm DL-TRANSMIT {SUCCESS}; Schedule Link	Idle
Talk	XMIT SUCCESS_indication && Destination != Broadcast => Confirm DL-TRANSMIT {SUCCESS}; Schedule Link	Wait for ACK
Wait for ACK	No response indication || NACK => Return DLPDU to Tx queue; Schedule Link	Idle
Wait for ACK	ACK => Confirm DL-TRANSMIT {SUCCESS}; Schedule Link	Idle
Listen	No response => Schedule Link	Idle
Listen	packet accepted indication && Destination == Broadcast => Indicate DL-TRANSMIT {SUCCESS}; Schedule Link	Idle
Listen	packet NOT accepted indication && Destination == Broadcast => Schedule Link	Idle
Listen	packet discarded indication => Schedule Link	Idle
Listen	packet NOT accepted indication && Destination != Broadcast => Set ACK response to ERROR	Answer
Listen	packet accepted indication && Destination != Broadcast => Indicate DL-TRANSMIT {SUCCESS}; Set ACK response to SUCCESS	Answer
Answer	XMIT indication => Schedule Link	Idle

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6.4.5.2.2 Idle state

The following events can occur while in the “Idle” state.

a) Slot Timeout: the most frequent activity performed by the TDMA Machine is the servicing of a Slot-timeout event. This event indicates that a slot needs to be serviced.

   1) If the slot timed out for a transmission link and there is DLPDU waiting for transmission, then the TDMA shall change to "Talk" state.

   2) Else if it is receive link, then the TDMA shall change to "Listen" state.

b) Modification to the device's list of superframes or links: it affects link scheduling. These changes typically result in link definitions being revised and may result in a different number of transmit and receive attempts per second.

c) DL-Transmit request: this shall add a DLPDU to the device's Tx queue and it may affect link scheduling.

6.4.5.2.3 Talk state

In this state, the DLE shall attempt to transmit the DLPDU to its neighbor(s). The operation of this state is specified in 6.4.5.3. The attempt will result in either success or one of several negative outcomes.

- Successful propagation of a DLPDU with a destination address that is the broadcast address occurs as soon as the DLPDU is transmitted. The DLPDU buffer shall be released immediately upon completion of the DLPDU transmission and the link schedule shall be evaluated.
- Successful propagation of a DLPDU with a destination address that is not broadcast address occurs when a validated, successful ACK is received. This indicates that DLPDU propagation was completed successfully and the DLPDU buffer shall be released.
- If the ACK contains an error response-code then the destination neighbor has refused the DLPDU. When this occurs, the DLPDU shall be retained and its propagation retried.
- If no ACK response is received then the DLPDU shall be rescheduled and transmission retried. If the DLPDU times-out, the queued DLPDU is returned to the NLE for disposition and possible re-routing.
- If the transmission fails in the XMIT machine, then transaction shall be aborted and link schedule shall be evaluated.

Upon successful transmission and if the DLPDU destination is not broadcast, the TDMA machine shall transition to "Wait for ACK" state, which is described in 6.4.5.3. Upon entry into this state, the RxDelay timer shall be set to TsRxAckDelay and the RxWait timer (receive window) shall be set to TsAckWait.

6.4.5.2.4 Wait for ACK state

The TDMA Machine stays in this state until the RECV machine completes. If the RECV machine indicates there was "No Response" the transaction fails. If it was a shared link, the Backoff_exp and Backoff_cntr shall be re-evaluated to produce a random back-off period before the next transmission attempt in a shared slot (see 6.4.4.4). If it was not a shared link, the Backoff_exp and Backoff_cntr shall be reset to zero. Then, after link schedule evaluation, the TDMA Machine shall change to "Idle" state.

If an ACK containing the "Success" Response Code is received then communication was successful. However, if an error response-code was received, then the neighbor did not accept the DLPDU. In either case, network time synchronization may be assessed using the Time-adjustment field in the neighbor's response. If the neighbor is a time-source for the device, then the device shall resynchronize its network time using the Time-adjustment field. If the neighbor is not a time source then, no time correction shall be performed.

Receiving an ACK indicates the neighbor device has successfully received the message and accepted it. The DLPDU buffer containing the transmitted DLPDU shall be released. The TDMA Machine shall change to "Idle" and evaluate the link schedule.

6.4.5.2.5 Listen state

In this state, the DLE shall attempt to receive the DLPDU. The operation of this state is specified in 6.4.5.4. The reception of a DLPDU has three possible outcomes:

- the DLPDU's final destination is the DLE itself, then the DLPDU shall be retained for processing by the DLE;
- the DLPDU's final destination is not the DLE itself, then the DLPDU shall be forwarded by the DLE toward the message's final destination;

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- the DLPDU is not addressed to the device, the DLPDU shall be discarded.

In all cases, when a DLPDU is received, the corresponding neighbor table entry shall be updated or if necessary the table entry shall be created.

The DLPDU reception cycle consists of an attempt to receive a DLPDU, the validation of any DPDU received and, if the DLPDU destination address is not broadcast, then the transmission of a response to a valid received DLPDU.

When attempting to receive a DLPDU, the RxDelay timer shall be set to TsRxOffset and the RxWait timer (receive window) shall be set to TsTxWait. The TsTxWait time sets the duration of the receive window and represents the largest time drift between neighboring devices allowed by this standard.

If no DLPDU is received in “Listen” state, then the TDMA Machine shall re-evaluate the link schedule and return to the "Idle" state. If a DLPDU is received, then network time synchronization shall be assessed. TsError shall be calculated by taking the difference between the actual start time and the expected start time of the received DLPDU. If the neighbor sending the DLPDU is one of the time sources of the DLE, then the device shall use the measured TsError to resynchronize its network time. If the neighbor is not a time source then, no time correction shall be performed.

While in the "Listen" state and upon successful DLPDU reception the device shall determine whether to accept the DLPDU or discard it. The device accepts or discards the DLPDU based on the DLPDU priority, the current Priority_threshold (see 6.3.3) and the number of DLPDU buffers currently occupied in the device. If the DLPDU is accepted by the device, it is either consumed by the DLE itself or forwarded to the NLE using DL-TRANSMIT indication service and the DLE shall update the link schedule.

Once the data-link layer has determined DLPDU disposition (accepting or discarding the DLPDU), the TDMA machine shall exit "Listen" state as follows:

- If the DLPDU destination address is the broadcast address, then the TDMA machine shall change to the "Idle" state.
- If the destination address is not the broadcast address and the DLPDU was accepted, then the DLE shall transmit ACK DLPDU, with response-code value equal to "Success" to the sender of the just received DLPDU. The TDMA machine shall change to "Answer" state.
- If the destination address is not the broadcast address and the DLPDU was not accepted, then the DLE shall transmit ACK DLPDU, with response-code value equal to an error code to the sender of the just received DLPDU. The TDMA machine shall change to "Answer" state.

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6.4.5.2.6 Answer state

The DLE shall copy the measured TsError into the Time-adjustment field of the ACK DLPDU. The TDMA machine operates as ACK transmission machine described in 6.4.5.5.

After transmission of the ACK is completed, the TDMA Machine shall evaluate the link schedule and change to the "Idle" state.

6.4.5.3 XMIT machine

6.4.5.3.1 General

Figure 24 shows the state machine that is used to transmit a DLPDU through either a dedicated or a shared slot. The transitions are shown in Table 43. This machine is started to transmit a DLPDU.

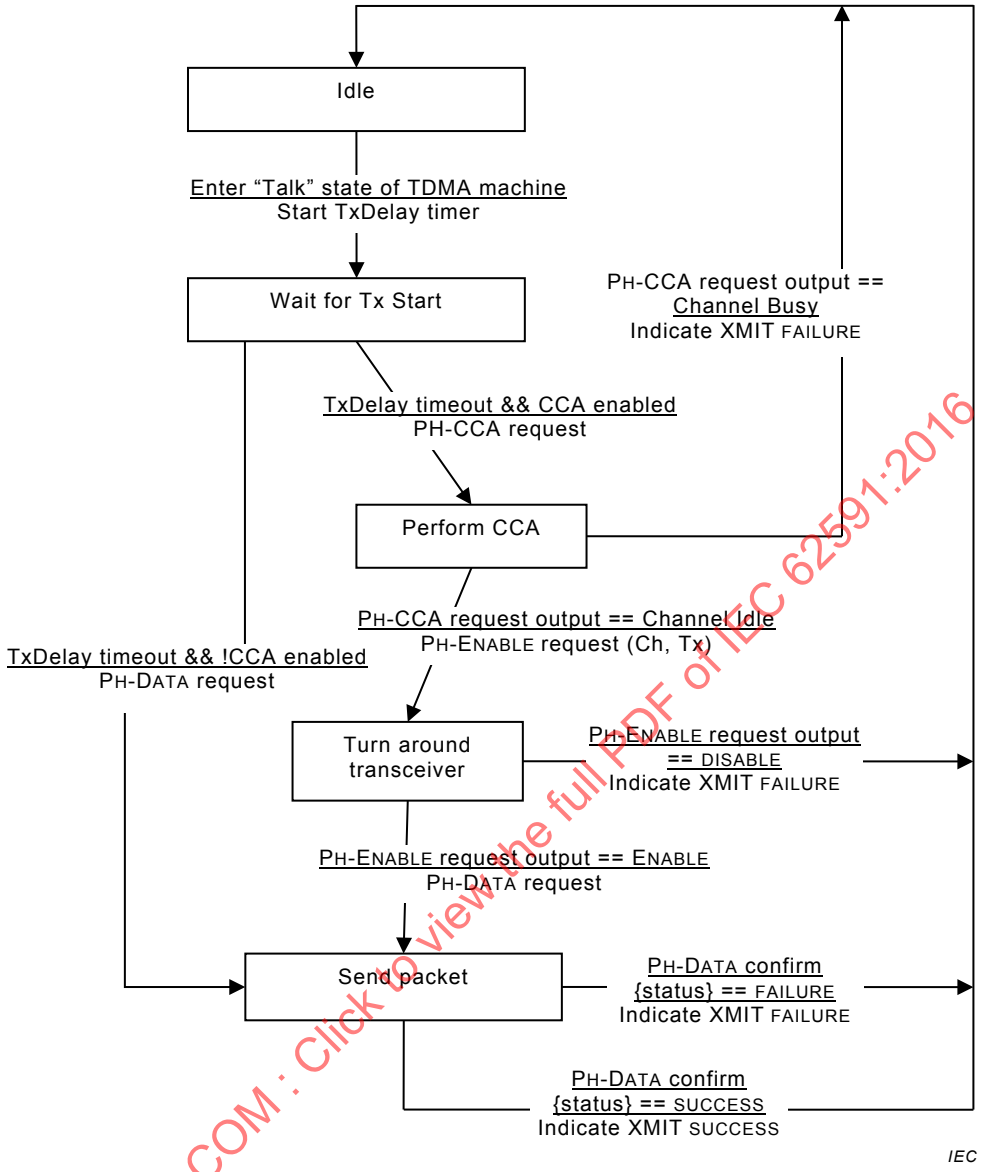

Figure 24 – XMIT state machine

Table 43 – XMIT state transitions

Current state	Event or condition => action	Next state
Idle	Enter "Talk" state of TDMA machine => Start TxDelay timer	Wait for Tx Start
Wait for Tx Start	TxDelay timeout && !CCA enabled => PH-DATA request {DLPDU}	Send packet
Wait for Tx Start	TxDelay timeout && CCA enabled => PH-CCA request	Perform CCA
Perform CCA	PH-CCA request output == Channel Idle => PH-ENABLE request {channel number, transmit}	Turn around transceiver
Perform CCA	PH-CCA request output == Channel Busy => XMIT FAILURE indication	Idle
Turn around transceiver	PH-ENABLE request output == ENABLE PH-DATA request {DLPDU}	Send packet
Turn around transceiver	PH-ENABLE request output == DISABLE XMIT FAILURE indication	Idle

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Current state	Event or condition => action	Next state
Send Packet	PH-DATA confirm {status} == success => XMIT SUCCESS indication	Idle
Send Packet	PH-DATA confirm {status} == FAILURE => XMIT FAILURE indication	Idle

6.4.5.3.2 Idle state

When XMIT machine is started, the DLE shall start TxDelay timer. The TxDelay time shall be set so that the transmission starts at the center of the neighbor's receive window. The device may use the TxDelay time to construct the DLPDU, run its AES-128 cipher engine and generate the MIC for the DLPDU.

The machine shall change to "Wait for Tx start" state.

6.4.5.3.3 Wait for Tx start state

While in the "Wait for Tx Start" state, the DLE shall select the channel for transmission (see 6.4.3.3.2). When TxDelay timer expires, the XMIT machine changes the state. Two transmit sequences are possible.

a) If CCAEnabled is FALSE, then the DLE shall issue PH-DATA request to transmit the DLPDU and change the state to "Send packet".

b) If the CCAEnabled is TRUE then the DLE shall issue Ph- CCA request and change the state to "Perform CCA".

6.4.5.3.4 Perform CCA state

The DLE shall wait until the PhE has completed the clear channel assessment.

a) It the DLE receives CCA request output with "Channel idle" status from the PhE then

   1) the XMIT machine shall change to "Turn around transceiver" state;

   2) the PhE shall be initialized using the PH-ENABLE request to place the transceiver into transmit mode.

b) Else, if the DLE receives CCA request output with "Channel busy" status, then XMIT engine shall terminate, indicate that the transmission attempt failed and shall not transmit the DLPDU.

6.4.5.3.5 Turn around transceiver state

When the DLE receives PH-ENABLE request output with Enable status from the PhE, the XMIT machine shall change to "Send packet" state. Else, if the returned status is "Disable", then XMIT engine shall terminate, indicate that the transmission attempt failed and shall not transmit the DLPDU.

6.4.5.3.6 Send packet state

The DLE shall start the packet transmission using the PH-DATA request service of the PhE. When the DLE receives PH-DATA confirm from the PhE, the XMIT machine shall terminate and indicate that the transmission was either successful or failed, depending upon the status returned in the PH-DATA confirm primitive.

6.4.5.4 RECV machine

6.4.5.4.1 General

Figure 25 shows the machine that is used to receive a DLPDU. This machine is started to receive a DLPDU that is being transmitted by one of the device's neighbors or immediately

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after the transmission of a DLPDU to receive ACK DLPDU. The transitions are shown in Table 44.

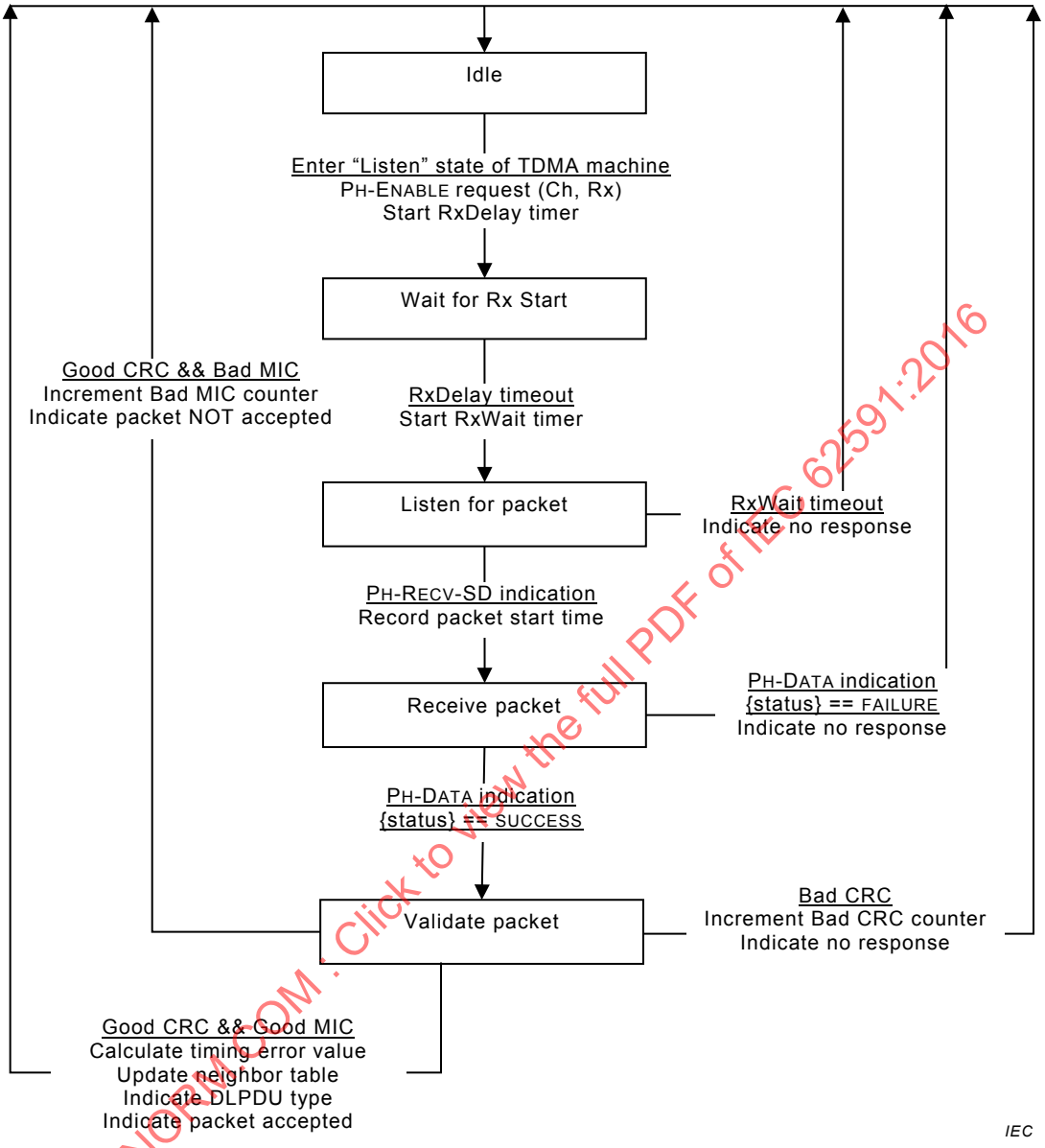

Figure 25 – RECV state machine

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Table 44 – RECV state machine

Current state	Event or condition => action	Next state
Idle	Enter “Listen” state of TDMA machine => PH-ENABLE request {channel number, receive} Start RxDelay timer	Wait for Rx start
Wait for Rx start	RxDelay timeout => Start RxWait timer	Listen for packet
Listen for packet	RxWait timeout => Indicate no response	Idle
Listen for packet	PH-RECV-SD indication => Record packet start time	Receive packet
Receive packet	PH-DATA indication {status} == FAILURE => Indicate no response	Idle
Receive packet	PH-DATA indication {status} == SUCCESS	Validate packet
Validate packet	Bad CRC => Increment Bad CRC counter; Indicate packet discarded	Idle
Validate packet	Good CRC && Bad MIC => Increment Bad MIC counter; Indicate packet NOT accepted	Idle
Validate packet	Good CRC && Good MIC => Calculate timing error value; Update neighbor table; Indicate DLPDU type; Indicate packet accepted	Idle

6.4.5.4.2 Idle state

When RECV machine is started:

a) the DLE shall select a channel based on the link's starting channel offset and current absolute slot number;

b) the DLE shall place the transceiver into receive mode using the Ph-enable request service of the PhE;

c) the DLE shall start the RxDelay timer; and

d) RECV machine shall change to "Wait for Rx start" state.

During the RxDelay the transceiver settles and synchronizes to the correct channel.

6.4.5.4.3 Wait for Rx start state

When RxDelay timer expires, the RECV machine shall change to “Listen for packet” state and start RxWait timer.

6.4.5.4.4 Listen for packet state

The transceiver is instructed to begin listening to the channel by using the Ph-Recv-SD indication service of the PhE. The RECV machine stays in the "Listen for Packet" state until either 1) the start of a DLPDU as indicated by reception of the end of a PhPDU start delimiter is detected or 2) the RxWait Timer expires. If the RxWait timer expires, then receive attempt fails, the RECV engine shall terminate indicating "No Response" and the DLE shall update the communication statistics.

If the expected start delimiter is detected, its time of arrival shall be recorded and the RECV engine shall change to the "Receive Packet" state to capture the DLPDU.

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6.4.5.4.5 Receive packet state

When RECV machine receives the PH-DATA indication service primitive from the PhE, it shall perform an initial evaluation of the received DLPDU. If the DLPDU addresses are not as expected for the link, the RECV machine shall terminate indicating "No Response" and the DLE shall update the communication statistics. Else, the RECV machine shall change to “Validate packet” state.

6.4.5.4.6 Validate packet state

If there are no addressing errors in the received DLPDU, then further validation shall be done. If the CRC is incorrect then the PhPDU was corrupted before or during reception; the RECV machine shall terminate indicating "packet discarded" and the DLE shall update the communication statistics.

If the received CRC is correct, the received keyed MIC shall be computed and checked. If the received MIC is not as expected, it indicates a possible attack. Therefore, reception is considered a failure and the DLE shall update both security and communication statistics. The RECV machine shall terminate indicating "packet NOT accepted".

If both the CRC and MIC are correct, then the reception is considered successful and the RECV machine shall terminate indicating the type of the DLPDU received.

6.4.5.5 ACK transmission machine

This machine is started to acknowledge the reception of a DLPDU. The DLE shall copy the measured TsError into the Time-adjustment field of that ACK DLPDU. The TDMA machine shall use the state machine shown in Figure 26 to transmit the DLPDU. The state transitions are shown in Table 45.

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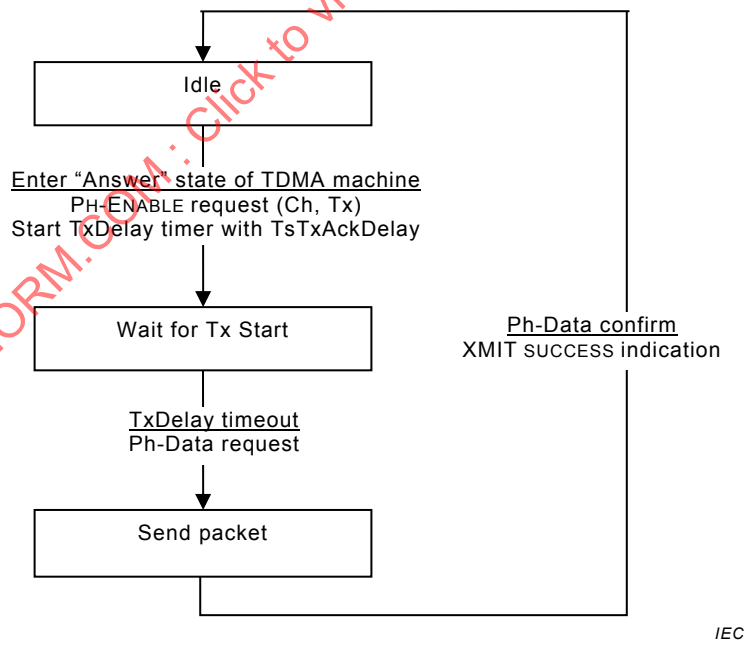

Figure 26 – ACK transmission state machine

Table 45 – ACK transmission state machine

Current state	Event or condition => action	Next state
Idle	Enter “Answer” state of TDMA machine => Ph-Enable request {channel number, transmit}; Start TxDelay timer with TsTxAckDelay;	Wait for Tx Start
Wait for Tx Start	TxDelay timeout => PH-Data request {ACK DLPDU}	Send Packet
Send Packet	PH-Data confirm => XMIT SUCCESS indication	Idle

6.5 DL-management-information

6.5.1 General

Several DL attributes shall be preconfigured before proper DLE operation is possible. These attributes are defined in 6.5.2. The DLE actions which can be requested through DL management are also summarized in 6.5.3.

6.5.2 DL attributes

Table 36 defines the superframe attributes.

Table 37 defines the link attributes.

Table 39 defines the graph attributes.

Network key used for MIC computation, see 6.3.4.2.3.

Other attributes are defined in Table 46.

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Table 46 – DL attributes

Attribute name	Range of values	Definition
Keep_alive_time	0 to 2^{32}-1 in units of ms	Interval during which a node shall successfully communicate with each linked neighbor
Path_fail_time	0 to 2^{32}-1 in units of ms	Interval of unsuccessful communication with a given neighbor, indicating a path failure
Advertise_time	0 to 2^{32}-1 in units of ms	Interval at which Advertise DLPDUs are transmitted
Discovery_time	0 to 2^{32}-1 in units of ms	Maximum interval between two consecutive transmission of Advertise DLPDUs on discovery link
Priority_threshold	ALARM | NORMAL | PROCESS DATA | COMMAND	Specifies the lowest priority DLPDU to be accepted from another device
Join_priority	0 to 15	Priority used in Advertise DLPDU sent by the DLE; lower number indicates a better choice for joining
Promiscuous_mode	TRUE FALSE	Indicates whether the DLE is in "receive all" mode i.e. the DLE accepts all DLPDUs received from the PhE.
Max_backoff_exp	{4, 5, 6, 7}	The maximum value that can be assumed for the back-off exponent used in shared slots, the default value is 4.
Active_search_shed_time	0 to 2^{32}-1 in units of ms	Max amount of time to stay in active search mode while joining (Defaults to 4 000 seconds). After this interval lapses the device transitions to passive search mode.
Passive_cycle_time	0 to 2^{32}-1 in units of ms	When in passive search mode, the period over which the device cycles between sleeping and listening (Defaults to 600 seconds). The sleep interval equals the PassiveCycleTime minus the PassiveWakeTime.
Passive_wake_time	0 to 2^{32}-1 in units of ms	When in passive search mode, the amount of time to be awake listening for the network (defaults to 6,5 s)

6.5.3 DLM actions

The DLE actions which DL management may request are defined in Table 47.

Table 47 – DL actions

Name	Description
RESET	Initialize the DLE
DISCONNECT	Disconnect the DLE from the network and cease all communications
RE-JOIN	Disconnect the DLE from the network; purge all outstanding DLS-user requests, clear all buffers and queues and clear all tables; rejoin the network
DELETE-SUPERFRAME	Delete an existing superframe and any associated links
DELETE-LINK	Delete an existing link, possibly updating the neighbor and connection tables associated with that link
DELETE-GRAPH	Delete an existing graph connection

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6.6 Network layer

6.6.1 Two level model of NL

6.6.1.1 General

The Network layer is modeled as

- a higher-level security function, and

- a lower-level routing function.

In addition the NL-management function operates with both levels.

6.6.1.2 Security function

A keyed message integrity code (MIC) is used for authentication of the NPDU, the encryption and the decryption of the NL payload. The keys are distributed by network manager.

6.6.1.3 Routing function

6.6.1.3.1 General

The network layer provides routing services. It manages sessions for end-to-end communication with correspondent devices. It receives the NPDU from the DLE. If the destination of the NPDU is the local NLS-user, then it transfers the user data to its user. Else, it forwards the NPDU destined to other devices using DLE. It also processes the NL-TRANSMIT request and prepares the NPDU for transmission.

The network layer of this standard routes a NPDU using one of the two methods.

- Graph

  The network topology can be represented as all of the devices and the directed links between them. A graph is a subset of the directed links and devices that provide redundant communication routes between a source and a destination device. The route actually taken is based on current network conditions when the NPDU is conveyed from the source to the destination. The NPDU contains the Graph_ID, but does not specify the complete route. Therefore, each intermediate DLE in the route shall be configured with a fragment of the overall graph prior to using that graph route. Graph routes are redundant and highly reliable. This method of routing should be used for normal, routine communications, both upstream and downstream from the gateway.

- Source

  It is a single directed route (devices and links) between a source and a destination device. The complete route is statically contained in the NPDU itself. The intermediate DLEs require no knowledge of the route in advance. As the NPDU is routed, each intermediate DLE propagates the NPDU to the next DLE using the source route contained in the NPDU. Source Routes are not redundant and may fail at any time. Current network conditions could break the route specified in the NPDU causing NPDU loss. This method of routing should be used only for testing routes, troubleshooting network paths or for ad-hoc communications such as routing join responses.

All devices are required to support both source and graph routing.

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6.6.1.3.2 Graph routing

Graph is a collection of directed paths that connect network endpoints. The specific paths associated with each graph are explicitly configured by the network manager in all network devices. A single network instance may have multiple graphs, some of which may overlap. Each network device may have multiple graphs going through it, even to the same neighbors. Graphs are unidirectional.

Every graph in a network has a unique Graph_ID. When using graph routing, the NLE places the Graph_ID value in NPDU header. NLE receiving the NPDU then forwards it along the set of paths belonging to that graph towards the destination.

Each Graph_ID in the device should have multiple associated neighbors. In a properly configured network, all devices have at least two neighbor devices in the graph to which the NLE can send the NPDU. This provides redundancy in the route and improves the reliability.

A NLE examines the Graph_ID in the received NPDU and forwards the NPDU to any of the neighbors listed in that graph.

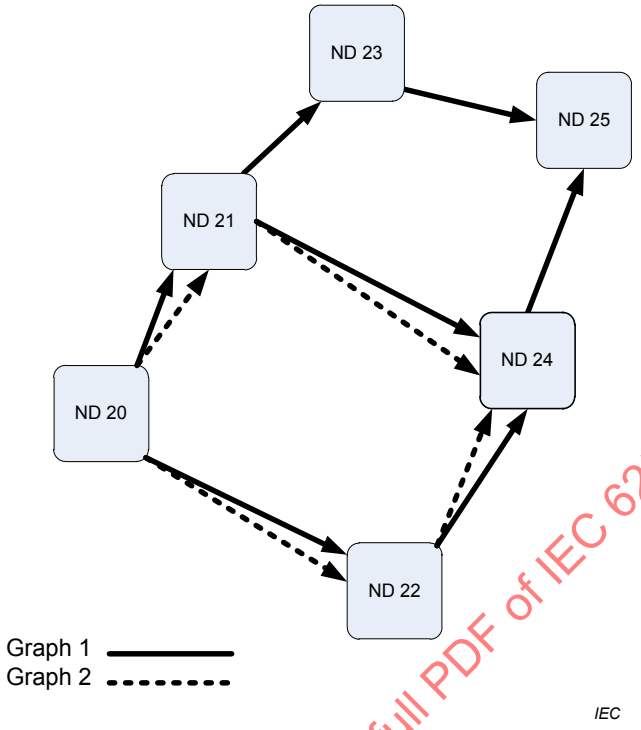

Figure 27 – Graph routing

As shown in Figure 27, for graph 1, ND 20 is the source and ND 25 is the destination; for graph 2, ND 20 is the source and ND 24 is the destination. To send a NPDU using graph 1, ND 20 may forward it to either ND 21 or ND 22. The NPDU may take several alternate routes, but either way, following graph 1, it will end up at ND 25. Thus, one NPDU from ND 20 to ND 25 could take the route through ND 21 and ND 23. Another NPDU from ND 20 to ND 25 could take the route through ND 21 and ND 24. Similarly, to communicate with ND 24, ND 20 sends NPDU using graph 2 through either ND 21 or ND 22.

A device shall support superframe routing. Superframe routes shall use Graph_ID 0x0000-0x00FF. When superframe routing is performed, the Superframe_ID is placed in the NPDU. The device receiving a Graph_ID less than 0x0100 looks for the Superframe_ID with the same value. If the Graph_ID is found then the NLE shall forward the packet to any neighbor with a normal, unicast transmit link in that superframe. In the case of superframe routing, candidate links shall be selected based on the Superframe_ID number. In the case of graph routing candidate links shall be selected based on the graph table entries (Graph_ID & neighbor).

6.6.1.3.3 Source routing

For source routing, the complete route from the source device to the destination device is specified in the NPDU. As the NPDU is propagated, each intermediate NLE looks at the source route address list and forwards the NPDU to the next DLE in the list. The route shall be configured in the NLE, usually by the network manager. Source routing specifies a single path and, if one of the intermediate links fails, then DLPDU is lost. The source routing is less reliable than graph routing. When a source route fails, the NLE at the point of the failure notifies the network manager. It is the responsibility of the network manager to take corrective action.

As shown in Figure 28, the route from ND 20 to ND 24 goes through ND 21, ND 23 and ND 25. The routing table in the NLE of ND 20 is configured with this path. The source NLE adds the list of addresses for ND 21, ND 23 and ND 25 in the header of the NPDU and sends

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the NPDU to ND 21. The NLE in ND 21 receives that NPDU; examines the header and forwards the NPDU to ND 23. NLE in ND 23 forwards the NPDU to ND 25; which then forwards it to ND 24. The route from ND 20 to ND 24 could also have been configured via ND 22 and ND 25.

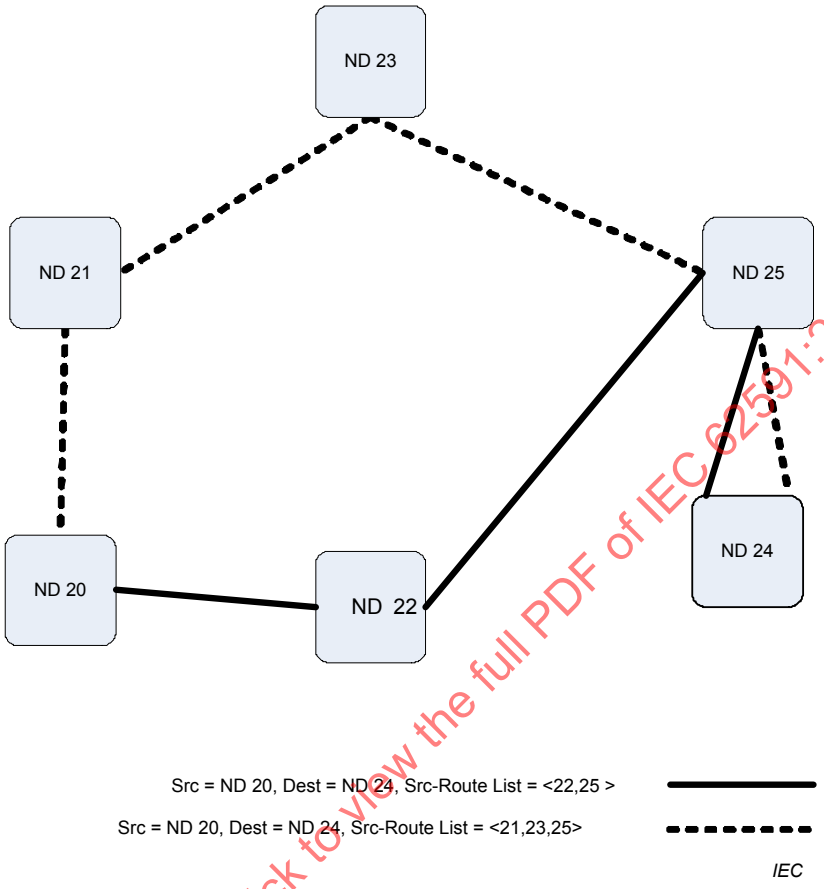

Figure 28 – Source routing

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6.6.2 NPDU structure

6.6.2.1 General

Figure 29 shows the NPDU structure. Each NPDU shall consist of the fields in a sequence described below:

- The 1-octet NL Control;
- The 1-octet Hop-to-live (HTL) counter;
- The 2-octets Sequence number;
- The 2-octet Graph_ID;
- Destination and Source Addresses in that sequence, either of which can be either 2 or 8 octets long;
- Zero or more routing octets;
- The 1-octet Security control;
- Counter;
- A 4-octet message integrity code; and
- NL payload.

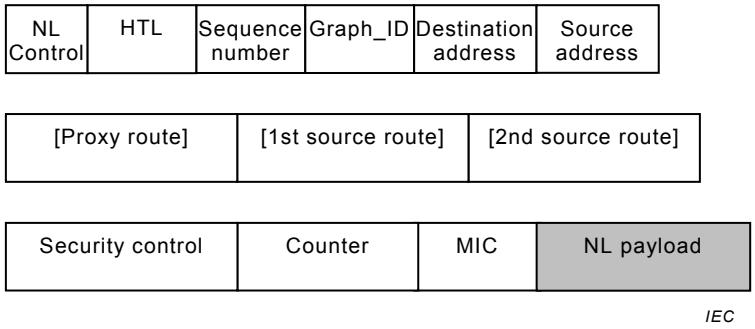

Figure 29 – NPDU Structure

6.6.2.2 NL control octet

This field specifies the length and type of destination, source addresses and presence of routing fields, as shown in Figure 30. The bit-7 specifies the destination address type; the bit-6 specifies the source address type. If the value of any of these two bits is '1', then the address in the NPDU, corresponding to that bit is EUI-64, else it is nickname (see 6.3.1.2.4). Any combination of address lengths can be used in a DLPDU.

The bits 5, 4 and 3 are reserved for future use. The NLE shall set the value of these bits to '000' before transmission. The NLE shall ignore any value of these bits in the received NPDU.

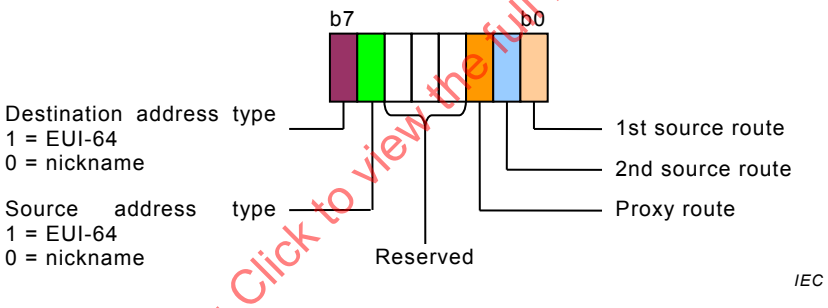

Figure 30 – NPDU control octet

If the value of any of bits 2, 1 and 0 bits is '1', then the corresponding routing field shall be present in the NPDU.

- Bit 2 specifies the presence of 2-octet long Proxy route field.
- Bit 1 specifies the presence of 8-octet long 2nd source route field.
- Bit 0 specifies the presence of 8-octet long 1st source route field.

NOTE The NPDU can specify a valid Graph_ID and source route both simultaneously.

6.6.2.3 Hop-to-live

This field keeps count of remaining number of hops that NPDU can travel before it is discarded.

6.6.2.4 Sequence number

The Sequence Number shall be set equal to the least significant 2 octets of the Absolute Slot Number (ASN) at the time of NL-TRANSMIT request is received. This field provides coarse but critical real-time performance metrics and diagnostic information on the operation of the network. It also provides, when the full ASN is recreated, the age of the packet.

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If the HTL is valid then the packet age shall be compared to max_packet_age. If the packet age is greater than the max_packet_age the packet shall be discarded. The difference between packet age and max_packet_age shall be provided as the timeout to the data-link.

6.6.2.5 Graph_ID

The Graph_ID is used to route the packet to its final destination. The Graph_ID indirectly identifies a list of devices, any of which can be used for forwarding the NPDU towards the final destination.

6.6.2.6 Destination and source Addresses

The NL supports two types of addresses: a 2-octet nickname and an 8-octet IEEE EUI-64 address. See 6.3.1.2.4 for the definition and formats of these addresses. These two addresses are not modified during the propagation of the NPDU.

6.6.2.7 Proxy route

Proxy routing shall be used to communicate with devices that have not yet been integrated into the network by the network manager. This includes devices that are in the process of joining. The 2-octet nickname of the proxy parent for the final destination is indicated in the Proxy-address.

If the Proxy address matches then the proxy parent is responsible for forwarding the NPDU to the device indicated by the destination address.

6.6.2.8 Source route

Each Source-route field contains a set of four addresses that designate the route the packet shall follow from the original source device to the packet's final destination. Each address is a 2-octet nickname. Any unused address shall be set to 0xFFFF. If both Source-route fields are used then up to eight intermediate addresses may be specified. Addresses shall be specified sequentially with unused addresses set to 0xFFFF at the end of the sequence. When scanning a source route sequence the scan is terminated upon encountering the first 0xFFFF. When the end of the source route is reached, the packet is transmitted to its final destination or along the NPDU Graph Route.

If the Source-route field is present, the addresses it contains shall be used to route the packet to its final destination. Source routes should only be used to test or troubleshoot network paths.

6.6.2.9 Security control

This field specifies the security strategy used for the NPDU, as shown in Figure 31. The sub-field consisting of bits 0-3 shall be encoded as an enumeration as following.

0: session keyed

1: join keyed

other values: reserved

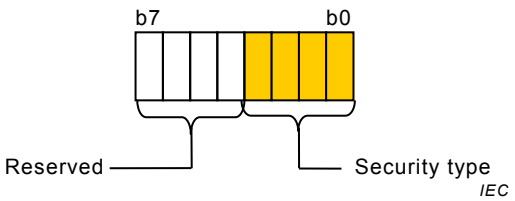

Figure 31 – Security control octet

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The bits 7, 6, 5 and 4 are reserved for future use. The NLE shall set the value of these bits to '0000' in the NPDU to be transmitted. The NLE shall ignore any value of these bits in the received NPDU.

6.6.2.10 Counter

This field shall be set to full or truncated value of the nonce counter. The value and length of this field depends upon the security type as shown in Table 48.

Table 48 – Counter value

Security type	Counter value
Session	Least 8-bits of nonce counter
Join	Full 32-bits of nonce counter

6.6.2.11 Message integrity code

A keyed message integrity code (MIC) is used for authentication of NPDU and the decryption of the security sublayer payload. It is 4-octet long.

6.6.2.12 NL payload

The NLS-user data is the NL payload.

6.6.3 Security function

6.6.3.1 General

The security function is provided at various layers and at overall device operation. The Annex A specifies the communications security functionality and related security aspects.

6.6.3.2 Session

6.6.3.2.1 Session types

The security is session oriented. A session enables private and secure communication between a pair of network devices. A field device always contains a Join session. Four sessions are set up as soon as the device joins the network.

- Unicast session between the device and network manager – it is used by the network manager to manage the device.
- Broadcast session between the device and network manager – it is used to globally manage devices. For example this can be used to roll a new network key out to all network devices. All devices in the network have the same key for this session.
- Unicast between the device and the gateway – it carries normal communications (for example process data) between the gateway and the device.
- Broadcast session between the device and the gateway – it is used by the gateway to send the identical application data to all devices.

In addition, each device has join session and it cannot be deleted. The Join_key is unique; it is the only key that can be written by directly connecting to the device's maintenance port. It can also be written by network manager.

Additional sessions may be added, if a handheld or another gateway joins the network. The network manager creates all sessions and their corresponding key, except the join-session. Join sessions shall always be present in the device. Only the network manager shall create or modify all sessions, except the join-session. Other device types are not permitted. Join sessions are always present in the field device and cannot be deleted.

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It is possible to deploy a session that connects two arbitrary devices in the network. However, this can result in undetected and unmonitored communication between the devices and represents a security and safety threat. If the network manager supports peer-to-peer sessions between field devices, then all of the resulting communications should be routed via the gateway to allow the detection and disruption of malicious behavior.

6.6.3.2.2 Session table

Table 49 shows the attributes of the session. The combination of the correspondent addresses and Session_type shall be unique i.e. two sessions are not allowed to have both, the identical correspondent addresses and Session_type values.

When and only when a new session is created, My_nonce_counter shall be reset to zero. Each element in the Nonce_counter_history shall be set to the nonce counter value in the NLM-SET command to write values of session attributes. All bits in the Nonce_counter_history shall be set (to 1) when the session is created. The device is not permitted to change Session_key value that was written by the network manager. The network device shall not allow any means to read back any session key.

Table 49 – Session attributes

Attribute name	Range of values	Join key values	Definition
Session_type	UNICAST BROADCAST JOIN	UNICAST	Type of session
Peer_unique_ID	0 to 2^{40}-1	0xF980000001	Unique ID of the correspondent device as defined in 3.2.105
Peer_nickname	0 to 65 534	0xF980	Nickname of the correspondent device as defined in 3.2.74
Session_key	128-bit number	0 to 2^{128}-1	Active Session_key. Join keys are stored in non-volatile memory.
Alt_key	128-bit number	Not used	The pending or previous Session Key.
Time_to_switch_keys	40-bit	Not used	ASN when the pending key becomes the active key. After this ASN the Alt_key is the previous session key. The previous key shall be discarded after 2 * Max_PDU_age.
Peer_nonce_counter	32-bit number	Not used	Largest nonce counter value received from the correspondent device
Nonce_counter_history	array of 32 bits	All bits set to 1 when device begins to join network	An array of bits recording the nonce counters received; most significant bit is always set and corresponds to the current Peer_nonce_counter value. The least significant bit corresponds to '1 + Peer_nonce_counter – size of Nonce_counter_history'. This creates a sliding window with each set bit recording a NPDU received with the corresponding nonce counter. The size of Nonce_counter_history equals the number of received NPDUs recorded. As the Nonce_counter_history is right shifted, history of the oldest recorded NPDU is dropped.
My_nonce_counter	32-bit number	0 to 2^{32}-1	Nonce counter for packets sourced by the device. For Join sessions these values are set to 0x00000000 at factory and never reset (only incremented) from then on.
Transport_table	Internal reference	Null	Reference to transport tables (normally 2) associated with correspondent. These are null for join sessions (join requests are not "acknowledged" transport operations).

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Attribute name	Range of values	Join key values	Definition
Route_table	Internal reference	Internal reference	Reference to Route tables associated with correspondent destination. For join key these values are generated from the received Advertisement PDU

6.6.3.2.3 Join session

Join session is unique and shall be created when the field device is first powered up in the factory. A device always has a join key. The addresses of the 'join session' shall be set to the standard network manager addresses. The My_nonce_counter entry shall be set to zero when the join session is first created and shall be incremented as it is used. The My_nonce_counter is never reset thereafter and persists through field device being powered on and off. The network device's My_nonce_counter is used for both join requests from the network device and join responses from the network manager. To protect against replay attacks on the Join_key, My_nonce_counter shall be stored in a non-volatile memory.

Several strategies may be used by the network manager to create the 'join session'. For example a 'join session' for a specific field device could be created in advance by using the field device's unique ID and the Join_key. No matter the strategy used to create the 'join session', when the network manager receives and validates a join request, the NPDU counter field is copied to the session's nonce counter entries and is used to construct the join response. Table 49 includes the attributes of the join session.

6.6.3.3 Security function elements of procedure

6.6.3.3.1 Receipt of NL-Transmit request primitive

When a NL-TRANSMIT request is received, the NLE shall construct the security header part of the NPDU for that request. A keyed MIC is used to ensure that the NPDU arrives successfully and unmolested from the indicated source device. The MIC is generated and confirmed using CCM* mode (combined counter with CBC-MAC (corrected)) in conjunction with the AES-128 block cipher to provide authentication as specified in IEEE 802.15.4-2011, Annex B. This cipher requires four octet-strings as parameters:

- 'a', the additional data to be authenticated but not enciphered;
- 'm', is the message to be enciphered;
- 'N', the 13-octet nonce; and
- 'K', the 128-bit AES Key.

The NL payload is enciphered and is the octet-string 'm'. The NPDU header, from the NPDU control octet through the MIC, is the octet-string 'a'. The HTL, Counter and MIC fields in octet-string 'a' are set to zero while authenticating the NPDU. These are replaced with their actual values before transmitting the packet.

The security layer nonce (the 'N' octet-string) is 13-octets long. The nonce is created as summarized in Table 50 and described below.

If the Session_type is "join" and NL-TRANSMIT request primitive is join response

a) then
   1) the LSB (octet number zero) of 'N' shall be set to '1';
   2) the next four octets of 'N' shall be set to Peer_nonce_counter value from the corresponding join request starting with the MSB of Peer_nonce_counter;
   3) the next eight octets of 'N' shall be set to the joining device's EUI-64 address;

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NOTE The join request and response always use EUI-64 address, because the device receives its nickname only after the device has successfully joined the network. The join response can only be transmitted from the network manager.

b) else,

1) the LSB (octet number zero) of 'N' shall be set to '0';

2) the My_nonce_counter shall be pre-incremented by one;

3) the next four octets of 'N' shall be set to My_nonce_counter value starting with the MSB of My_nonce_counter;

4) the next five octets of 'N' shall be set to the source address field in the NPDU, which is either the EUI-64 address or if the device is currently in the network the zero-padded nickname.

Table 50 – NPDU nonce

Octet number	Description
0	Set to 1 if join response, otherwise set to 0
1 – 4	Nonce counter starting with MSB in N[1]
For EUI-64 source address:	
5 – 12	EUI-64 address is copied (MSB to LSB) into N[5] through N[12]
For 2-octet nickname:	
5 – 10	Each octet is set to 0x00
11 – 12	The nickname is copied (MSB to LSB) into N[11] through N[12]

After the nonce is constructed, the NPDU is enciphered; and then NPDU security fields are populated.

6.6.3.3.2 Receipt of NPDU addressed to the device

6.6.3.3.2.1 General

The NLE shall process the received NPDU using the AES-128 engine to authenticate the NPDU and decipher the payload. This cipher requires four octet-strings as parameters:

- 'a', is the NPDU header, from the NPDU control octet through the NPDU MIC with the NPDU HTL, counter and NPDU MIC fields set to zero;
- 'm', is the NL payload;
- 'N', the 13-octet nonce; and
- 'K', the 128-bit AES Key.

Authentication and decipherment start by locating the correct session see 6.6.2.9 to determine the key and nonce counters.

If the received NPDU is not discarded, then the payload shall be forwarded to the NLS-user in NL-Transmit indication primitive. The NL payload shall be the NLS-user-data.

6.6.3.3.2.2 Nonce re-construction

The NLE shall re-construct the nonce for the received NPDU, as summarized in Table 50 and described below.

If the Session_type is "join"

a) then

1) If the received NPDU is join request, then

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i) the LSB (octet number zero) of 'N' shall be set to '0';

ii) the next four octets of 'N' shall be set to Counter field of the received NPDU starting with the MSB of counter;

NOTE The join request NPDU is received only by the network manager.

2) Else the received NPDU is a join response,

i) the LSB (octet number zero) of 'N' shall be set to '1';

ii) if the Counter field of the received NPDU is equal to My_nonce_counter, then the next four octets of 'N' shall be set to My_nonce_counter value starting with the MSB of My_nonce_counter;

iii) else, the NLE shall discard the received NPDU.

3) If the NPDU was not discarded then the next five octets of 'N' shall be set to the source EUI-64 address from the received NPDU;

b) Else the Session_type is not "join",

1) the LSB (octet number zero) of 'N' shall be set to '0';

2) the next three octets of 'N' shall be set to the most-significant three octets of the corresponding Peer_nonce_counter value starting with the MSB of Peer_nonce_counter;

3) if the 1-octet Counter value of the received NPDU is less than the quantity (1 + LSB of Peer_nonce_counter – size of Nonce_counter_history), then the 24-bit value in N[1]-N[3] shall be incremented;

4) the next octet of 'N' shall be set to Counter field of the received NPDU;

5) the next five octets of 'N' shall be set to the received NPDU source address field, which is either the EUI-64 address or the zero-padded nickname.

The reconstructed nonce count is compared to the Nonce_counter_history. If it corresponds to any of the bits set in the Nonce_counter_history, the received NPDU shall be discarded. If the reconstructed nonce count is less than Peer_nonce_counter – size of (Nonce_counter_history) then the received NPDU shall be discarded.

6.6.3.3.2.3 Authentication

If the nonce is successfully constructed and the received NPDU is not a duplicate of a previously received NPDU, authentication and decipherment shall be performed. If this authentication fails, the packet shall be discarded.

6.6.3.3.2.4 Replay Protection

If the packet is authentic then the Nonce_counter_history shall be updated. Since NPDU can arrive out of order or be lost completely, this sliding window algorithm is used to facilitate the communications and eliminate duplicate packets. The Peer_nonce_counter and the Nonce_counter_history together chronicle the NPDUs received by the device.

The octet number 1 to 4 of 'N' is the reconstructed nonce counter. The reconstructed nonce counter shall be compared to the Nonce_counter_history. If it corresponds to any of the bits set in the Nonce_counter_history, the received NPDU is a duplicate of previously received NPDU and the NPDU shall be discarded. If the reconstructed nonce counter is outside of the window of the Nonce_counter_history, then the DLE shall discard the received NPDU.

If the reconstructed nonce counter is less than the Peer_nonce_counter, then the appropriate bit in the Nonce_counter_history shall be set. Otherwise, the Nonce_counter_history shall be right shifted and the Peer_nonce_counter value updated. This is accomplished by subtracting the Peer_nonce_counter from the reconstructed nonce counter. The resulting difference indicates the number of times the Nonce_counter_history shall be right-shifted. After shifting, the most significant bit of the Nonce_counter_history shall be set. Finally, the reconstructed nonce counter shall be copied to the Peer_nonce_counter in the session table entry.

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6.6.4 Network layer tables

6.6.4.1 General

All devices shall maintain a series of tables that control the communications performed by the device, supply routing information, support end-end acknowledgements, ensure the privacy of the communications, and collect statistics on those communications.

The tables controlling communication activities are:

- Session table – an entry in this table establishes a secure pipe between the device and a specific correspondent device. No communication to a correspondent device is possible without a security session (see 6.6.3.2.1). See 6.6.3.2.2 for session attributes.
- Transport table – it is used to support end-end acknowledge transaction with automatic retries (see 6.7.3).
- Route table – it serves as the locus for adding routing information to a new NPDU being generated as the result of a NL-TRANSMIT request (see 6.6.4.2).
- Source route table – it is attached to some routes (see 6.6.4.3).
- Timetable table – it indicates the destination, route, and scheduling quota allocated by the network manager (see 6.6.4.4).

The relationship among these tables is shown in Figure 32. Within the device the session table is central. The NLE also uses Neighbor table (see 6.4.3.4) and Graph table (see 6.4.3.5) of the DLE. The figure shows the relationships around a route. A route is identified by a route_ID. A route is associated with a specific correspondent. A route may contain an optional source route. A route is always associated with a graph. In some cases the specialized form of graph, superframe, is used. A graph may be associated with 0 (superframe) or more neighbor. A Timetable is associated with one route. A route is associated with 0 or more Timetables. The relationship with Timetables is directed, because the Timetable knows about the route but the route does not need to know about the Timetable.

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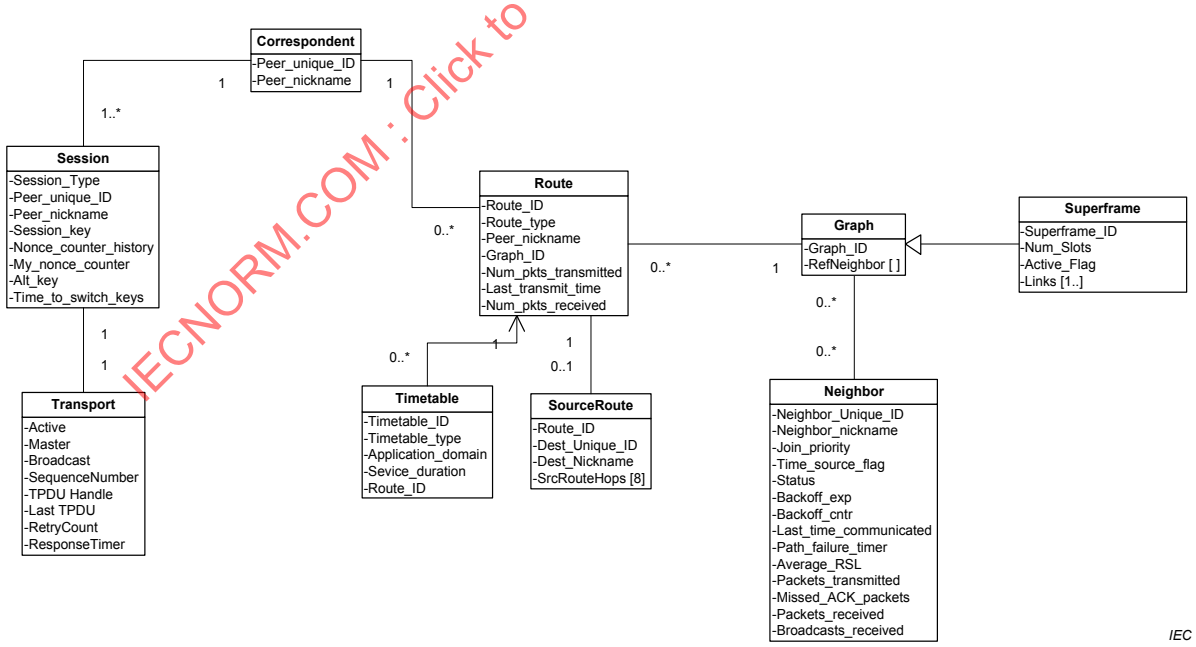

Figure 32 – NLE tables and relationship

Devices shall support the minimum number of table entries and buffer space shown in Table 51.

Table 51 – Minimum NLE Table space requirement

Table name	Required minimum entries
Session	8
Correspondent device	1 per session
Transport	2 per session
Route	8
Source-route	2
Timetable	16

Some of the attributes of these tables described in this standard may be calculated or derived from other information, and it is not necessarily to store these separately.

NOTE Although specific implementation of data and configuration storage is left up to the designers of the device, general description of the fields contained in the data structures is important to overall operation.

6.6.4.2 Route table

Table 52 shows the route attributes. The route table is associated with a security session and a correspondent address. This is used to aid in the selection of the graph used for communication to the correspondent device. NLE shall collect statistics to allow the network manager to optimize communication resources over time.

Table 52 – Route attributes

Attribute name	Range of values	Definition
Route_ID	0 to 255	Route identifier
Route_type	MAINTENANCE PUBLISH BLOCK TRANSFER EVENT	Indicates the type of route; MAINTENANCE is default value.
Dest_nickname	0 to 65 534 – see 6.3.1.2.4	Nickname of the destination device with which the route is established
Graph_ID	256 to 65 535	Identifier for the graph associated with this route. If null then only a source route exists to the destination. A null Graph_ID is indicated by 0xFFFF.
Src_route_ID	0 to 255	If non-zero, then the identifier of the source route table for this route, else absence of the source route for this route
Num_pkts_transmitted	0 to 65 535[a]	Number of packets Transmitted on this route
Last_transmit_time	0 to 2^{32}-1 in the units of 1/32 ms	Time last NPDU was generated for this route
Num_pkts_received	0 to 65 535[a]	Number of packets received on this Route updated based on the Graph_ID in the NPDU
[a] The value of packet counters rolls over from 65 535 to 0.		

6.6.4.3 Source route table

The source route table contains a list of up to 8 device addresses tracing the route from this device to the correspondent device as shown in Table 53.

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Table 53 – Source route attributes

Attribute name	Range of values	Definition
Route_ID	1 to 255	Route identifier
dest_Unique_ID	0 to 2^{40}-1	Unique ID of the destination device as defined in 3.2.105
dest_Nickname	0 to 65 534	The short address of the neighbor as defined in 3.2.74
Src_route_hops [8]	Device nickname	Up to 8 nicknames that lead to the destination. Unused addresses shall be set to the destination's nickname

6.6.4.4 Timetable table

When a device needs to establish a communication connection another device it sends a request to the network manager to allocate a Timetable for that communication. Each destination and Application_domain has its own Timetable. Table 54 shows the Timetable attributes. It identifies the route to the destination device and the scheduling quota allocated for this communication. When the device deletes a Timetable, the network manager is expected to de-allocate the network resources supporting that Timetable. The same route may be used by more than one Timetable.

Table 54 – TimeTable attributes

Attribute name	Range of values	Definition
Timetable_ID	0 to 255	Timetable identifier
Timetable_type	SOURCE | SINK | INTERMITTENT	Indicates the type of Timetable
Application_domain	MAINTENANCE | PUBLISH | BLOCK TRANSFER | EVENT	The application domain using this Timetable
Dest_nickname	0 to 65 534	The short address of the destination for which this Timetable has been allocated
Service_duration	0 to 2^{32}-1 in the units of 1/32 ms	For cyclical communications (for example Publish data), packets are generated with this period. Latency for cyclical communication shall not exceed 1/3 the period. For intermittent communications, this is the required maximum latency.
Route_ID	0 to 255	Route identifier for this Timetable. More than one Timetable can use the Route_ID.

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6.6.5 NLE machine

6.6.5.1 General operation

The NLE progresses through a series of states starting in the ‘Idle’ state and continuing until the device is ‘Operational’ and a full participant in the mesh network. There are five states and they are described in Table 55.

Table 55 – NLE states

State	Description
Idle	The device is quiescent and its wireless transceiver is not active. It has no knowledge of the network.
Joining	The device is listening for the network, attempting to acquire an Advertise DLPDU and requesting admission to the network.
Quarantined	The device has successfully joined the network but only has a security clearance to talk with the network manager. It is not available or allowed to perform data acquisition or control functions or otherwise communicate with the gateway.
Operational	The device can be accessed by host applications via the gateway. It is integrated in the system's operation.
Suspended	The device is quiescent. All of its network tables are intact.

The state transition diagram is shown in Figure 33. This diagram depicts the events that allow the device to start-up, locate and join the network, and finally progress from being a new network member to becoming a fully operational network device. In addition, the diagram shows the device (and network) being suspended. Furthermore, the device can be forced to disconnect (for example to be removed from the process for depot-level maintenance) or to re-join at any time.

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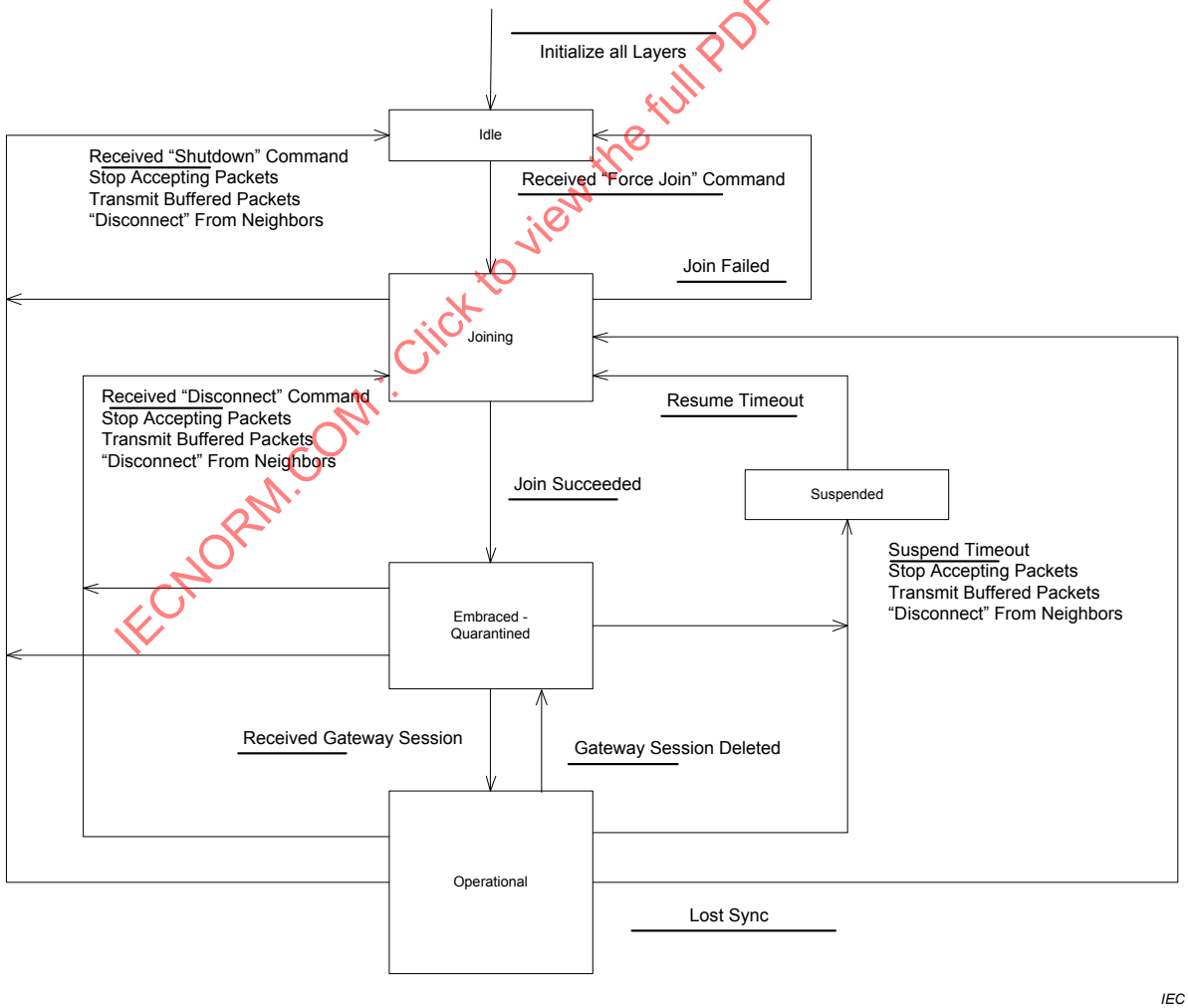

Figure 33 – NLE state machine

6.6.5.2 Idle state

After a device reset or on power up the device shall enter the ‘Idle’ state. While in this state the device shall not attempt to communicate wirelessly. The device shall update the Join_key and network_ID, if it is written via the maintenance port. When the device receives the Join command from the NL-management, the NLE shall change to ‘Joining’ state.

6.6.5.3 Joining state

The NLE shall locate the network and synchronize to the network. It shall wait to receive Advertise packets. After receiving one or more Advertise packets, the NLE shall request admission to the network, using the Join_key. The network manager is expected to send network key and network manager session to the requesting NLE. The network manager is also expected to provision the NLE with superframe, graphs and links. After the NLE has received these parameters, it shall change to ‘Quarantined’ state.

The Join request may be answered by the network manager immediately or the NLE may need to retry the request. A failure shall occur if the device sends number of join requests equal to max_join_retries (see Table 58), without receiving the security keys and session parameters from the network manager. In this case, the NLE shall return to the ‘Idle’ state.

If the NLE receives Disconnect command from the NL-management, then it shall change to ‘Idle’ state.

6.6.5.4 Embraced-Quarantined state

Embraced-Quarantined devices are limited network partners. The NLE shall remain in this state until approved for deployment into the network application. Approval may take the form of the human operator authorizing the use of the device in the system and placing the device into service. This quarantine step parallels normal practices in the process industry and adds an additional layer of security to the join process.

While quarantined the device shall be enabled by the network manager to source and sink packets. The device shall also forward packets as configured by the network manager. Normal network reports (for example neighbor reports) shall be generated.

After receiving the gateway session parameters, the NLE shall change to ‘Operational’ state.

6.6.5.5 Operational

This allows host application access to the device and begin its interaction with the device.

In the operational state, the device is a full network partner and shall begin performing the tasks designated by its configuration. It shall route packets onward through the network to their final destination. The device shall also participate in advertising and support new devices joining the network. If configured to publish data, it shall request bandwidth to do so. It shall receive user requests and responses for transmission.

6.6.5.6 Suspended state

When in ‘Quarantined’ or ‘Operational’ state, the device may be forced into ‘Suspended’ state for the specified time. This is normally a brief amount of time and done, for example for safety purposes during mining blast operations. In this state the device continues to track elapsed time while leaving the radio disabled. After the specified time has elapsed, the device shall change to the ‘Joining’ state.

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6.6.6 NLE elements of procedure

6.6.6.1 Receipt of a NL-TRANSMIT request primitive

When a NL-TRANSMIT request is received from the NLS-user, the NLE shall use the Timetable_ID received in the service primitive to locate the Timetable for this request. If the destination is not the network manager and if there is insufficient remaining bandwidth in the Timetable for this request then an error shall be returned and the request shall be deleted.

The NLE shall construct the NPDU for that request. The field shall be set according the procedures indicated in Table 56. The NLE shall find the Route_ID from the Timetable attribute as shown in Table 54. Once the route has been identified the Graph_ID from rote attribute, as shown in Table 52, shall be copied into the NPDU.

The packets shall be graph routed, unless the route is being tested. However if a source-route is attached to the route, then the source route addresses shall be included in the NPDU. Unused source route address entries in the NPDU shall be set to 0xFFFF. If source routing is used the Graph_ID shall also be valid.

Table 56 – NPDU construction

Field	Procedure
Control	Set the address bits based on source and destination address sizes. Destination addresses are indicated in the request primitive. If the destination is broadcast address, then the destination address size shall be short. Source address shall be the device's EUI-64 address until the device's nickname is initialized. Set the routing bits based on results of route selection.
HTL	Set to Default_HTL.
Sequence number	Set to current ASN value.
Graph_ID	Set based on results of route selection.
Destination address	Set to the value in the request primitive. If the destination address is broadcast address, then the value of this field shall be 0xFFFF.
Source address	Set to EUI-64 address if nickname not initialized, else set to nickname.
Proxy route	Set based on results of route selection.
Source routes(s)	Set based on results of route selection.

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6.6.6.2 Receipt of a DL-RECEIVE indication primitive

The NLE shall examine the destination address in the NPDU received from the DLE. It shall route these packets to the correct destination: forward to the next DLE in the route, forward to the joining device, or deliver to the local NLS-user.

6.6.6.3 Receipt of DL-TRANSMIT confirm primitive

6.6.6.3.1 General

The NLE shall delete all data and table items for the service associated with the handle and return confirm to the NL-user.

6.6.6.3.2 NPDU addressed to the device

If the destination in the received NPDU is the local NLS-user, then the NLE shall forward it to the security function.

6.6.6.3.3 NPDU with broadcast address

If the destination address in the received NPDU is the broadcast address then the NLE shall forward the NPDU as described in 6.6.6.3.4 and also forward it to the security function.

6.6.6.3.4 Forwarding Received NPDU

The NLE shall process the received NPDU in the sequence described below.

The NLE shall check and update the HTL. If the HTL count in the received NPDU is zero,

a) then the NPDU shall be discarded;

b) else,

   1) if the HTL is not 0xFF, then the NLE shall decrement it by 1 and use this value to construct the NPDU to be forwarded;

   2) the sequence number shall be inspected and, if the packet age of the received NPDU is more than max_packet_age, then it shall be discarded, otherwise the difference between the packet age and the max_packet_age shall be provided as the timeout to the DLE;

   3) else, the NLE shall check the destination address;

   4) if the NPDU contains a proxy address that matches the local NLE address

      i) then the final destination is a joining device. The NLE shall route the packet to the joining device by forwarding the NPDU to the DLE indicating the DLL destination address that of the joining device;

      ii) else, if NPDU destination address is Unicast and it matches a neighbor, then the NPDU shall be routed directly to that neighbor. The device shall route the packet to the neighbor device by forwarding the NPDU to the DLE indicating the DLL destination address that of the neighbor device.

When analyzing a received NPDU, the columns in Figure 34 shall be evaluated from left to right i.e., starting with “Source routing in the NPDU”. A "No" in the “Graph routing in the NPDU” column means that the received Graph_ID does not match either a Graph_ID or a Superframe_ID found in the field device that received the NPDU. The decision ends with a letter identifier for the routing decision, which is described in Table 57.

Packet age may be calculated as

```
If ((current ASN && 0xFFFF) <  sequence number)
     Packet age = ((current ASN && 0xFFFF) – sequence number) + 63356)
Else
     Packet age = (current ASN && 0xFFFF) – sequence number
End If
```

NOTE If the destination address in the received DLPDU is broadcast then the Graph_ID in that NPDU holds the Superframe_ID to identify the corresponding broadcast links.

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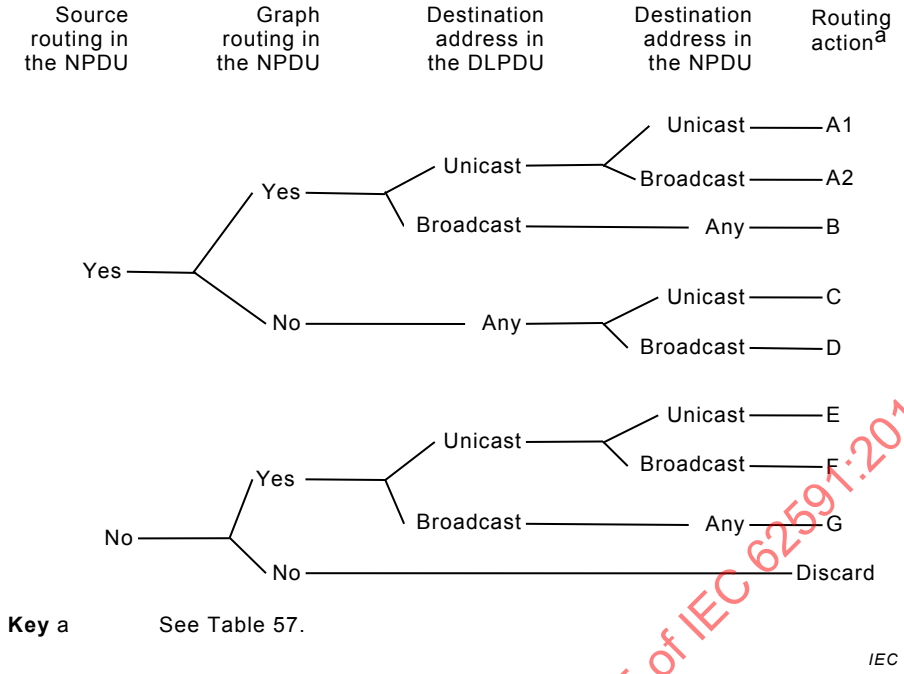

Figure 34 – Routing decision of the NPDU

Table 57 – Routing actions

Action code	Action description
A1	If this was the end of the source route list in the received NPDU or if the next address in the source route is not that of a neighbor, then forward the received NPDU along the graph route in the received NPDU, else forward the received NPDU to the next address in the source route. If both the graph route and the source route are exhausted, then signal a source route error.
A2	If this was the end of the source route list in the received NPDU, then broadcast to the Superframe_ID (Graph_ID contains the Superframe_ID), else forward the received NPDU to the next address in the source route.
B	Graph_ID shall be the Superframe_ID. Continue broadcasting to the graph. Use broadcast link in the superframe.
C	If the received NPDU has another valid destination in the source route list then forward the NPDU to that address. Else, indicate a source route error to the NLM.
D	Forward the received NPDU to the next address in the source route. The NPDU is discarded at the end of the source route.
E	Forward the received NPDU along the graph, using any normal link to neighbor on the graph; if end of the graph then indicate a graph route error to the NLM.
F	Forward the received NPDU to all neighbors in the graph; discard NPDU if at the end of the graph.
G	Graph_ID is Superframe_ID; continue broadcasting the NPDU using broadcast link in the superframe
Discard	The received NPDU is invalid; discard it.

The timeout value to be passed to the DLE shall be re-calculated using the received ASN.

The NLE shall forward the NPDU to the DLE such that it can be transmitted in the next slot i.e. the slot immediately following the slot in which the PDU was received.

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6.6.7 NL-management information

6.6.7.1 General

Several NL attributes shall be configured before proper NLE operation is possible. These attributes are defined in 6.6.7.2. The NLE actions which can be requested through NL management are also summarized in 6.6.7.3.

6.6.7.2 NL attributes

Session attributes are shown in Table 49.

Route attributes are shown in Table 52.

Source-route attributes are shown in Table 53.

Other attributes are defined in Table 58.

Table 58 – NL attributes

Attribute name	Range of values	Definition
Unique ID	0 to 2^{40}-1	Unique ID of the device as defined in 3.2.105
Nickname	0 to 65 534	Nickname of the device as defined in 3.2.74
Default_HTL	0 to 255	Packet life limit in hops; specifying the number of hops a packet can travel before being discarded; with a default value of 249
max_packet_age	0 to 65 535	Packet life limit in time using the ASN; indicating the number of slots after which a packet shall be discarded; with a default value of 30 000 ASN time (equal to 300 s). May be set to a value between 100 and 60000.
min_ads_needed	0 to 255	Preferred number of different Advertisements before issuing join request; with a default value of 3
Ad_wait_timeout	0 to 2^{32}-1 in units of ms	The amount of time to wait while attempting to receive additional Advertisements; with a default value of 30 s
max_join_retries	0 to 255	Join retry limit; with a default value of 5
Join_rsp_time	0 to 2^{32}-1 in units of ms	Join response timeout duration; with a default value of 120 s
Bcast_reply_time	0 to 2^{32}-1 in units of ms	Maximum amount of time to reply to a broadcast message; with a default value of 60 s
Health_report_time	0 to 65 535 in units of ms	Interval at which to publish health reports; with a default value of 15 minutes
Session_table_size	up to 255	Size of session table (i.e., maximum number of entries)
Num_session_table_entries	up to 255	Number of entries currently in the session table
Route_table_size	up to 255	Size of route table (i.e., maximum number of entries)
Num_route_table_entries	up to 255	Number of entries currently in the route table

6.6.7.3 NLM actions

The NLE actions which NL management may request are defined in Table 59.

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Table 59 – NL actions

Name	Description
RESET	Reset and initialize the NLE. All network tables are cleared when this primitive is invoked. This primitive is normally invoked on device power-up or when the device is being installed in a new network.
WRITE-SESSION	Adds a new session
DELETE-SESSION	Deletes an existing session
ADD-ROUTE	Adds a new route
DELETE-ROUTE	Deletes an existing route
DEFAULT-ROUTE	Sets a route as default route
ADD-TIMETABLE	Adds a new Timetable
DELETE- TIMETABLE	Deletes an existing Timetable
JOIN	Changes state from Idle to Joining
DISCONNECT	Changes state to Idle

6.6.7.4 Network management

The network manager is responsible for the overall management, scheduling, and optimization of the network. The network management function is specified in Annex C.

6.7 Transport layer

6.7.1 General

The transport layer is used to ensure that the TLS-user data is communicated to its final destination. The transport layer supports both acknowledged and unacknowledged transactions.

Unacknowledged service allows a device to send TLS-user data without requiring acknowledgement from the receiving end. The data may be delivered at the destination device in a different order than the order in which it was originally sent from the source device.

The acknowledged service is used to construct a synchronous transport pipe across the network connecting two devices. This pipe allows devices to send data and confirm its delivery. The TLS-user can send data which will be delivered without loss, duplication or misordering to the receiving TLS-user. This service is suited for user request and response traffic. When the acknowledged service is used, the communication is synchronous. Only one outstanding transaction across the network for that transport pipe is permitted at a time.

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6.7.2 TPDU structure

6.7.2.1 General

Figure 35 shows the TPDU structure. It shall consist of the fields in a sequence described below:

- A single octet transport control, and
- TL payload.

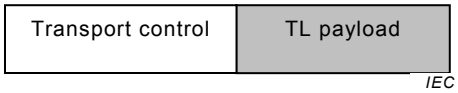

Figure 35 – TPDU Structure

6.7.2.2 Transport control

This field specifies the length and type of service as shown in Figure 36. It has four sub-fields.

TACK: if bit-7 is set to '1' then the TPDU is for acknowledged service, else it is for unacknowledged service;

TRESP: if bit-6 is set to '1' then the TPDU is for response as specified transport-type parameter of the TLS primitive,

TBROAD: if bit-5 is set to '1' then the TPDU is for broadcast pipe; this bit is set to '1' for request and response both,

TSEQN: the bits 4 – 0 form the sequence number for the TPDU to detect duplicate, missing TPDU and to correlate the response with request.

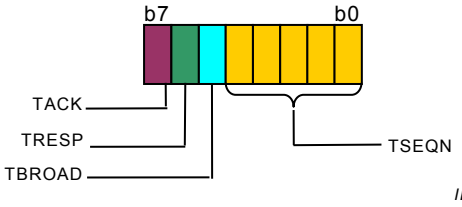

Figure 36 – TPDU control octet

6.7.3 Transport pipe table

Table 60 shows the transport pipe attributes. For each acknowledged data exchange a new entry in the transport pipe table shall be created. Unacknowledged data transfer does not require an entry in this table.

The field device is required to have capacity for following transport pipes:

- unicast data exchange slave with network manager,
- broadcast data exchange slave with network manager,
- unicast data exchange slave with gateway,
- master for event notifications to the network manager, and
- master for event notifications to the gateway.

The gateway and the network manager are required to track many transport pipes for each device and pipes for all of field devices connected to the network. When an acknowledged broadcast is generated by the network manager or gateway, the TLE shall ensure acknowledges are received from all affected devices, which can potentially be all devices.

Each entry in the Transport pipe table includes attributes indicating whether it is active (a transaction is in process), the device is performing as the master, and whether it is broadcast. The TL-Data-exchange request originates at the master end of the pipe. The TL-Data-exchange indication is provided at the slave end of the pipe.

If the transport pipe table entry is for a master end of the pipe, then the retry count and retry timer are also required.

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Table 60 – Transport pipe attributes

Attribute name	Range of values	Definition
Active	TRUE, FALSE	TRUE if the transport pipe is active
Master	TRUE, FALSE	TRUE if it is the master end of the pipe
Broadcast	TRUE, FALSE	TRUE if the transport pipe is for a broadcast request
Bcast_reply_time	0 to 65 535 in units of ms	Maximum amount of time to reply to a broadcast message; default value is 60 s.
sequence_number	0 to 31	On master end of the pipe, the sequence number for the outstanding request; On slave end of the pipe, the sequence number last acknowledged
TPDU_handle	0 to 255	On master end of the pipe only, the handle from the TL-DATA-EXCHANGE request corresponding to last_TPDU; not used on slave end of the pipe
last_TPDU		On master end of the pipe, the last unacknowledged TPDU (or NULL if none); On slave end of the pipe, the last acknowledged TPDU
retry_count	0 to 255	On master end of the pipe only, number of communication attempts; not used on slave end of the pipe
max_reply_time		Amount of time to wait for a response to the outstanding request, before retrying; default value is 30 s.
max_retries	0 to 255	Number of retries used by the transport layer when performing an acknowledged packet transmission; default value is 5.

6.7.4 TLE elements of procedure

6.7.4.1 Receipt of TL-DATA-TRANSFER request primitive

The TLE shall encode transport control octet as shown in Table 61.

Table 61 – Transport control encoding for TL-DATA-TRANSFER request

Transport-type	tbroad	tack	tresp
Block-transfer request	0	0	0
Block-transfer response	0	0	1
Search-broadcast	1	0	0
Search-response	1	0	1
Publish-broadcast	1	0	1
Response-broadcast	1	1	1
Publish-unicast	0	0	1
NOTE Other values of Transport-type are used by other services – see Table 62 and Table 63.			

On the Master side of the transport pipe, the TLE shall increment sequence_number and copy its least significant five into TSEQN sub-field. On the Slave (responder) side of the transport pipe, the TLE shall copy the least significant five bits of the Handle received in the request primitive, into TSEQN sub-field. The TLE shall forward the TPDU to NLE using NL-TRANSMIT request primitive. The Timetable_ID parameter value in this request primitive shall be used in the NL-TRANSMIT request primitive.

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6.7.4.2 Receipt of TL-DATA-EXCHANGE request primitive

6.7.4.2.1 General

If this transport pipe is waiting for acknowledgement for a previous TPDU, and no more buffers are available then the service fails and TL-DATA-EXCHANGE confirm primitive shall be returned to the TLS-user to signal the error and the request shall be discarded.

Else, the TLE shall check the transport-type parameter of the request primitive and encode transport control octet as shown in Table 62. The Timetable_ID parameter value in this request primitive shall be used in the NL-TRANSMIT request primitive.

Table 62 – Transport control encoding for TL-DATA-EXCHANGE request

Transport-type	tbroad	tack	tresp
Request-unicast	0	1	0
Request-broadcast	1	1	0
NOTE Other values of Transport-type are used by other services – see Table 61 and Table 63.			

6.7.4.2.2 Unacknowledged request

The request does not require a response from the destination. Therefore TACK sub-field of transport control field is set to '0'. The TLE shall forward the TPDU to the NLE using the NL-TRANSMIT request primitive.

6.7.4.2.3 Acknowledged request

The request requires a response from the destination. Therefore TACK sub-field of transport control field is set to '1'. The TLE shall look for an entry in transport pipe table that corresponds to the service primitive. If no such entry exists, then the TLE shall create an entry in transport pipe table and set sequence_number for that entry to a random number.

If a transport pipe is available, and there is already a request in this transport pipe waiting for acknowledgement from the destination TLE, and no more buffers are available then the request fails. TLE shall forward the TL-DATA-EXCHANGE confirm primitive to TLS-user with error status.

If a transport pipe is available, and either there is no pending request in this transport pipe, or a buffer is available then the sequence_number from the table entry shall be incremented and the least significant five bits shall be copied to the TSEQN sub-field of transport control field. In the transport pipe entry for this service primitive, Active flag shall be set to TRUE; the retry_count shall be reset to 0; and replyTimer shall be set to max_reply_time and started to await the response.

The TLE shall forward the TPDU to NLE using NL-TRANSMIT request primitive. The TPDU shall also be buffered for possible future retries.

6.7.4.3 Receipt of TL-DATA-EXCHANGE response primitive

The TLE shall search the transport pipe table to find the entry that corresponds to the correspondent address. There may be two such entries for each correspondent address – broadcast and unicast. The TLE shall use the transport-type parameter of the primitive to find the correct transport pipe.

The TLE shall compare the Handle (sequence_number) parameter in the response primitive to the sequence_number in the transport pipe entry. If the sequence_number is not one greater

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than that in the transport pipe entry, then the service fails and the response shall be discarded. The TLE shall not forward any TPDU to the NLE.

Else, the TLE shall prepare the TPDU, update the sequence_number in the transport pipe entry, encode transport control octet as shown in Table 63. If transport-type is Response-unicast, then the TPDU shall be forwarded to NLE immediately using NL-TRANSMIT request primitive. Else, the transport-type is Response-broadcast; the TLE shall wait for a random amount of time between zero and Bcast_reply_time (see Table 60) value and at the expiration of this time, the TLE shall forward the TPDU to NLE using NL-TRANSMIT request primitive. TLE shall also place the TPDU in a buffer for possible future retry.

Table 63 – Transport control encoding for TL-DATA-EXCHANGE response

Transport-type	tbroad	tack	tresp
Response-unicast	0	1	1
NOTE Other values of Transport-type are used by other services – see Table 61 and Table 62.			

6.7.4.4 Receipt of NL-Transmit indication primitive

6.7.4.4.1 General

When the TLE receives an indication primitive from the NLE, it shall inspect the transport control sub-fields TACK and TRESP, and use it to process the received TPDU.

6.7.4.4.2 Unacknowledged data transfer

If the TACK sub-field of transport control is FALSE, then the TLE shall forward the received TSDU to TLS-user in TL-DATA-TRANSFER indication primitive. The TSEQN sub-field shall be forwarded as sequence-number.

6.7.4.4.3 Acknowledged indication data transfer

If the TACK sub-field of transport control is TRUE and TRESP is FALSE, then the TLE shall validate the TSEQN sub-field. The TLE shall search the transport pipe table to find the entry that corresponds to the correspondent address. There may be two such entries for each correspondent address – broadcast and unicast. The TLE shall use the TBROAD sub-field of transport control to find the correct transport pipe.

If there is no such transport pipe table entry, then the TLE shall create a new entry. The TLE shall set Active attribute to true, Master attribute bit to false and set sequence_number attribute to one less than the TSEQN sub-field in the received TPDU. The TLE shall forward the TL-DATA-EXCHANGE indication primitive to TLS-user. The transport-type and sequence number in the primitive shall be set to the values received in the transport control field.

If the transport pipe table entry exists, then the TSEQN sub-field in the received TPDU shall be compared to sequence_number in that transport pipe table entry. If both are identical, then the TPDU is a duplicate and the previously buffered response TLDPU shall be forwarded to NLE in NL-TRANSMIT request primitive. Else, if the TSEQN sub-field in the received TPDU is not one greater than that in the transport pipe table entry then the TPDU shall be discarded.

Else, the TSEQN sub-field in the received TPDU is one greater than that in the transport pipe table entry. The TLE shall forward the received TL-payload as TLS-user-data in the TL-DATA-EXCHANGE indication primitive to TLS-user. The transport-type and sequence number in the primitive shall be set to the values received in the transport control field.

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6.7.4.4.4 Acknowledged response data transfer

If the TACK sub-field of transport control is TRUE and TRESP is TRUE, then the TLE shall validate the TSEQN sub-field. The TLE shall search the transport pipe table to find the entry that corresponds to the correspondent address. There may be two such entries for each correspondent address – broadcast and unicast. The TLE shall use the TBROAD sub-field of transport control to find the correct transport pipe.

If there is no such transport pipe table entry, then the TLE shall discard the received TPDU.

If the transport pipe table entry exists, then the TSEQN sub-field in the received TPDU shall be compared to sequence_number in that transport pipe table entry. If both are identical, then the TPDU is a response to previously sent request. The TLE shall set Active attribute of that entry to false, disable replyTimer and delete the buffer that was used to store the TPDU for the request. The TLE shall forward the received TL-payload as TLS-user-data in TL-DATA-EXCHANGE confirm primitive to TLS-user. The Handle in the primitive shall be set to the values received in the corresponding indication primitive.

6.7.4.5 Receipt of NL-TRANSMIT confirm primitive

If the corresponding NL-TRANSMIT request was due to TL-DATA-TRANSFER request, then the TLE shall forward TL-DATA-TRANSFER confirm primitive to the TLE-user. If the corresponding NL-TRANSMIT request was due to TL-DATA-EXCHANGE request with Transport-type value of Request-broadcast, then the TLE shall forward TL-DATA-EXCHANGE confirm primitive to the TLE-user.

6.7.4.6 Expiration of replyTimer

If replyTimer expires it indicates that either the request TPDU or the corresponding response TPDU is lost. If the retry_count is not equal to max_retries, then the TLE shall send the request TPDU and increment retry_count. Else, the retry_count is at its maximum value, the request has failed and the TLE shall set Active attribute of that entry to false, disable replyTimer and delete the buffer that was used to store the TPDU for the request. The TLE shall forward the TL-DATA-EXCHANGE confirm primitive to TLS-user with error status. The Handle in the primitive shall be set to the value received in the corresponding request primitive.

When the request has failed the TLE shall construct a transport layer failed alarm response and send it to the network manager. Upon receiving notice of a transport layer failure the network manager shall delete and reestablish the corresponding session. If this is not possible then the network manager shall force the device to re-join the network.

6.7.5 TLE state machines

6.7.5.1 Client data transfer state machine

The states are shown in Figure 37 and the complete state machine is described in Table 64.

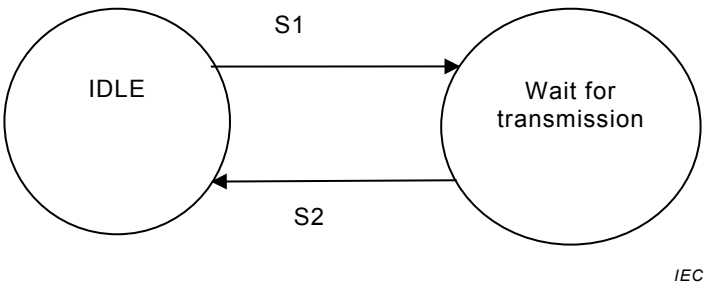

Figure 37 – Transition diagram of the client data transfer state machine

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Table 64 – Client data transfer state table

#	Current state	Event or condition => action	Next state
S1	IDLE	TL-DATA-TRANSFER.request => NL-TRANSMIT.request { destination address:= TL-DATA-TRANSFER.request.destination address, priority:= TL-DATA-TRANSFER.request.priority, Timetable_ID:= TL-DATA-TRANSFER.request.Timetable_ID, NLS-user-data:= TLPDU } (see 6.7.4.1)	Wait for transmission
S2	Wait for transmission	NL-TRANSMIT.confirm => TL-DATA-TRANSFER.confirm { Status:= status } (see 6.7.4.5)	IDLE

6.7.5.2 Client data exchange state machine

The states are shown in Figure 38 and the complete state machine is described in Table 65.

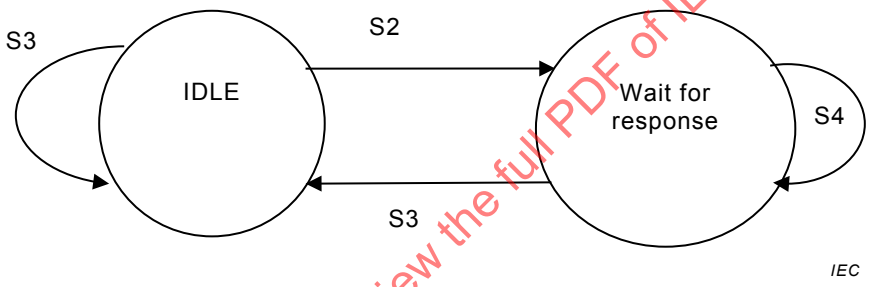

Figure 38 – Transition diagram of the client data exchange state machine

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Table 65 – Client data exchange state table

#	Current state	Event or condition => action	Next state

S1	IDLE	TL-DATA-EXCHANGE.request && waiting for acknowledgement for a previous TPDU
		=>
		TL-DATA-TRANSFER.confirm {
		Status:= failure
		}
			IDLE

S2	IDLE	TL-DATA- EXCHANGE.request && !waiting for acknowledgement for a previous TPDU => retry_count:= 0, replyTimer:= max_reply_time, NL-TRANSMIT.request { destination address:= TL-DATA-TRANSFER.request.destination address, priority:= TL-DATA-TRANSFER.request.priority, Timetable_ID:= TL-DATA-TRANSFER.request.Timetable_ID, NLS-user-data:= TLPDU } (see 6.7.4.2)	Wait for response
S3	Wait for response	NL-TRANSMIT.confirm && corresponding Transport-type == Request-broadcast => TL-DATA- EXCHANGE.confirm { Status:= status } (see 6.7.4.5)	IDLE
S3	Wait for response	NL-TRANSMIT.indication && TLPDU.TACK == TRUE && TLPDU. TRESP == TRUE && transport pipe table entry exists && TLPDU. TSEQN == sequence_number in the transport pipe table entry => Disable replyTimer, Delete the buffer that was used to store the TPDU for the request, TL-DATA- EXCHANGE.confirm { TLS-user-data:= TLPDU payload, Status:= status } (see 6.7.4.4.4)	IDLE
S4	Wait for response	replyTimer expires && retry_count != max_retries => Increment retry_count, NL-TRANSMIT.request { destination address:= TL-DATA-TRANSFER.request.destination address, priority:= TL-DATA-TRANSFER.request.priority, Timetable_ID:= TL-DATA-TRANSFER.request.Timetable_ID, NLS-user-data:= TLPDU } (see 6.7.4.6)	Wait for response
S3	Wait for response	replyTimer expires && retry_count == max_retries => TL-DATA-TRANSFER.confirm { Status:= failure } (see 6.7.4.6)	IDLE

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6.7.5.3 Server state machine

The states are shown in Figure 39 and the complete state machine is described in Table 66.

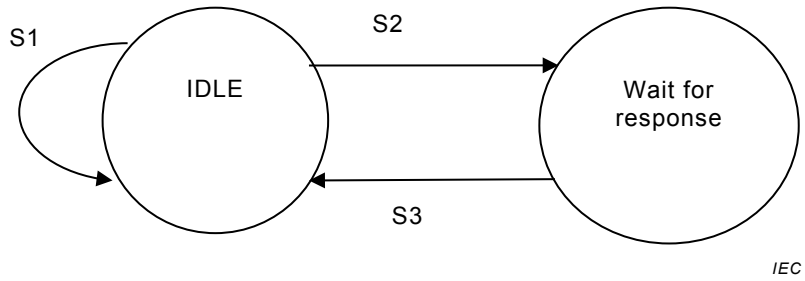

Figure 39 – Transition diagram of the server state machine

Table 66 – Server state table

#	Current state	Event or condition => action	Next state
S1	IDLE	TL-DATA-TRANSFER.request => NL-TRANSMIT.request { destination address:= TL-DATA-TRANSFER.request.destination address, priority:= TL-DATA-TRANSFER.request.priority, Timetable_ID:= TL-DATA-TRANSFER.request.Timetable_ID, NLS-user-data:= TLPDU } (see 6.7.4.1)	IDLE
S1	IDLE	NL-TRANSMIT.indication && TLPDU.TACK == FALSE => TL-DATA-TRANSFER.indication { source address:= NL-TRANSMIT.indication.source address, Transport-type:= TLPDU.transport-type, priority:= TLPDU priority, TLS-user-data:= TLPDU payload } (see 6.7.4.4.2)	IDLE
S1	IDLE	NL-TRANSMIT.indication && TLPDU.TACK == TRUE && TLPDU. TRESP == FALSE && TLPDU. TSEQN == sequence_number in the transport pipe table entry (duplicate indication, see 6.7.4.4.3) => NL-TRANSMIT.request { destination address:= previously buffered destination address, priority:= previously buffered priority, Timetable_ID:= previously buffered Timetable_ID, NLS-user-data:= previously buffered TLPDU } (see 6.7.4.4.3)	IDLE
S2	IDLE	NL-TRANSMIT.indication && TLPDU.TACK == TRUE && TLPDU. TRESP == FALSE && transport pipe table entry does not exist => Create transport pipe table entry, sequence_number in the transport pipe table entry = TLPDU. TSEQN -1 TL-DATA- EXCHANGE.indication { source address:= NL-TRANSMIT.indication.source address, sequence number:= TLPDU. TSEQN, Transport-type:= TLPDU.transport-type, priority:= TLPDU priority, TLS-user-data:= TLPDU payload } (see 6.7.4.4.3)	Wait for response
S2	IDLE	NL-TRANSMIT.indication && TLPDU.TACK == TRUE && TLPDU. TRESP == FALSE && transport pipe table entry exists && TLPDU. TSEQN == sequence_number in the transport pipe table entry + 1 => TL-DATA- EXCHANGE.indication { source address:= NL-TRANSMIT.indication.source address, sequence number:= TLPDU. TSEQN, Transport-type:= TLPDU.transport-type, priority:= TLPDU priority, TLS-user-data:= TLPDU payload } (see 6.7.4.4.3)	Wait for response
S3	Wait for response	TL-DATA- EXCHANGE.response && transport pipe table entry exists && sequence_number in the transport pipe table entry == response sequence number -1 => Increment sequence_number in the transport pipe table entry, NL-TRANSMIT.request { destination address:= TL-DATA- EXCHANGE.response.destination address, priority:= TL-DATA- EXCHANGE.response.priority, Timetable_ID:= TL-DATA- EXCHANGE.response.Timetable_ID, NLS-user-data:= TLPDU } (see 6.7.4.3), Buffer TLPDU and NL-TRANSMIT.request parameters	IDLE

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6.7.6 TL-management information

Several TL attributes shall be configured before proper TLE operation is possible. These attributes are defined in Table 60.

7 Application layer service definition – Type 20 elements

7.1 Common concepts

7.2 General

This document defines the wireless Application layer service of Type 20 in addition to the wired Application layer service of Type 20 specified in IEC 61158-5-20.

The common concepts and templates used to describe the application layer service in this standard are detailed in IEC 61158-1:2014, Clause 9.

7.3 Data type ASE

7.3.1 Overview

7.3.1.1 General

Fieldbus data types specify the machine independent syntax for application data conveyed by FAL services. The Fieldbus application layer supports the definition and transfer of both basic and constructed data types. Encoding rules for the data types specified in this clause are provided in Clause 8.

Basic types are atomic types that cannot be decomposed into more elemental types. Constructed types are types composed of basic types and other constructed types. Their complexity and depth of nesting is not constrained by this standard.

Data types are defined as instances of the data type class, as shown in Figure 40.

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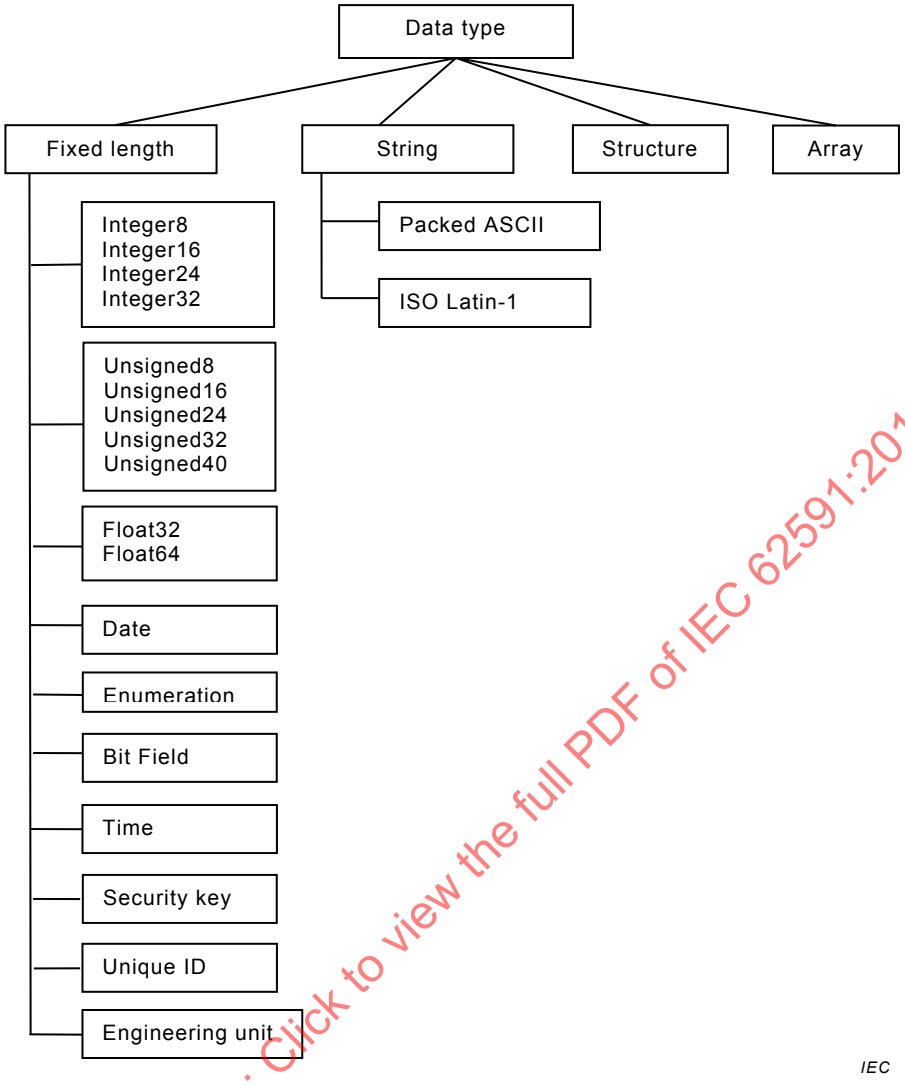

Figure 40 – Data type class hierarchy

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The data type definitions are represented as a class/format/instance structure beginning with data type class entitled "Data type". The formats for data types are defined by the data type class.

The basic data classes are used to define fixed length data types. Standard types taken from ISO/IEC 8824 are referred to as *simple* data types. Other standard basic data types are defined specifically for Fieldbus applications and are referred to as specific types.

The constructed types specified in this standard are strings, arrays and structures.

7.3.1.2 Overview of basic types

Most basic types are defined from a set of ISO/IEC 8824 types (simple types). Some ISO/IEC 8824 types have been extended for Fieldbus specific use (specific types).

Simple types are ISO/IEC 8824 universal types. They are defined in this standard to provide them with Fieldbus class identifiers.

Specific types are basic types defined specifically for use in the Fieldbus environment. They are defined as simple class subtypes.

Basic types have a constant length. Two variations are defined, one for defining data types whose length is an integral number of octets, and one for defining data types whose length is bits.

NOTE Integer, Packed ASCII, ISO Latin-1 and Date are defined in this standard for the purpose of assigning Fieldbus class identifiers to them. This standard does not change their definitions as specified in ISO/IEC 8824.

7.3.1.3 Fixed length types

The length of fixed length types is an integral number of octets.

7.3.1.4 Constructed types

7.3.1.4.1 Overview

Constructed data types are needed to completely convey the variety of information present on the Fieldbus. There are three kinds of constructed types defined for this standard – string, array and structure.

7.3.1.4.2 String

A string is composed of an ordered set, variable in number of homogeneously typed fixed-length elements.

7.3.1.4.3 Structure

A structure is made of an ordered set of heterogeneously typed elements called fields. This standard does not restrict the data type of fields. However, the fields within a structure do not have to be of the same type.

7.3.1.4.4 Array

An array is composed of an ordered set of homogeneously typed elements. The data type of array elements can be fixed length basic type or structure. All elements of an array shall be of the same type.

7.3.1.4.5 Nesting level

This standard permits structures and arrays to contain structures and arrays.

7.3.1.5 Specification of user defined data types

User defined types are not supported by this standard.

7.3.1.6 Transfer of user data

User data is transferred between applications by the FAL protocol. All encoding and decoding are performed by the FAL user.

The rules for encoding user data in FAL protocol data units is data type dependent. These rules are defined in IEC 61158-6-20.

7.3.2 Formal definition of data type objects

7.3.2.1 Data type class

The data type class specifies the root of the data type class tree. Its parent class "top" indicates the top of the FAL class tree.

FAL ASE: Data type ASE

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CLASS:	Data type	
CLASS ID:	Not used	
PARENT CLASS:		TOP
ATTRIBUTES:		
(m)	Key Attribute:	Data type Name
(m)	Attribute:	Format (FIXED LENGTH, STRING, STRUCTURE, ARRAY)
(c)	Constraint:	Format = FIXED LENGTH | STRING
(m)	Attribute:	Octet Length
(c)	Constraint:	Format = STRUCTURE
(m)	Attribute:	Number of Fields
(m)	Attribute:	List of Fields
(m)	Attribute:	Field Name
(m)	Attribute:	Field Data type
(c)	Constraint:	Format = ARRAY
(m)	Attribute:	Number of Array Elements
(m)	Attribute:	Array Element Data type

7.3.2.2 Attributes

Format

This attribute identifies the data type as a fixed-length, string, structure or array.

Octet Length

This conditional attribute defines the representation of the dimensions of the associated type object. It is present when the value of the format attribute is "FIXED LENGTH" or "STRING". For FIXED LENGTH data types, it represents the length in octets. For STRING data types, it represents the length in octets for a single element of a string.

Number of Fields

This conditional attribute defines the number of fields in a structure. It is present when the value of the format attribute is "STRUCTURE".

List of Fields

This conditional attribute is an ordered list of fields contained in the structure. Each field is specified by its type. Fields are described in the order in which they occur. Partial access to fields within a structure is not supported.

Field Name

This conditional attribute specifies the name of the field. It is present when the value of the format attribute is "STRUCTURE".

Field Data type

This conditional attribute specifies the data type of the field. It is present when the value of the format attribute is "STRUCTURE". This attribute may itself specify a constructed data type by referencing a constructed data type definition by embedding a constructed data type definition here.

Number of Array Elements

This conditional attribute defines the number of elements for the array type. This attribute is present when the value of the format attribute is "ARRAY".

Array Element Data type

This conditional attribute specifies the data type for the elements of an array. All elements of the array have the same data type. It is present when the value of the format attribute is "ARRAY". This attribute may itself specify a constructed data type either by referencing a constructed data type definition by its numeric id.

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7.3.3 FAL defined data types

7.3.3.1 Fixed length types

7.3.3.1.1 Integer8

CLASS: **Data type**

ATTRIBUTES:

1	Data type Name	= Integer8
2	Format	= FIXED LENGTH
2.1	Octet Length	= 1

This integer type is a two's complement binary number with a length of one octet.

7.3.3.1.2 Integer16

CLASS: **Data type**

ATTRIBUTES:

1	Data type Name	= Integer16
2	Format	= FIXED LENGTH
2.1	Octet Length	= 2

This integer type is a two's complement binary number with a length of two octets.

7.3.3.1.3 Integer24

CLASS: **Data type**

ATTRIBUTES:

1	Data type Name	= Integer24
2	Format	= FIXED LENGTH
2.1	Octet Length	= 3

This integer type is a two's complement binary number with a length of three octets.

7.3.3.1.4 Integer32

CLASS: **Data type**

ATTRIBUTES:

1	Data type Name	= Integer32
2	Format	= FIXED LENGTH
2.1	Octet Length	= 4

This integer type is a two's complement binary number with a length of four octets.

7.3.3.1.5 Unsigned8

CLASS: **Data type**

ATTRIBUTES:

1	Data type Name	= Unsigned8
2	Format	= FIXED LENGTH
2.1	Octet Length	= 1

This type is a binary number. The most significant bit of the most significant octet is always used as the most significant bit of the binary number; no sign bit is included. This type has a length of one octet.

7.3.3.1.6 Unsigned16

CLASS: **Data type**

ATTRIBUTES:

1	Data type Name	= Unsigned16
2	Format	= FIXED LENGTH

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2.1 Octet Length = 2

This type is a binary number. The most significant bit of the most significant octet is always used as the most significant bit of the binary number; no sign bit is included. This unsigned type has a length of two octets.

7.3.3.1.7 Unsigned24

CLASS: **Data type**

ATTRIBUTES:

1 Data type Name = Unsigned24

2 Format = FIXED LENGTH

2.1 Octet Length = 3

This type is a binary number. The most significant bit of the most significant octet is always used as the most significant bit of the binary number; no sign bit is included. This unsigned type has a length of three octets.

7.3.3.1.8 Unsigned32

CLASS: **Data type**

ATTRIBUTES:

1 Data type Name = Unsigned32

2 Format = FIXED LENGTH

2.1 Octet Length = 4

This type is a binary number. The most significant bit of the most significant octet is always used as the most significant bit of the binary number; no sign bit is included. This unsigned type has a length of four octets.

7.3.3.1.9 Unsigned40

CLASS: **Data type**

ATTRIBUTES:

1 Data type Name = Unsigned40

2 Format = FIXED LENGTH

2.1 Octet Length = 5

This type is a binary number. The most significant bit of the most significant octet is always used as the most significant bit of the binary number; no sign bit is included. This unsigned type has a length of five octets.

7.3.3.1.10 Float32

CLASS: **Data type**

ATTRIBUTES:

1 Data type Name = Float32

2 Format = FIXED LENGTH

2.1 Octet Length = 4

This type has a length of four octets. The format for Float32 is that defined by IEEE 754 as single precision.

7.3.3.1.11 Float64

CLASS: **Data type**

ATTRIBUTES:

1 Data type Name = Float64

2 Format = FIXED LENGTH

2.1 Octet Length = 8

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This type has a length of eight octets. The format for Float64 is that defined by IEEE 754 as double precision.

7.3.3.1.12 Date

CLASS: **Data type**

ATTRIBUTES:

1	Data type Name	= Date
2	Format	= FIXED LENGTH
2.1	Octet Length	= 3

This data type is consists of day, month and year minus 1900. This allows the representation of any date between 1 January 1900 and 31 December 2155.

7.3.3.1.13 Enumeration

CLASS: **Data type**

ATTRIBUTES:

1	Data type Name	= Enumeration
2	Format	= FIXED LENGTH
2.1	Octet Length	= 1

Data items that take on a single meaning from a list or table are encoded as Enumeration. This data type uses an unsigned integer of one octet length. The largest integer value is reserved and not used by any service.

7.3.3.1.14 Bit Field

CLASS: **Data type**

ATTRIBUTES:

1	Data type Name	= Bit Field
2	Format	= FIXED LENGTH
2.1	Octet Length	= 1 or 2

This data type is a series of eight bits numbered from 0 to 7 or sixteen bits numbered 0 to 15. Communication of information encoded as single-bit data (such as status and diagnostic information) uses this data type.

7.3.3.1.15 Time

CLASS: **Data type**

ATTRIBUTES:

1	Data type Name	= Time
2	Format	= FIXED LENGTH
2.1	Octet Length	= 4

This data type is an unsigned binary integer and represents time in the increments of 1/32 of a millisecond. If this data type is used to represent time of day, then it indicates number of 1/32 of milliseconds since midnight.

7.3.3.1.16 Security key

CLASS: **Data type**

ATTRIBUTES:

1	Data type Name	= Security key
2	Format	= FIXED LENGTH
2.1	Octet Length	= 16

This type is a string of sixteen octets. Each octet can have any value from 0 to 255. The interpretation of this data type is application dependent.

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7.3.3.1.17 Unique ID

CLASS: **Data type**

ATTRIBUTES:

1	Data type Name	= Unique ID
2	Format	= FIXED LENGTH
2.1	Octet Length	= 5

This type is a string of five octets. Each octet can have any value from 0 to 255. The interpretation of this data type is application dependent.

7.3.3.1.18 Engineering unit

CLASS: **Data type**

ATTRIBUTES:

1	Data type Name	= Engineering unit
2	Format	= FIXED LENGTH
2.1	Octet Length	= 1

This type defines the measurement unit of a measured variable. The interpretation of this data type is specified by the communication profile (see 9.3.1) and beyond the scope of this standard.

7.3.3.2 String Types

7.3.3.2.1 Packed ASCII

CLASS: **Data type**

ATTRIBUTES:

1	Data type Name	= Packed ASCII
2	Format	= STRING
2.1	Octet Length	= 1 to n

This type is a modified subset of the ASCII character code set. This subset is shown in Table 379. It is produced by compressing four Packed ASCII characters into three 8-bit octets.

7.3.3.2.2 ISO Latin-1

CLASS: **Data type**

ATTRIBUTES:

1	Data type Name	= Latin-1
2	Format	= STRING
2.1	Octet Length	= 1 to n

This type is a subset of the ISO 8859-1 (ISO Latin-1) string type. The subset is shown in Table 380.

7.3.4 Data type ASE service specification

There are no operational services defined for the data type object.

7.3.5 Summary of data types

This clause contains a summary of the defined data types as shown in Table 67.

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Table 67 – Data type summary

Data type	Clause
Integer8	7.3.3.1.1
Integer16	7.3.3.1.2
Integer24	7.3.3.1.3
Integer32	7.3.3.1.4
Unsigned8	7.3.3.1.5
Unsigned16	7.3.3.1.6
Unsigned24	7.3.3.1.7
Unsigned32	7.3.3.1.8
Unsigned40	7.3.3.1.9
Float32	7.3.3.1.10
Float64	7.3.3.1.11
Date	7.3.3.1.12
Enumeration	7.3.3.1.13
Bit Field	7.3.3.1.14
Time	7.3.3.1.15
Security Key	7.3.3.1.16
Unique ID	7.3.3.1.17
Engineering unit	7.3.3.1.18
Packed ASCII	7.3.3.2.1
ISO Latin-1	7.3.3.2.2

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7.4 Communication model specification

7.4.1 Common parameters

7.4.1.1 General

Many services have the parameters specified in 7.4.1.2 to 7.4.1.5. Instead of defining them with each service, the common definitions are provided in 7.4.1.

7.4.1.2 AREP ID

This parameter specifies sufficient information to identify the AREP of the remote end of the AR. The value of this parameter can be the Unique ID of the remote end. One value of this parameter is reserved as broadcast address.

7.4.1.3 Response Code

If there is no communication error then this parameter specifies a command completion report indicating the status of the command's execution by the device. The possible values of this parameter are shown in Table 68. Its data type is Enumeration.

Table 68 – Response code values

Value	Description
Success	Command (read or write) was executed properly
Warning	Command (write) was executed with the deviation as described in response (for example a value was set to its nearest legal value)
Error	Command (read or write) was not executed properly. Response Code indicates the reason (for example the device is in Write Protect mode)

7.4.1.4 Application process status

This parameter indicates the status provided by the FAL user and it is not associated with the completion of any command. Its length is one octet.

7.4.1.5 Extended status

This parameter indicates the VFD status. It is not associated with the completion of any command. Its length is one octet.

7.4.2 ASEs

7.4.2.1 Virtual field device ASE

The virtual field device (VFD) ASE shall be according to IEC 61158-5-20: 2014, 6.2.1.

7.4.2.2 Variable ASE

7.4.2.2.1 Overview

The Variable ASE provides services to read or write a variable object in Server device. The variable is identified by a number. This numeric identifier completely describes the data type and structure of the object. The object can be any of the types defined in 7.3.3.

7.4.2.2.2 Variable model – common

7.4.2.2.2.1 Simple variable

####### 7.4.2.2.2.1.1 Formal model

The simple variable object represents a single, simple variable which is characterized by a defined Data type.

ASE: **VARIABLE ASE**
CLASS: **Simple VARIABLE**
PARENT CLASS: **TOP**
ATTRIBUTES:

1	(m)	Key Attribute:	Numeric Identifier
2	(o)	Attribute:	Variable Name
3	(m)	Attribute:	Data type Name

SERVICES:

1	(m)	OpsService:	Read
2	(o)	OpsService:	Write
3	(o)	OpsService:	Information report

####### 7.4.2.2.2.1.2 Attributes

Numeric Identifier

Identifies an instance of this object class.

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Variable Name

It is the name assigned to the object.

Data type Name

It is the name assigned to the data type as specified in 7.3.3.1.

7.4.2.2.2.1.3 Services

Read

This confirmed service permits a client to read the value of a variable.

Write

This confirmed service permits a client to write the value of a variable.

Information report

This unconfirmed service permits a server to send value of a variable to any one or all clients.

7.4.2.2.2.2 Structure variable

7.4.2.2.2.2.1 General

The record object consists of a collection of simple variables of an array of Structure variables of different data types. The record object is accessed completely and its individual fields cannot be accessed separately.

ASE:			**VARIABLE ASE**
CLASS:			**Structure VARIABLE**
PARENT CLASS:			**TOP**
ATTRIBUTES:			
1	(m)	Key Attribute:	Numeric Identifier
2	(o)	Attribute:	Variable Name
3	(m)	Attribute:	Number of Fields
4	(m)	Attribute:	List of Fields
4.1	(o)	Attribute:	Field Name
4.2	(m)	Attribute:	Field Data type Name
SERVICES:			
1	(m)	OpsService:	Read
2	(o)		OpsService: Write
3	(o)		OpsService: Information report

7.4.2.2.2.2.2 Attributes

Numeric Identifier

Identifies an instance of this object class.

Variable Name

It is the name assigned to the object.

Number of Fields

This attribute defines the number of fields in a structure.

Field Name

This optional attribute specifies the name of the field.

Field Data type Name

It is the name assigned to the data type as specified in 7.3.3.1.

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7.4.2.2.2.3 Services

Read

This confirmed service permits a client to read the value of a variable.

Write

This confirmed service permits a client to read the value of a variable.

Information report

This unconfirmed service permits a server to send value of a variable to any one or all clients.

7.4.2.2.3 Array of simple variable

7.4.2.2.3.1 Formal model

This Array Object is used to define a constructed variable in which all elements have the identical Data type and length and are of Simple Variable class. One or more elements of this object type can be accessed at a time by specifying the starting subindex and the number of elements to be accessed.

ASE:			**VARIABLE ASE**
CLASS:			**Array of Simple VARIABLE**
PARENT CLASS:			**Simple variable**
ATTRIBUTES:			
ATTRIBUTES:			
1	(m)	Attribute:	Array size

7.4.2.2.3.2 Attributes

Array size

It states how many elements are contained in the Array. If the value of this attribute is "Variable" then the number of elements is not fixed.

7.4.2.2.4 Array of structure variable

7.4.2.2.4.1 Formal model

This Array Object is used to define a constructed variable in which all elements have the identical Data type and length and are of Structure Variable class. One or more elements of this object type can be accessed at a time by specifying the starting subindex and the number of elements to be accessed.

ASE:			**VARIABLE ASE**
CLASS:			**Array of Structure VARIABLE**
PARENT CLASS:			**Structure variable**
ATTRIBUTES:			
ATTRIBUTES:			
1	(m)	Attribute:	Array size

7.4.2.2.4.2 Attributes

Array size

It states how many elements are contained in the Array. If the value of this attribute is "Variable" then the number of elements is not fixed.

7.4.2.2.3 Variable ASE service specification

7.4.2.2.3.1 Supported services

This subclause contains the definition of services that are unique to this ASE. The services defined for this ASE are:

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– Read variable from Server device,
– Write variable to Server device, and
– Send Information report from a server device.

There are separate services for each variable, which is identified by a number. The common format of Read service is defined in 7.4.2.2.3.3. The common format of Write service is defined in 7.4.2.2.3.4. The common format of Information report service is defined in 7.4.2.2.3.5.

For every variable there is a separate read and write service. These services are defined in 7.4.2.4, 7.4.2.5, 7.4.2.6 and 7.4.2.7.

NOTE The service definitions in this subclause are not independent of the variable being accessed. This subclause only shows the format of the service. The service specific definitions include the variable model and the service specific parameters.

7.4.2.2.3.2 Primitive correlation

At the client, there is only one outstanding request for one value of AREP ID. The AREP ID is conveyed as destination address in the transport layer service primitives. Therefore, the confirm primitive is correlated with the request primitive using AREP ID. At the server, there is only one outstanding indication primitive at any time. Therefore, the response primitive is correlated with the indication primitive waiting for the response.

7.4.2.2.3.3 Read service – common format

7.4.2.2.3.3.1 Service overview

This service permits a client to read the value of a variable from the server.

7.4.2.2.3.3.2 Service primitives

The service parameters for this service are shown in Table 69.

Table 69 – Read service parameters

Parameter name	Req	Ind	Rsp	Cnf
Argument				
AREP ID	M	M (=)		
Numeric Identifier	M	M (=)	M (=)	M (=)
Additional identifier	C	M (=)	M (=)	M (=)
Subindex	C	M (=)	M (=)	M (=)
Element count	C	M (=)	CM	M (=)
Array size			C	M (=)
Result (+)				
Variable value			S	S (=)
Response Code			M	M (=)
Application process status			M	M (=)
Extended status			M	M (=)
Result (–)			S	S (=)
Status				S
Response Code			M	M (=)
Application process status			M	M (=)
Extended status			M	M (=)

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Argument

The argument contains the parameters of the service request.

Numeric Identifier

This parameter identifies the variable. This is the key attribute assigned to the variable to be read. It is also called command number.

Additional identifier

For some of the Numeric Identifiers, this parameter provides additional information required to identify the variable(s) to be read.

Subindex

This parameter identifies the individual element in an array variable by its position within the variable. This can be either a numeric value or an Enumeration.

Element count

This parameter specifies the number of array elements to be read. This parameter is present only if the variable is an array variable and if the Subindex is a numeric value. The default value of this parameter is one (1). In the request and indication primitives, its value is the desired number of the elements to be read. In the response and confirm primitives its value is the actual number of elements read.

Array size

This parameter specifies the total number of array elements available. This parameter present only if the variable is an array variable.

Variable value

This parameter specifies the value read from the server.

Status

This parameter specifies the local reason for failure such as communication timeout. If the server sends a response, but it could not send the “Variable value, then it is shown in “Response code”.

7.4.2.2.3.4 Write service – common format

7.4.2.2.3.4.1 Service overview

This service permits a client to write the value of a variable to the server.

7.4.2.2.3.4.2 Service primitives

The service parameters for this service are shown in Table 70.

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Table 70 – Write service parameters

Parameter name	Req	Ind	Rsp	Cnf
Argument				
AREP ID	M	M (=)		
Numeric Identifier	M	M (=)	M (=)	M (=)
Additional identifier	C	M (=)	M (=)	M (=)
Subindex	C	M (=)	M (=)	M (=)
Variable value	M	M (=)		
Result (+)				
Variable value			S	S (=)
Response Code			M	M (=)
Application process status			M	M (=)
Extended status			M	M (=)
Result (–)				
Status				S
Response Code			M	M (=)
Application process status			M	M (=)
Extended status			M	M (=)

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Argument

The argument contains the parameters of the service request.

Numeric Identifier

This parameter identifies the variable. This is the key attribute assigned to the variable to be read. It is also called command number.

Additional identifier

For some of the Numeric Identifiers, this parameter provides additional information required to identify the variable(s) to be read.

Subindex

This parameter identifies the individual element in an array variable by its position within the variable. This can be either a numeric value or an Enumeration.

Variable value

In the request primitive, this parameter specifies the desired value of the variable to be written. In the response primitive, this parameter states the actual value of the variable that was written. In some cases, the responding server writes a value different than the value in indication primitive, for example it may round the value to the nearest allowed value or the nearest value the server can support.

NOTE The returned variable value can be used by the FAL-user to validate the write operation.

Status

This parameter specifies the local reason for failure such as communication timeout. If the server sends a response, but it could not write the “Variable value, then it is shown in “Response code”.

7.4.2.2.3.5 Information report service – common format

7.4.2.2.3.5.1 Service overview

This service permits a master or slave to send the value of a variable. It is used to publish variable data, to send event information or to acknowledge event.

7.4.2.2.3.5.2 Service primitives

The service parameters for this service are shown in Table 71.

Table 71 – Information report service parameters

Parameter name	Req	Ind
Argument		
AREP ID	M	M (=)
Numeric Identifier	M	M (=)
Subindex	C	M (=)
Variable value	M	M (=)
Report Code	M	M (=)
Application process status	M	M (=)
Extended status	M	M (=)

Argument

The argument contains the parameters of the service request.

Numeric Identifier

This parameter identifies the variable. This is the key attribute assigned to the variable to be read. It is also called command number.

Subindex

This parameter identifies the individual element in an array variable by its position within the variable. This can be either a numeric value or an Enumeration.

Variable value

This parameter specifies the value reported from the server.

7.4.2.3 Action ASE

7.4.2.3.1 Service overview

This service permits a client to command a specified action of the server. The common format of Action service is defined in this clause. For every action, there is a separate service.

NOTE The service definitions in 7.4.2.3 are not independent of the action being requested. Subclause 7.4.2.3 only shows the format of the service. The service specific definitions include the action behavior and the service specific parameters.

7.4.2.3.2 Primitive correlation

At the client, there is only one outstanding request for one value of AREP ID. The AREP ID is conveyed as destination address in the transport layer service primitives. Therefore, the confirm primitive is correlated with the request primitive using AREP ID. At the server, there is only one outstanding indication primitive at any time. Therefore, the response primitive is correlated with the indication primitive waiting for the response.

7.4.2.3.3 Action model

7.4.2.3.3.1 General

Some of the actions require a variable to validate the action. The model for such actions is defined in this subclause.

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7.4.2.3.3.2 Formal model

ASE: **Simple Action**
PARENT CLASS: **TOP**
ATTRIBUTES:

1	(m)	Key Attribute:	Numeric Identifier

ASE: **Qualified Action**
PARENT CLASS: **TOP**
ATTRIBUTES:

1	(m)	Key Attribute:	Numeric Identifier
2	(m)	Attribute:	Qualifier Name
3	(m)	Attribute:	Data type Name

ASE: **Simple Variable Action**
PARENT CLASS: **TOP**
ATTRIBUTES:

1	(m)	Key Attribute:	Numeric Identifier
2	(m)	Attribute:	Variable Name
3	(m)	Attribute:	Data type Name

ASE: **Structure Variable Action**
PARENT CLASS: **TOP**
ATTRIBUTES:

1	(m)	Key Attribute:	Numeric Identifier
2	(m)	Attribute:	Variable Name
3	(m)	Attribute:	Number of Fields
4	(m)	Attribute:	List of Fields
4.1	(o)	Attribute:	Field Name
4.2	(m)	Attribute:	Field Data type Name

7.4.2.3.3.3 Attributes

See 7.4.2.2.2 for the definition of attributes.

7.4.2.3.4 Action service primitives – common format

The service parameters for this service are shown in Table 72.

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Table 72 – Action service parameters

Parameter name	Req	Ind	Rsp	Cnf
Argument				
AREP ID	M	M (=)		
Numeric Identifier	M	M (=)	M (=)	M (=)
Action qualifier	C	M (=)	M (=)	M (=)
Subindex	C	M (=)	M (=)	M (=)
Variable value	C	M (=)		
Result (+)				
Variable value			S	S (=)
Response Code			M	M (=)
Application process status			M	M (=)
Extended status			M	M (=)
Result (–)				
Status				S
Response Code			M	M (=)
Application process status			M	M (=)
Extended status			M	M (=)

Argument

The argument contains the parameters of the service request.

Numeric identifier

This parameter identifies the action. It is also called command number.

Action qualifier

For some of the Numeric Identifiers, this parameter provides additional information required to identify action to be performed. If the action requires a variable and if the Numeric identifier is not sufficient, then this parameter identifies that variable.

Subindex

If the action requires an array variable, then this parameter identifies the individual element in that array variable. This parameter can be either a numeric value of an Enumeration.

NOTE This parameter is present if the action is to add an element in the array or delete an element from the array.

Variable value

If the action requires a variable, then this parameter specifies the value of the variable. If the action is “add” then in the request parameter, this parameter specifies the desired value of the variable to be added; in the response primitive, this parameter states the actual value of the variable that was added.

Status

This parameter specifies the local reason for failure such as communication timeout. If the server sends a response, but it could not complete the action successfully, then it is shown in “Response code”.

7.4.2.4 Device application services

7.4.2.4.1 Read primary variable

This service is specified in IEC 61158-5-20:2014, 6.2.2.3.3.

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7.4.2.4.2 Read loop current and percent of range

This service is specified in IEC 61158-5-20:2014, 6.2.4.2.

7.4.2.4.3 Read dynamic variables and loop current

This service is specified in IEC 61158-5-20:2014, 6.2.4.3.

7.4.2.4.4 Write loop configuration

This service is specified in IEC 61158-5-20:2014, 6.2.4.4.

7.4.2.4.5 Read loop configuration

This service is specified in IEC 61158-5-20:2014, 6.2.4.5.

7.4.2.4.6 Read dynamic variable families classifications

This service is specified in IEC 61158-5-20:2014, 6.2.4.6.

7.4.2.4.7 Read device variables with status

This service is specified in IEC 61158-5-20:2014, 6.2.4.7.

7.4.2.4.8 Read message

This service is specified in IEC 61158-5-20:2014, 6.2.4.8.

7.4.2.4.9 Read tag, descriptor and date

This service is specified in IEC 61158-5-20:2014, 6.2.4.9.

7.4.2.4.10 Read primary variable transducer information

This service is specified in IEC 61158-5-20:2014, 6.2.4.10.

7.4.2.4.11 Read device information

This service is specified in IEC 61158-5-20:2014, 6.2.4.11.

7.4.2.4.12 Read final assembly number

This service is specified in IEC 61158-5-20:2014, 6.2.4.12.

7.4.2.4.13 Write message

This service is specified in IEC 61158-5-20:2014, 6.2.4.13.

7.4.2.4.14 Write tag, descriptor and date

This service is specified in IEC 61158-5-20:2014, 6.2.4.14.

7.4.2.4.15 Write final assembly number

This service is specified in IEC 61158-5-20:2014, 6.2.4.15.

7.4.2.4.16 Read long tag

This service is specified in IEC 61158-5-20:2014, 6.2.4.16.

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7.4.2.4.17 Write long tag

This service is specified in IEC 61158-5-20:2014, 6.2.4.17.

7.4.2.4.18 Reset configuration changed flag

7.4.2.4.18.1 Service overview

This service resets the “Configuration changed” bit associated with the client issuing this write service.

7.4.2.4.18.2 Request parameters

CLASS:		**Simple Variable Action**
ATTRIBUTES:		
1	Numeric Identifier	= 38
2	Variable Name	= Configuration change counter
3	Data type Name	= Unsigned16

7.4.2.4.19 Perform self test

7.4.2.4.19.1 Service overview

This service initiates the self test function in the device.

7.4.2.4.19.2 Request parameters

CLASS:		**Simple Action**
ATTRIBUTES:		
1	Numeric Identifier	= 41

7.4.2.4.20 Perform device reset

7.4.2.4.20.1 Service overview

This service initiates the self test function in the device.

7.4.2.4.20.2 Request parameters

CLASS:		**Simple Action**
ATTRIBUTES:		
1	Numeric Identifier	= 42

7.4.2.4.21 Read additional device status

7.4.2.4.21.1 Service overview

This service reads device status information not included in the Response code or Device status octet.

7.4.2.4.21.2 Variable model

There are three different Variable models depending upon the type of device. The device responds with only one of these three types of variables. If the device supports more than one Analog channel, then it supports “Additional device status 2”. Some of the devices may use “Additional device status 3”. All other devices support “Additional device status 1”.

CLASS:	**STRUCTURE VARIABLE**
ATTRIBUTES:	

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1 Numeric Identifier = 48
2 Variable name = Additional device status 1
3 Number of fields = variable
4 List of Fields
4.1 (m) Field name = Device specific status 0
4.2 (m) Field data type name = Bit Field
4.3 (m) Field name = Extended status
4.4 (m) Field data type name = Bit Field
4.5 (m) Field name = Device operating mode
4.6 (m) Field data type name = Bit Field
4.7 (m) Field name = Standardized status 0
4.8 (m) Field data type name = Bit Field

CLASS: STRUCTURE VARIABLE
ATTRIBUTES:
5 Numeric Identifier = 48
6 Variable name = Additional device status 2
7 Number of fields = variable
8 List of Fields
8.1 (m) Field name = Device specific status 0
8.2 (m) Field data type name = Bit Field
8.3 (m) Field name = Extended status
8.4 (m) Field data type name = Bit Field
8.5 (m) Field name = Device operating mode
8.6 (m) Field data type name = Bit Field
8.7 (m) Field name = Standardized status 0
8.8 (m) Field data type name = Bit Field
8.9 (m) Field name = Standardized status 1
8.10 (m) Field data type name = Bit Field
8.11 (m) Field name = Analog channel saturated
8.12 (m) Field data type name = Bit Field
8.13 (m) Field name = Standardized status 2
8.14 (m) Field data type name = Bit Field
8.15 (m) Field name = Standardized status 3
8.16 (m) Field data type name = Bit Field
8.17 (m) Field name = Analog channel fixed
8.18 (m) Field data type name = Bit Field

CLASS: STRUCTURE VARIABLE
ATTRIBUTES:
9 Numeric Identifier = 48
10 Variable name = Additional device status 3
11 Number of fields = variable
12 List of Fields
12.1 (m) Field name = Device specific status 0
12.2 (m) Field data type name = Bit Field
12.3 (m) Field name = Extended status
12.4 (m) Field data type name = Bit Field
12.5 (m) Field name = Device operating mode
12.6 (m) Field data type name = Bit Field
12.7 (m) Field name = Standardized status 0
12.8 (m) Field data type name = Bit Field
12.9 (m) Field name = Standardized status 1

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12.10 (m) Field data type name = Bit Field
12.11 (m) Field name = Analog channel saturated
12.12 (m) Field data type name = Bit Field
12.13 (m) Field name = Standardized status 2
12.14 (m) Field data type name = Bit Field
12.15 (m) Field name = Standardized status 3
12.16 (m) Field data type name = Bit Field
12.17 (m) Field name = Analog channel fixed
12.18 (m) Field data type name = Bit Field
12.19 (m) Field name = Device specific status 1
12.20 (m) Field Data type name = Array of Status

CLASS: **Data type**
ATTRIBUTES:
1 Data type Name = Array of Status
2 Format = ARRAY
2.1 Number of Array Elements = 1 to 11
2.2 Array Element Data type = Bit Field

7.4.2.4.22 Reset more status available

7.4.2.4.22.1 Service overview

This service resets the “More status available” bit corresponding to the requesting device (primary master, secondary master or gateway). The number of fields in the associated structure variable depends upon the server, and it is the minimum of 4 and the maximum of 10.

7.4.2.4.22.2 Request parameters

CLASS: **Structure Variable Action**
ATTRIBUTES:
1 Numeric Identifier 48
2 Variable Name = Additional device status
3 Number of fields = variable
4 List of Fields
4.1 (m) Field name = Device specific status 0
4.2 (m) Field data type name = Bit Field
4.3 (m) Field name = Extended status
4.4 (m) Field data type name = Bit Field
4.5 (m) Field name = Device operating mode
4.6 (m) Field data type name = Bit Field
4.7 (m) Field name = Standardized status 0
4.8 (m) Field data type name = Bit Field
4.9 (m) Field name = Standardized status 1
4.10 (m) Field data type name = Bit Field
4.11 (m) Field name = Analog channel saturated
4.12 (m) Field data type name = Bit Field
4.13 (m) Field name = Standardized status 2
4.14 (m) Field data type name = Bit Field
4.15 (m) Field name = Standardized status 3
4.16 (m) Field data type name = Bit Field
4.17 (m) Field name = Analog channel fixed
4.18 (m) Field data type name = Bit Field
4.19 (m) Field name = Device specific status 1

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4.20 (m) Data type = Array of status

CLASS: **Data type**
ATTRIBUTES:

1	Data type Name	= Array of Status
2	Format	= ARRAY
2.1	Number of Array Elements	= 1 to 11
2.2	Array Element Data type	= Bit Field

7.4.2.4.23 Read device variable information

7.4.2.4.23.1 Service overview

This service reads device variable related parameters.

7.4.2.4.23.2 Request parameters

1	Numeric Identifier	= 54
2	Subindex	
2.1	Subindex Name	= Variable code
2.2	Subindex Data type	= Unsigned8

7.4.2.4.23.3 Response parameters

1	Numeric Identifier	= 54
2	Subindex	
2.1	Subindex Name	= Variable code
2.2	Subindex Data type	= Unsigned8

7.4.2.4.23.4 Variable model

CLASS: **Array of Structure VARIABLE**
ATTRIBUTES:
Numeric Identifier = 54
Variable Name = Device variable information
Number of Fields = 9
List of Fields
Field Name = Transducer serial number
Field Data type Name = Unsigned24
Field Name = Transducer unit
Field Data type Name = Enumeration
Field Name = Upper transducer limit
Field Data type Name = Float32
Field Name = Lower transducer limit
Field Data type Name = Float32
Field Name = Damping value
Field Data type Name = Float32
Field Name = Minimum span
Field Data type Name = Float32
Field Name = Device variable classification
Field Data type Name = Enumeration
Field Name = Device variable family
Field Data type Name = Enumeration
Field Name = Update period

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Field Data type Name = Time
Array size = Variable

1 Numeric Identifier = 54
2 Variable Name = device variable information
3 Number of Fields = 9
4 List of Fields
4.1 Field Name = Transducer serial number
4.2 Field Data type Name = Unsigned24
4.3 Field Name = Transducer unit
4.4 Field Data type Name = Enumeration
4.5 Field Name = Upper Transducer limit
4.6 Field Data type Name = Float32
4.7 Field Name = Lower Transducer limit
4.8 Field Data type Name = Float32
4.9 Field Name = Damping value
4.10 Field Data type Name = Float32
4.11 Field Name = Minimum span
4.12 Field Data type Name = Float32
4.13 Field Name = device variable classification
4.14 Field Data type Name = Enumeration
4.15 Field Name = device variable family
4.16 Field Data type Name = Enumeration
4.17 Field Name = Update period
4.18 Field Data type Name = Time
5 Array size = variable

7.4.2.4.24 Write device variable

7.4.2.4.24.1 Service overview

This service allows a Device variable to be temporarily forced to a fixed value.

7.4.2.4.24.2 Request parameters

1 Numeric Identifier = 79
2 Subindex
2.1 Subindex Name = Variable code
2.2 Subindex Data type = Unsigned8

7.4.2.4.24.3 Response parameters

1 Numeric Identifier = 79
2 Subindex
2.1 Subindex Name = Variable code
2.2 Subindex Data type = Unsigned8

7.4.2.4.24.4 Variable model

CLASS: **Array of Structure VARIABLE**
ATTRIBUTES:
1 Numeric Identifier = 79
2 Variable Name = device variable record
3 Number of Fields = 4
4 List of Fields

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4.1 Field Name = device variable command
4.2 Field Data type Name = Enumeration
4.3 Field Name = device variable unit
4.4 Field Data type Name = Engineering unit
4.5 Field Name = device variable value
4.6 Field Data type Name = Float32
4.7 Field Name = device variable status
4.8 Field Data type Name = Bit Field
5 Array size = variable

7.4.2.4.25 Read real-time clock

7.4.2.4.25.1 Service overview

This service reads the Real-time clock including the current time as estimated by the device and the last time the clock was set.

7.4.2.4.25.2 Variable model

CLASS: STRUCTURE VARIABLE
ATTRIBUTES:
1 Numeric Identifier = 90
2 Variable Name = Real-Time clock
3 Number of Fields = 5
4 List of Fields
4.1 Field Name = Date
4.2 Field Data type Name = Date
4.3 Field Name = Current Time
4.4 Field Data type Name = Time
4.5 Field Name = Date last set
4.6 Field Data type Name = Date
4.7 Field Name = Time last set
4.8 Field Data type Name = Time
4.9 Field Name = RTC flags
4.10 Field Data type Name = Bit Field

7.4.2.4.26 Write publish data period

7.4.2.4.26.1 Service overview

This service selects the minimum and maximum update period of a publish data message.

7.4.2.4.26.2 Request parameters

1 Numeric Identifier = 103
2 Subindex
2.1 Subindex Name = Publish data message ref
2.2 Subindex Data type = Unsigned8

7.4.2.4.26.3 Response parameters

1 Numeric Identifier = 103
2 Subindex
2.1 Subindex Name = Publish data message ref
2.2 Subindex Data type = Unsigned8

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7.4.2.4.26.4 Variable model

CLASS: **Array of Structure VARIABLE**
ATTRIBUTES:
Numeric Identifier = 103
Variable Name = Publish data period
Number of Fields = 2
List of Fields
Field Name = Update period
Field Data type Name = Time
Field Name = Maximum update period
Field Data type Name = Time
Array size = Variable

7.4.2.4.27 Write publish data trigger

7.4.2.4.27.1 Service overview

This service configures the trigger that forces publishing of the Publish data message.

7.4.2.4.27.2 Request parameters

Numeric Identifier = 104
Subindex
Subindex Name = Publish data message ref
Subindex Data type = Unsigned8

7.4.2.4.27.3 Response parameters

Numeric Identifier = 104
Subindex
Subindex Name = Publish data message ref
Subindex Data type = Unsigned8

7.4.2.4.27.4 Variable model

CLASS: **Array of Structure VARIABLE**
ATTRIBUTES:
Numeric Identifier = 104
Variable Name = Publish data trigger
Number of Fields = 4
List of Fields
Field Name = Trigger mode
Field Data type Name = Enumeration
Field Name = Device variable classification
Field Data type Name = Enumeration
Field Name = Device variable unit
Field Data type Name = Engineering unit
Field Name = Trigger level
Field Data type Name = Float32
Array size = Variable

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7.4.2.4.28 Read publish data mode configuration

7.4.2.4.28.1 Service overview

This service reads the publish data mode configuration.

7.4.2.4.28.2 Request parameters

Numeric Identifier = 105
Subindex
Subindex Name = Publish data message ref
Subindex Data type = Unsigned8

7.4.2.4.28.3 Response parameters

Numeric Identifier = 105
Subindex
Subindex Name = Publish data message ref
Subindex Data type = Unsigned8

7.4.2.4.28.4 Variable model

CLASS: Array of Structure VARIABLE
ATTRIBUTES:
Numeric Identifier = 105
Variable Name = Publish data mode configuration
Number of Fields = 18
List of Fields
Field Name = Publish data mode control
Field Data type Name = Enumeration
Field Name = Command number expansion
Field Data type Name = Unsigned8
Field Name = Device variable code 0
Field Data type Name = Unsigned8
Field Name = Device variable code 1
Field Data type Name = Unsigned8
Field Name = Device variable code 2
Field Data type Name = Unsigned8
Field Name = Device variable code 3
Field Data type Name = Unsigned8
Field Name = Device variable code 4
Field Data type Name = Unsigned8
Field Name = Device variable code 5
Field Data type Name = Unsigned8
Field Name = Device variable code 6
Field Data type Name = Unsigned8
Field Name = Device variable code 7
Field Data type Name = Unsigned8
Field Name = Max publish count
Field Data type Name = Unsigned8
Field Name = Extended command number
Field Data type Name = Unsigned16
Field Name = Update period
Field Data type Name = Time
Field Name = Maximum update period

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Field Data type Name = Time
Field Name = Trigger mode
Field Data type Name = Enumeration
Field Name = Device variable classification
Field Data type Name = Enumeration
Field Name = Device variable unit
Field Data type Name = Engineering unit
Field Name = Trigger level
Field Data type Name = Float32
Array size = Variable

7.4.2.4.29 Flush delayed responses

7.4.2.4.29.1 Service overview

This command clears all pending delayed responses for the Master that issued the command.

7.4.2.4.29.2 Request parameters

CLASS: **Simple Action**
ATTRIBUTES:
Numeric Identifier = 106

7.4.2.4.30 Write publish data device variables

7.4.2.4.30.1 Service overview

This service selects the Device variables that shall be used by a publishing device in Publish data mode.

7.4.2.4.30.2 Request parameters

Numeric Identifier = 107
Subindex
Subindex Name = Publish data message ref
Subindex Data type = Unsigned8

7.4.2.4.30.3 Response parameters

Numeric Identifier = 107
Subindex
Subindex Name = Publish data message ref
Subindex Data type = Unsigned8

7.4.2.4.30.4 Variable model

CLASS: **Array of Structure VARIABLE**
ATTRIBUTES:
Numeric Identifier = 107
Variable Name = Publish data device variables
Number of Fields = 8
List of Fields
Field Name = Device variable code 0
Field Data type Name = Unsigned8
Field Name = Device variable code 1
Field Data type Name = Unsigned8
Field Name = Device variable code 2

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Field Data type Name = Unsigned8
Field Name = Device variable code 3
Field Data type Name = Unsigned8
Field Name = Device variable code 4
Field Data type Name = Unsigned8
Field Name = Device variable code 5
Field Data type Name = Unsigned8
Field Name = Device variable code 6
Field Data type Name = Unsigned8
Field Name = Device variable code 7
Field Data type Name = Unsigned8
Array size = Variable

7.4.2.4.31 Write publish data mode command number

7.4.2.4.31.1 Service overview

This service selects the response message that the publishing device transmits in Publish data mode.

7.4.2.4.31.2 Request parameters

Numeric Identifier = 108
Subindex
Subindex Name = Publish data message ref
Subindex Data type = Unsigned8

7.4.2.4.31.3 Response parameters

Numeric Identifier = 108
Subindex
Subindex Name = Publish data message ref
Subindex Data type = Unsigned8

7.4.2.4.31.4 Variable model

CLASS: Array of Simple VARIABLE
ATTRIBUTES:
Numeric Identifier = 108
Variable Name = Publish data mode command number
Data type Name = Unsigned16 / Unsigned8
Array size = Variable

7.4.2.4.32 Write publish data mode control

7.4.2.4.32.1 Service overview

This service is used to enable or disable the Publish data mode for devices.

7.4.2.4.32.2 Request parameters

Numeric Identifier = 109
Subindex
Subindex Name = Publish data message ref
Subindex Data type = Unsigned8

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7.4.2.4.32.3 Response parameters

Numeric Identifier = 109
Subindex
Subindex Name = Publish data message ref
Subindex Data type = Unsigned8

7.4.2.4.32.4 Variable model

CLASS: Array of Simple VARIABLE
ATTRIBUTES:
Numeric Identifier = 109
Variable Name = Publish data mode control
Data type Name = Enumeration
Array size = Variable

7.4.2.4.33 Read event notification summary

7.4.2.4.33.1 Service overview

This service reads the configuration of the Event Notification.

7.4.2.4.33.2 Request parameters

Numeric Identifier = 115
Subindex
Subindex Name = Event number ref
Subindex Data type = Unsigned8

7.4.2.4.33.3 Response parameters

Numeric Identifier = 115
Subindex
Subindex Name = Event number ref
Subindex Data type = Unsigned8

7.4.2.4.33.4 Variable model

CLASS: Array of Structure VARIABLE
ATTRIBUTES:
Numeric Identifier = 115
Variable Name = event notification summary
Number of Fields = 9
List of Fields
Field Name = Maximum event count
Field Data type Name = Unsigned8
Field Name = Event status
Field Data type Name = Bit Field
Field Name = Event notification control
Field Data type Name = Bit Field
Field Name = Event occurrence time
Field Data type Name = Time
Field Name = Event notification retry time
Field Data type Name = Time
Field Name = Maximum update time
Field Data type Name = Time

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Field Name = Event de-bounce interval
Field Data type Name = Time
Field Name = Device status mask
Field Data type Name = Bit Field
Field Name = Event mask
Field Data type Name = variable size array of Bit Field
Array size = Variable

7.4.2.4.34 Write event notification bit mask

7.4.2.4.34.1 Service overview

This service sets the Event mask that is used to trigger an Event notification.

7.4.2.4.34.2 Request parameters

Numeric Identifier = 116
Subindex
Subindex Name = Event number ref
Subindex Data type = Unsigned8

7.4.2.4.34.3 Response parameters

Numeric Identifier = 116
Subindex
Subindex Name = Event number ref
Subindex Data type = Unsigned8

7.4.2.4.34.4 Variable model

CLASS: Array of Simple VARIABLE
ATTRIBUTES:
Numeric Identifier = 116
Variable Name = Device status mask
Data type Name = Bit Field
Variable Name = event notification bit mask

7.4.2.4.35 Write event notification timing

7.4.2.4.35.1 Service overview

This service sets the timing parameters for event notification.

7.4.2.4.35.2 Request parameters

Numeric Identifier = 117
Subindex
Subindex Name = Event number ref
Subindex Data type = Unsigned8

7.4.2.4.35.3 Response parameters

Numeric Identifier = 117
Subindex
Subindex Name = Event number ref
Subindex Data type = Unsigned8

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7.4.2.4.35.4 Variable model

CLASS: **Array of Structure VARIABLE**
ATTRIBUTES:
Numeric Identifier = 117
Variable Name = Event notification timing
Number of Fields = 3
List of Fields
Field Name = Event notification retry time
Field Data type Name = Time
Field Name = Maximum update time
Field Data type Name = Time
Field Name = Event de-bounce interval
Field Data type Name = Time
Array size = Variable

7.4.2.4.36 Write event notification control

7.4.2.4.36.1 Service overview

This service is used to enable or disable the Event notification.

7.4.2.4.36.2 Request parameters

Numeric Identifier = 118
Subindex
Subindex Name = Event number ref
Subindex Data type = Unsigned8

7.4.2.4.36.3 Response parameters

Numeric Identifier = 118
Subindex
Subindex Name = Event number ref
Subindex Data type = Unsigned8

7.4.2.4.36.4 Variable model

CLASS: **Array of Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 118
Variable Name = Event notification control
Data type Name = Bit Field
Array size = Variable

7.4.2.4.37 Write event notification acknowledgement

7.4.2.4.37.1 Service overview

This service is used to acknowledge the Event Notification.

7.4.2.4.37.2 Request parameters

Numeric Identifier = 119
Subindex
Subindex Name = Event number ref
Subindex Data type = Unsigned8

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7.4.2.4.37.3 Response parameters

Numeric Identifier = 119
Subindex
Subindex Name = Event number ref
Subindex Data type = Unsigned8

7.4.2.4.37.4 Variable model

CLASS: **Array of Structure VARIABLE**
ATTRIBUTES:
Numeric Identifier = 119
Variable Name = Event notification acknowledgement
Number of Fields = 4
List of Fields
Field Name = Event occurrence time
Field Data type Name = Time
Field Name = Configuration change counter
Field Data type Name = Unsigned16
Field Name = Application process status
Field Data type Name = Bit Field
Field Name = Additional device status
Field Data type Name = See Note
Array size = Variable

The “Additional device status” is same as the entire Structure variable defined in 7.4.2.4.21.2.

7.4.2.5 Layer management services

7.4.2.5.1 Write Join_key

7.4.2.5.1.1 Service overview

This command modifies the devices Join_key. The command may be issued by the network manager or the entered via a local maintenance tool (for example a handheld).

7.4.2.5.1.2 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 768
Variable Name = Join_key
Data type Name = Security key

7.4.2.5.2 Read join status

7.4.2.5.2.1 Service overview

This service reads the field device status as it transitions through the joining process.

7.4.2.5.2.2 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 769
Variable Name = Join status

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Number of Fields = 7
List of Fields
Field Name = Wireless mode
Field Data type Name = Enumeration
Field Name = Join status
Field Data type Name = Bit Field
Field Name = Neighbors
Field Data type Name = Unsigned8
Field Name = Advertising packets
Field Data type Name = Unsigned8
Field Name = Max_join_retries
Field Data type Name = Unsigned8
Field Name = Join_rsp_time
Field Data type Name = Time
Field Name = Search time
Field Data type Name = Time

7.4.2.5.3 Write active_search_shed_time

7.4.2.5.3.1 Service overview

This command requests faster advertising. Generally, this is received locally by a network member from a local maintenance tool (for example a handheld) and is propagated to the network manager.

7.4.2.5.3.2 Request variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 770
Variable Name = Active_search_shed_time
Data type Name = Time

7.4.2.5.3.3 Response variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 770
Variable Name = Shed_time
Number of Fields = 3
List of Fields
Variable Name = Active_search_shed_time
Data type Name = Time
Variable Name = Advertise_time
Data type Name = Time
Field Name = Neighbors
Field Data type Name = Unsigned8

7.4.2.5.4 Write join mode configuration

7.4.2.5.4.1 Service overview

This command allows a host system or handheld device to force a field device into active join mode.

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7.4.2.5.4.2 Variable model

CLASS:	**STRUCTURE VARIABLE**
ATTRIBUTES:	
Numeric Identifier	= 771
Variable Name	= Join mode configuration
Number of Fields	= 3
List of Fields	
Field Name = Join mode	
Field Data type Name	= Enumeration
Variable Name	= Active_search_shed_time
Data type Name	= Time
Variable Name	= max_join_retries
Data type Name	= Unsigned8

7.4.2.5.5 Read join mode configuration

7.4.2.5.5.1 Service overview

This command reads the Join mode configuration from a network device.

7.4.2.5.5.2 Variable model

CLASS:	**STRUCTURE VARIABLE**
ATTRIBUTES:	
Numeric Identifier	= 772
Variable Name	= Join mode configuration
Number of Fields	= 3
List of Fields	
Field Name = Join mode	
Field Data type Name	= Enumeration
Variable Name	= Active_search_shed_time
Data type Name	= Time
Variable Name	= max_join_retries
Data type Name	= Unsigned8

7.4.2.5.6 Write network_ID

7.4.2.5.6.1 Service overview

This command configures the device to recognize the proper Network_ID. This command should only be issued by the network manager or via the maintenance port. The device receiving this command is required to reject this command from any other source.

7.4.2.5.6.2 Request variable model

CLASS:	**Simple VARIABLE**
ATTRIBUTES:	
Numeric Identifier	= 773
Variable Name	= new Network_ID
Data type Name	= Unsigned16

7.4.2.5.6.3 Response variable model

CLASS:	**Simple VARIABLE**
ATTRIBUTES:	
Numeric Identifier	= 773

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Variable Name = new Network_ID
Data type Name = Unsigned16
Variable Name = current Network_ID
Data type Name = Unsigned16

7.4.2.5.7 Read network_ID

7.4.2.5.7.1 Service overview

This command reads the current setting of the Network_ID in a device.

7.4.2.5.7.2 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 774
Variable Name = new Network_ID
Data type Name = Unsigned16
Variable Name = current Network_ID
Data type Name = Unsigned16

7.4.2.5.8 Write network_tag

7.4.2.5.8.1 Service overview

This command writes the tag for the network. The Network_tag is a proxy for the network_ID, so that the network can be identified in a text form at the application level. The same Network_tag should be written to devices in the same network.

7.4.2.5.8.2 Variable model

CLASS: **String VARIABLE**
ATTRIBUTES:
Numeric Identifier = 775
Variable Name = Network_tag
Data type Name = Latin-1
Octet Length = 32

7.4.2.5.9 Read network_tag

7.4.2.5.9.1 Service overview

This command reads the current setting of the tag of the network.

7.4.2.5.9.2 Variable model

CLASS: **String VARIABLE**
ATTRIBUTES:
Numeric Identifier = 776
Variable Name = Network_tag
Data type Name = Latin-1
Octet Length = 32

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7.4.2.5.10 Read wireless device capabilities

7.4.2.5.10.1 Service overview

This service is used to determine operational characteristics of a network device. The network manager is expected to use Peak packet rate and Recovery time to accommodate rechargeable or power scavenging devices.

7.4.2.5.10.2 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 777
Variable Name = Wireless device capabilities
Number of Fields = 8
List of Fields
Field Name = Power source
Field Data type Name = Enumeration
Field Name = Peak packet rate
Field Data type Name = Float32
Field Name = Load duration
Field Data type Name = Time
Field Name = Recovery time
Field Data type Name = Time
Field Name = Good RSL
Field Data type Name = Integer8
Field Name = Min Keep_alive_time
Field Data type Name = Time
Field Name = Neighbor count
Field Data type Name = Unsigned16
Field Name = Packet buffer
Field Data type Name = Unsigned16

7.4.2.5.11 Read battery life

7.4.2.5.11.1 Service overview

This service reads the current state of the battery in a network device.

7.4.2.5.11.2 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 778
Variable Name = Battery life
Data type Name = Unsigned16

7.4.2.5.12 Report device health

7.4.2.5.12.1 Service overview

This command response is periodically published by the field device.

7.4.2.5.12.2 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:

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Numeric Identifier = 779
Variable Name = Device health
Number of Fields = 14
List of Fields
Field Name = Packets generated
Field Data type Name = Unsigned16
Field Name = Packets terminated
Field Data type Name = Unsigned16
Field Name = DLL MIC failures
Field Data type Name = Unsigned8
Field Name = NL MIC failures
Field Data type Name = Unsigned8
Field Name = Power status
Field Data type Name = Enumeration
Field Name = CRC errors
Field Data type Name = Unsigned8
Field Name = Packets missed
Field Data type Name = Unsigned8
Field Name = Maximum buffer queue
Field Data type Name = Unsigned8
Field Name = Average buffer queue
Field Data type Name = Float32
Field Name = Average latency
Field Data type Name = Time
Field Name = Variance of latency
Field Data type Name = Time
Field Name = Packets received
Field Data type Name = Unsigned32
Field Name = Packets late or lost
Field Data type Name = Unsigned32
Field Name = Unknown session
Field Data type Name = Unsigned8

7.4.2.5.13 Read neighbor health list

7.4.2.5.13.1 Service overview

This service reads the entries in the Neighbor table from the network device.

7.4.2.5.13.2 Request parameters

Numeric Identifier = 780
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned8
Element count
Element count Name = Entry count
Element count Data type = Unsigned8

7.4.2.5.13.3 Response parameters

Numeric Identifier = 780
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned8

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Element count
Element count Name = Entry count
Element count Data type = Unsigned8
Array size
Array size Name = Neighbor count
Array size Data type = Unsigned8

7.4.2.5.13.4 Variable model

CLASS: Array of Structure VARIABLE
ATTRIBUTES:
Numeric Identifier = 780
Variable Name = Neighbor health
Number of Fields = 6
List of Fields
Field Name = Neighbor_nickname
Field Data type Name = Unsigned16
Field Name = Neighbor flags
Field Data type Name = Bit Field
Field Name = Average_RSL
Field Data type Name = Integer8
Field Name = Packets_transmitted
Field Data type Name = Unsigned16
Field Name = Missed_ACK_packets
Field Data type Name = Unsigned16
Field Name = Packets_received
Field Data type Name = Unsigned16
Array size = Variable

7.4.2.5.14 Read device nickname

7.4.2.5.14.1 Service overview

This service reads a network device's nickname (short address).

7.4.2.5.14.2 Variable model

CLASS: Simple VARIABLE
ATTRIBUTES:
Numeric Identifier = 781
Variable Name = Device nickname
Data type Name = Unsigned16

7.4.2.5.15 Read session list

7.4.2.5.15.1 Service overview

This service reads the entries in the Session table from the network device.

7.4.2.5.15.2 Request parameters

Numeric Identifier = 782
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned8
Element count

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Element count Name = Entry count
Element count Data type = Unsigned8

7.4.2.5.15.3 Response parameters

Numeric Identifier = 782
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned8
Element count
Element count Name = Entry count
Element count Data type = Unsigned8
Array size
Array size Name = Session count
Array size Data type = Unsigned8

7.4.2.5.15.4 Variable model

CLASS: Array of Structure VARIABLE
ATTRIBUTES:
Numeric Identifier = 782
Variable Name = Session
Number of Fields = 5
List of Fields
Field Name = Session_type
Field Data type Name = Enumeration
Field Name = Peer_nickname
Field Data type Name = Unsigned16
Field Name = Peer_unique_ID
Field Data type Name = Unique ID
Field Name = Peer_nonce_counter
Field Data type Name = Unsigned32
Field Name = My_nonce_counter
Field Data type Name = Unsigned32
Array size = Variable

7.4.2.5.16 Read superframe list

7.4.2.5.16.1 Service overview

This service reads the entries in the superframe table from the network device.

7.4.2.5.16.2 Request parameters

Numeric Identifier = 783
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned8
Element count
Element count Name = Entry count
Element count Data type = Unsigned8

7.4.2.5.16.3 Response parameters

Numeric Identifier = 783
Subindex

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Subindex Name = Table index
Subindex Data type = Unsigned8
Element count
Element count Name = Entry count
Element count Data type = Unsigned8
Array size
Array size Name = Superframe count
Array size Data type = Unsigned8

7.4.2.5.16.4 Variable model

CLASS: Array of Structure VARIABLE
ATTRIBUTES:
Numeric Identifier = 783
Variable Name = Superframe
Number of Fields = 3
List of Fields
Field Name = Superframe_ID
Field Data type Name = Unsigned8
Field Name = Num_Slots
Field Data type Name = Unsigned16
Field Name = Superframe mode
Field Data type Name = Bit Field
Array size = Variable

7.4.2.5.17 Read link list

7.4.2.5.17.1 Service overview

This service reads the entries in the Link table from the network device.

7.4.2.5.17.2 Request parameters

Numeric Identifier = 784
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned16
Element count
Element count Name = Entry count
Element count Data type = Unsigned8

7.4.2.5.17.3 Response parameters

Numeric Identifier = 784
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned16
Element count
Element count Name = Entry count
Element count Data type = Unsigned8
Array size
Array size Name = Link count
Array size Data type = Unsigned16

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7.4.2.5.17.4 Variable model

CLASS: **Array of Structure VARIABLE**
ATTRIBUTES:
Numeric Identifier = 784
Variable Name = Link
Number of Fields = 6
List of Fields
Field Name = Link_ID
Field Data type Name = Unsigned8
Field Name = Slot
Field Data type Name = Unsigned16
Field Name = Channel_Offset
Field Data type Name = Unsigned8
Field Name = Neighbor_nickname
Field Data type Name = Unsigned16
Field Name = Link options
Field Data type Name = Bit Field
Field Name = Link_type
Field Data type Name = Enumeration
Array size = Variable

7.4.2.5.18 Read graph list

7.4.2.5.18.1 Service overview

This service reads one item in the Graph table from the network device.

7.4.2.5.18.2 Request parameters

Numeric Identifier = 785
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned8

7.4.2.5.18.3 Response parameters

Numeric Identifier = 785
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned8
Array size
Array size Name = Graph count
Array size Data type = Unsigned8

7.4.2.5.18.4 Response variable model

CLASS: **Array of Structure VARIABLE**
ATTRIBUTES:
Numeric Identifier = 785
Variable Name = Graph
Number of Fields = 3
List of Fields
Field Name = Graph_ID
Field Data type Name = Unsigned16
Field Name = Neighbor count

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Field Data type Name = Unsigned8
Field Name = Neighbor list
Field Data type Name = Array of Neighbor_nickname
Array size = Variable

CLASS: **Data type**
ATTRIBUTES:
Data type Name = Array of Neighbor_nickname
Format = ARRAY
Number of Array Elements = value of Neighbor count
Array Element Data type = Unsigned16

7.4.2.5.19 Read neighbor attribute flag

7.4.2.5.19.1 Service overview

This command reads the attributes of a neighbor from the network device.

7.4.2.5.19.2 Request parameters

Numeric Identifier = 786
Additional Identifier
Name = Neighbor_nickname
Data type = Unsigned8

7.4.2.5.19.3 Response parameters

Numeric Identifier = 786
Additional Identifier
Name = Neighbor_nickname
Data type = Unsigned8

7.4.2.5.19.4 Response variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 786
Variable Name = Neighbor flags
Data type Name = Bit Field

7.4.2.5.20 Read neighbor signal level

7.4.2.5.20.1 Service overview

This service reads the signal level in the Neighbor table from the network device.

7.4.2.5.20.2 Request parameters

Numeric Identifier = 787
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned16
Element count
Element count Name = Entry count
Element count Data type = Unsigned8

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7.4.2.5.20.3 Response parameters

Numeric Identifier = 787
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned16
Element count
Element count Name = Entry count
Element count Data type = Unsigned8
Array size
Array size Name = Neighbor count
Array size Data type = Unsigned16

7.4.2.5.20.4 Variable model

CLASS: Array of Structure VARIABLE
ATTRIBUTES:
Numeric Identifier = 787
Variable Name = Neighbor signal level
Number of Fields = 2
List of Fields
Field Name = Neighbor_nickname
Field Data type Name = Unsigned16
Field Name = Average_RSL
Field Data type Name = Integer8
Array size = Variable

7.4.2.5.21 Report path down alarm

7.4.2.5.21.1 Service overview

The device publishes the path down alarm response using this service.

7.4.2.5.21.2 Variable model

CLASS: Simple VARIABLE
ATTRIBUTES:
Numeric Identifier = 788
Variable Name = Neighbor_nickname
Data type Name = Unsigned16

7.4.2.5.22 Report source route failed alarm

7.4.2.5.22.1 Service overview

The device publishes the source route failed alarm response using this service.

7.4.2.5.22.2 Variable model

CLASS: STRUCTURE VARIABLE
ATTRIBUTES:
Numeric Identifier = 789
Variable Name = Source route failure
Number of Fields = 2
List of Fields
Field Name = Unreachable neighbor
Field Data type Name = Unsigned16

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Field Name = NL MIC
Field Data type Name = Unsigned32

7.4.2.5.23 Report graph route failed alarm

7.4.2.5.23.1 Service overview

The device publishes the graph route failed alarm response using this service.

7.4.2.5.23.2 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 790
Variable Name = Graph_ID
Data type Name = Unsigned16

7.4.2.5.24 Report transport layer failed alarm

7.4.2.5.24.1 Service overview

The device publishes the transport layer failed alarm response using this service.

7.4.2.5.24.2 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 791
Variable Name = Unreachable peer
Data type Name = Unsigned16

7.4.2.5.25 Write UTC time mapping

7.4.2.5.25.1 Service overview

This service sets the start of ASN zero time to the time in this request, in a network device.

7.4.2.5.25.2 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 793
Variable Name = UTC time mapping
Number of Fields = 2
List of Fields
Field Name = Date
Field Data type Name = Date
Variable Name = Time of day
Data type Name = Time

7.4.2.5.26 Read UTC time mapping

7.4.2.5.26.1 Service overview

This service reads the UTC time when the ASN zero started, as set in the network device.

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7.4.2.5.26.2 Variable model

CLASS:	**STRUCTURE VARIABLE**
ATTRIBUTES:	
Numeric Identifier	= 794
Variable Name	= UTC time mapping
Number of Fields	= 2
List of Fields	
Field Name	= Date
Field Data type Name	= Date
Variable Name	= Time of day
Data type Name	= Time

7.4.2.5.27 Write timer interval

7.4.2.5.27.1 Service overview

This service sets the time interval for the timer specified by Timer_type in a network device.

7.4.2.5.27.2 Variable model

CLASS:	**STRUCTURE VARIABLE**
ATTRIBUTES:	
Numeric Identifier	= 795
Variable Name	= Interval
Number of Fields	= 2
List of Fields	
Variable Name	= Timer_type
Data type Name	= Enumeration
Field Name	= Timer interval
Field Data type Name	= Unsigned32

7.4.2.5.28 Read timer interval

7.4.2.5.28.1 Service overview

This service reads the time interval for the timer specified by Timer_type from a network device.

7.4.2.5.28.2 Request variable model

CLASS:	**Simple VARIABLE**
ATTRIBUTES:	
Numeric Identifier	= 796
Variable Name	= Timer_type
Data type Name	= Enumeration

7.4.2.5.28.3 Response variable model

CLASS:	**STRUCTURE VARIABLE**
ATTRIBUTES:	
Numeric Identifier	= 796
Variable Name	= Interval
Data type Name	= Enumeration
Number of Fields	= 2

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List of Fields
Variable Name = Timer_type
Data type Name = Enumeration
Field Name = Timer interval
Field Data type Name = Unsigned32

7.4.2.5.29 Write radio power output

7.4.2.5.29.1 Service overview

This service sets the radio power output for a device or gateway.

7.4.2.5.29.2 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 797
Variable Name = Transmit power
Data type Name = Integer8

7.4.2.5.30 Read radio power output

7.4.2.5.30.1 Service overview

This service reads the radio power output from a device or gateway.

7.4.2.5.30.2 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 798
Variable Name = Transmit power
Data type Name = Integer8

7.4.2.5.31 Request timetable

7.4.2.5.31.1 Service overview

This service is used by a wireless device to add a service connection to another wireless device with specified bandwidth and latency characteristics.

7.4.2.5.31.2 Request variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 799
Variable Name = Timetable
Number of Fields = 5
List of Fields
Field Name = Timetable_ID
Field Data type Name = Unsigned8
Field Name = Timetable_type
Field Data type Name = Bit Field
Field Name = Application domain
Field Data type Name = Enumeration
Field Name = Peer_nickname
Field Data type Name = Unsigned16

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Variable Name = Duration
Data type Name = Time

7.4.2.5.31.3 Response variable model

CLASS: STRUCTURE VARIABLE
ATTRIBUTES:
Numeric Identifier = 799
Variable Name = Timetable
Number of Fields = 6
List of Fields
Field Name = Timetable_ID
Field Data type Name = Unsigned8
Field Name = Timetable_type
Field Data type Name = Bit Field
Field Name = Application domain
Field Data type Name = Enumeration
Field Name = Peer_nickname
Field Data type Name = Unsigned16
Variable Name = Duration
Data type Name = Time
Variable Name = Route_ID
Data type Name = Unsigned8

7.4.2.5.32 Read timetable list

7.4.2.5.32.1 Service overview

This service reads the entries in the Timetable table from the network device.

7.4.2.5.32.2 Request parameters

Numeric Identifier = 800
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned8
Element count
Element count Name = Entry count
Element count Data type = Unsigned8

7.4.2.5.32.3 Response parameters

Numeric Identifier = 800
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned8
Element count
Element count Name = Entry count
Element count Data type = Unsigned8
Array size
Array size Name = Timetable count
Array size Data type = Unsigned8

7.4.2.5.32.4 Variable model

CLASS: Array of Structure VARIABLE

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ATTRIBUTES:
Numeric Identifier = 800
Variable Name = Timetable
Number of Fields = 6
List of Fields
Field Name = Timetable_ID
Field Data type Name = Unsigned8
Field Name = Timetable_type
Field Data type Name = Bit Field
Field Name = Application domain
Field Data type Name = Enumeration
Field Name = Peer_nickname
Field Data type Name = Unsigned16
Field Name = Service_duration
Field Data type Name = Time
Field Name = Route_ID
Field Data type Name = Unsigned8
Array size = Variable

7.4.2.5.33 Delete timetable connection

7.4.2.5.33.1 Service overview

This service notifies a device of Timetable deletion.

7.4.2.5.33.2 Request parameters

CLASS: **Qualified Action**
ATTRIBUTES:
Numeric Identifier = 801
Variable name = Timetable_ID
Data type name = Unsigned8
Qualifier Name = Reason
Data type Name = Enumeration

7.4.2.5.33.3 Response parameters

CLASS: **Qualified Action**
ATTRIBUTES:
Numeric Identifier = 801
Variable name = Timetable_ID
Data type name = Unsigned8
Qualifier Name = Reason
Data type Name = Enumeration

7.4.2.5.33.4 Response variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 801
Variable Name = Timetable count
Data type Name = Unsigned8

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7.4.2.5.34 Read route list

7.4.2.5.34.1 Service overview

This service reads the entries in the Route table from the network device.

7.4.2.5.34.2 Request parameters

Numeric Identifier = 802
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned8
Element count
Element count Name = Entry count
Element count Data type = Unsigned8

7.4.2.5.34.3 Response parameters

Numeric Identifier = 802
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned8
Element count
Element count Name = Entry count
Element count Data type = Unsigned8
Array size
Array size Name = Route count
Array size Data type = Unsigned8

7.4.2.5.34.4 Variable model

CLASS: Array of Structure VARIABLE
ATTRIBUTES:
Numeric Identifier = 802
Variable Name = Route
Number of Fields = 5
List of Fields
Field Name = Routes remaining
Field Data type Name = Unsigned8
Field Name = Route_ID
Field Data type Name = Unsigned8
Field Name = Destination nickname
Field Data type Name = Unsigned16
Field Name = Graph_ID
Field Data type Name = Unsigned16
Field Name = Source route flag
Field Data type Name = Unsigned8
Array size = Variable

7.4.2.5.35 Read source route

7.4.2.5.35.1 Service overview

This service reads the contents of a particular Source route.

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7.4.2.5.35.2 Request parameters

Numeric Identifier = 803
Additional Identifier
Name = Route_ID
Data type = Unsigned8

7.4.2.5.35.3 Response parameters

Numeric Identifier = 803
Additional Identifier
Name = Route_ID
Data type = Unsigned8

7.4.2.5.35.4 Variable model

CLASS: STRUCTURE VARIABLE
ATTRIBUTES:
Numeric Identifier = 803
Variable Name = Source route
Number of Fields = 2
List of Fields
Field Name = Hop count
Field Data type Name = Unsigned8
Field Name = Hop list
Field Data type name = Array of Hop

CLASS: Data type
ATTRIBUTES:
Data type Name = Array of Hop
Format = ARRAY
Number of Array Elements = value of Hop count
Array Element Data type = Unsigned16

7.4.2.5.36 Read CCA mode

7.4.2.5.36.1 Service overview

This service reads the Clear Channel Assessment (CCA) mode from a network device.

7.4.2.5.36.2 Variable model

CLASS: Simple VARIABLE
ATTRIBUTES:
Numeric Identifier = 804
Variable Name = CCA mode
Data type Name = Enumeration

7.4.2.5.37 Write CCA mode

7.4.2.5.37.1 Service overview

This service writes the Clear Channel Assessment (CCA) mode in a network device.

7.4.2.5.37.2 Variable model

CLASS: Simple VARIABLE

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ATTRIBUTES:
Numeric Identifier = 805
Variable Name = CCA mode
Data type Name = Enumeration

7.4.2.5.38 Read handheld superframe

7.4.2.5.38.1 Service overview

This service is used to determine if the handheld superframe in a network device is enabled.

7.4.2.5.38.2 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 806
Variable Name = Superframe
Number of Fields = 3
List of Fields
Field Name = Superframe_ID
Field Data type Name = Unsigned8
Field Name = Num_Slots
Field Data type Name = Unsigned16
Field Name = Superframe mode
Field Data type Name = Bit Field

7.4.2.5.39 Write handheld superframe

7.4.2.5.39.1 Service overview

This service allows a handheld device to request that a network device enables the handheld superframe, so that maintenance can be done.

7.4.2.5.39.2 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 807
Variable Name = Superframe
Number of Fields = 2
List of Fields
Field Name = Superframe_ID
Field Data type Name = Unsigned8
Field Name = Superframe mode
Field Data type Name = Bit Field

7.4.2.5.40 Read packet hop-to-live

7.4.2.5.40.1 Service overview

This service reads the current value of Hop-to-live configured for a network device.

7.4.2.5.40.2 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 808

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Variable Name = Hop-to-live
Data type Name = Unsigned8

7.4.2.5.41 Write packet hop-to-live

7.4.2.5.41.1 Service overview

This service writes the Hop-to-live value in a network device.

7.4.2.5.41.2 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 809
Variable Name = Hop-to-live
Data type Name = Unsigned8

7.4.2.5.42 Read join_priority

7.4.2.5.42.1 Service overview

This service reads the current value of Join_priority from a network device.

7.4.2.5.42.2 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 810
Variable Name = Join_priority
Data type Name = Unsigned8

7.4.2.5.43 Write join_priority

7.4.2.5.43.1 Service overview

This service writes the Join_priority value in a network device.

7.4.2.5.43.2 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 811
Variable Name = Join_priority
Data type Name = Unsigned8

7.4.2.5.44 Read receive Priority_threshold

7.4.2.5.44.1 Service overview

This service reads the current value of Receive Priority_threshold from a network device.

7.4.2.5.44.2 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 812
Variable Name = Priority_threshold
Data type Name = Unsigned8

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7.4.2.5.45 Write receive Priority_threshold

7.4.2.5.45.1 Service overview

This service writes the Receive Priority_threshold value in a network device.

7.4.2.5.45.2 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 813
Variable Name = Priority_threshold
Data type Name = Unsigned8

7.4.2.5.46 Read device list

7.4.2.5.46.1 Service overview

This service reads the entries in the Device table for the type of list specified by Device code in the request.

7.4.2.5.46.2 Request parameters

Numeric Identifier = 814
Additional Identifier
Name = Device code
Data type = Enumeration
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned16
Element count
Element count Name = Entry count
Element count Data type = Unsigned8

7.4.2.5.46.3 Response parameters

Numeric Identifier = 802
Additional Identifier
Name = Device code
Data type = Enumeration
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned16
Element count
Element count Name = Entry count
Element count Data type = Unsigned8
Array size
Array size Name = Device count
Array size Data type = Unsigned16

7.4.2.5.46.4 Variable model

CLASS: **Array of Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 814
Variable Name = Device list

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Data type Name	= Unique ID
Array size	= Variable

7.4.2.5.47 Add device list entry

7.4.2.5.47.1 Service overview

This service adds a device in the Device table for the type of list specified by Device code.

7.4.2.5.47.2 Request parameters

CLASS:	**Qualified Action**
ATTRIBUTES:	
Numeric Identifier	= 815
Variable name	= Device code
Data type name	= Enumeration
Qualifier Name	= Unique ID
Data type Name	= Unique ID

7.4.2.5.47.3 Response parameters

CLASS:	**Qualified Action**
ATTRIBUTES:	
Numeric Identifier	= 815
Variable name	= Device code
Data type name	= Enumeration
Qualifier Name	= Unique ID
Data type Name	= Unique ID

7.4.2.5.47.4 Response variable model

CLASS:	**Simple VARIABLE**
ATTRIBUTES:	
Numeric Identifier	= 815
Variable Name	= Device count
Data type Name	= Unsigned16

7.4.2.5.48 Delete device list entry

7.4.2.5.48.1 Service overview

This service deletes a device in the Device table for the type of list specified by Device code in a gateway or network manager.

7.4.2.5.48.2 Request parameters

CLASS:	**Qualified Action**
ATTRIBUTES:	
Numeric Identifier	= 816
Variable name	= Device code
Data type name	= Enumeration
Qualifier Name	= Unique ID
Data type Name	= Unique ID

7.4.2.5.48.3 Response parameters

CLASS:	**Qualified Action**

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ATTRIBUTES:
Numeric Identifier = 816
Variable name = Device code
Data type name = Enumeration
Qualifier Name = Unique ID
Data type Name = Unique ID

7.4.2.5.48.4 Response variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 816
Variable Name = Device count
Data type Name = Unsigned16

7.4.2.5.49 Read channel blacklist

7.4.2.5.49.1 Service overview

This service reads the current channel blacklist and the blacklist that shall be used after the next restart.

7.4.2.5.49.2 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 817
Variable Name = Channel blacklist
Number of Fields = 3
List of Fields
Field Name = Channel count
Field Data type Name = Unsigned8
Field Name = Current channel map
Field Data type Name = Bit Field
Field Name = Pending channel map
Field Data type Name = Bit Field

7.4.2.5.50 Write channel blacklist

7.4.2.5.50.1 Service overview

This service writes the pending channel map, which is the blacklist to the gateway. It is used after the next restart.

7.4.2.5.50.2 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 818
Variable Name = Channel blacklist
Number of Fields = 2
List of Fields
Field Name = Channel count
Field Data type Name = Unsigned8
Field Name = Pending channel map
Field Data type Name = Bit Field

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7.4.2.5.51 Read back-off exponent

7.4.2.5.51.1 Service overview

This service reads the current value of Max_backoff_exp from a network device.

7.4.2.5.51.2 Variable model

CLASS:	**Simple VARIABLE**
ATTRIBUTES:	
Numeric Identifier	= 819
Variable Name	= Max_backoff_exp
Data type Name	= Unsigned8

7.4.2.5.52 Write back-off exponent

7.4.2.5.52.1 Service overview

This service writes the Max_backoff_exp value in a network device.

7.4.2.5.52.2 Variable model

CLASS:	**Simple VARIABLE**
ATTRIBUTES:	
Numeric Identifier	= 820
Variable Name	= Max_backoff_exp
Data type Name	= Unsigned8

7.4.2.5.53 Write network access mode

7.4.2.5.53.1 Service overview

This service writes the network access mode value in a network device.

7.4.2.5.53.2 Variable model

CLASS:	**Simple VARIABLE**
ATTRIBUTES:	
Numeric Identifier	= 821
Variable Name	= Network access mode
Data type Name	= Enumeration

7.4.2.5.54 Read network access mode

7.4.2.5.54.1 Service overview

This service reads the current value of network access mode from a network device.

7.4.2.5.54.2 Variable model

CLASS:	**Simple VARIABLE**
ATTRIBUTES:	
Numeric Identifier	= 822
Variable Name	= Network access mode
Data type Name	= Enumeration

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7.4.2.5.55 Request session

7.4.2.5.55.1 Service overview

This service requests a unicast session from a handheld to a device.

7.4.2.5.55.2 Request parameters

Numeric Identifier = 823
Additional Identifier
Name = Peer_nickname
Data type = Unsigned16

7.4.2.5.55.3 Response parameters

Numeric Identifier = 823
Additional Identifier
Name = Peer_nickname
Data type = Unsigned16

7.4.2.5.55.4 Variable model

CLASS: STRUCTURE VARIABLE
ATTRIBUTES:
Numeric Identifier = 823
Variable Name = Session
Number of Fields = 2
List of Fields
Field Name = Peer_nonce_counter
Field Data type Name = Unsigned32
Field Name = Join_key
Field Data type Name = Security key

7.4.2.6 Gateway and network manager services

7.4.2.6.1 Read network device identity using Unique ID

7.4.2.6.1.1 Service overview

This service reads the identity information of the device with matching Device ID from the gateway.

7.4.2.6.1.2 Request parameters

Numeric Identifier = 832
Additional Identifier
Name = Unique ID
Data type = Unique ID

7.4.2.6.1.3 Response parameters

Numeric Identifier = 832
Additional Identifier
Name = Unique ID
Data type = Unique ID

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7.4.2.6.1.4 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 832
Variable Name = Device identity
Number of Fields = 2
List of Fields
Field Name = Device nickname
Field Data type Name = Unsigned16
Field Name = Long_tag
Field Data type Name = Latin-1
Octet Length = 32

7.4.2.6.2 Read device's neighbor health

7.4.2.6.2.1 Service overview

This service reads from the gateway, information regarding the quality of the connection to each active neighbor or potential neighbor for the device specified in the request.

7.4.2.6.2.2 Request parameters

Numeric Identifier = 833
Additional Identifier
Name = Unique ID
Data type = Unique ID
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned8
Element count
Element count Name = Entry count
Element count Data type = Unsigned8

7.4.2.6.2.3 Response parameters

Numeric Identifier = 833
Additional Identifier
Name = Unique ID
Data type = Unique ID
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned8
Element count
Element count Name = Entry count
Element count Data type = Unsigned8

7.4.2.6.2.4 Variable model

CLASS: **Array of Structure VARIABLE**
ATTRIBUTES:
Numeric Identifier = 833
Variable Name = Neighbor health
Number of Fields = 5
List of Fields
Field Name = Neighbor_nickname

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Field Data type Name = Unsigned16
Field Name = Average_RSL
Field Data type Name = Integer8
Field Name = Packets_transmitted
Field Data type Name = Unsigned32
Field Name = Missed_ACK_packets
Field Data type Name = Unsigned32
Field Name = Packets_received
Field Data type Name = Unsigned32
Field Name = Neighbor flags
Field Data type Name = Bit Field
Array size = Variable

7.4.2.6.3 Read network topology information

7.4.2.6.3.1 Service overview

This service reads one item in the Graph table for the specified network device from the gateway. By reading the device list using the Read device list service, Command 814, the application layer can determine how many graphs a particular device is participating in by using “Read graph list” (see 7.4.2.5.18). This service can then be issued as many times as needed to determine the specific Graph_IDs that the device is participating in.

7.4.2.6.3.2 Request parameters

Numeric Identifier = 834
Additional Identifier
Name = Unique ID
Data type = Unique ID
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned16

7.4.2.6.3.3 Response parameters

Numeric Identifier = 834
Additional Identifier
Name = Unique ID
Data type = Unique ID
Subindex
Subindex Name = Table index
Subindex Data type = Unsigned16
Array size
Array size Name = Graph count
Array size Data type = Unsigned16

7.4.2.6.3.4 Response variable model

CLASS: Array of Structure VARIABLE
ATTRIBUTES:
Numeric Identifier = 834
Variable Name = Graph
Number of Fields = 3
List of Fields
Field Name = Graph_ID
Field Data type Name = Unsigned16

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Field Name = Neighbor count
Field Data type Name = Unsigned16
Field Name = Neighbor list
Field Data type Name = Array of Neighbor
Array size = Variable

CLASS: Data type
ATTRIBUTES:
Data type Name = Array of Neighbor
Format = ARRAY
Number of Array Elements = value of Neighbor count
Array Element Data type = Unsigned16

7.4.2.6.4 Read publish data message list

7.4.2.6.4.1 Service overview

This service reads from the gateway, the publish data message list that the specified device participates in, including number of publish data mode commands that the specified device participates in. The requesting application can use this service to build the list of all publish data mode traffic in the system.

7.4.2.6.4.2 Request parameters

Numeric Identifier = 835
Additional Identifier
Name = Unique ID
Data type = Unique ID

7.4.2.6.4.3 Response parameters

Numeric Identifier = 835
Additional Identifier
Name = Unique ID
Data type = Unique ID

7.4.2.6.4.4 Variable model

CLASS: STRUCTURE VARIABLE
ATTRIBUTES:
Numeric Identifier = 835
Variable Name = Publish data message list
Number of Fields = 2
List of Fields
Field Name = Publish data count
Field Data type Name = Unsigned8
Field Name = Publish data
Field Data type Name = Array of Publish data

CLASS: Data type
ATTRIBUTES:
Data type Name = Array of Publish data
Format = ARRAY
Number of Array Elements = value of Publish data count
Array Element Data type = Publish data

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CLASS: **Data type**
ATTRIBUTES:
Data type Name = Publish data
Format = STRUCTURE
Number of Fields = 2
List of Fields
Field Name = Publish command
Field Data type Name = Unsigned16
Field Name = Packet count
Field Data type Name = Unsigned32

7.4.2.6.5 Flush cached responses for a device

7.4.2.6.5.1 Service overview

This service flushes the cached responses in the gateway, for the specified device.

7.4.2.6.5.2 Request parameters

CLASS: **Qualified Action**
ATTRIBUTES:
Numeric Identifier = 836
Variable name = Unique ID
Data type name = Unique ID

7.4.2.6.6 Read network device statistics

7.4.2.6.6.1 Service overview

This service reads the statistics for the specified device from the gateway.

7.4.2.6.6.2 Request parameters

Numeric Identifier = 840
Additional Identifier
Name = Unique ID
Data type = Unique ID

7.4.2.6.6.3 Response parameters

Numeric Identifier = 840
Additional Identifier
Name = Unique ID
Data type = Unique ID

7.4.2.6.6.4 Response variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 840
Variable Name = Device statistics
Number of Fields = 25
List of Fields
Field Name = Graph count
Field Data type Name = Unsigned16

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Field Name = Superframe count
Field Data type Name = Unsigned16
Field Name = Link count
Field Data type Name = Unsigned16
Field Name = Neighbor count
Field Data type Name = Unsigned8
Field Name = Upstream latency
Field Data type Name = Time
Field Name = Join count
Field Data type Name = Unsigned16
Field Name = Join date
Field Data type Name = Date
Field Name = Join time
Field Data type Name = Time
Field Name = Packets generated
Field Data type Name = Unsigned32
Field Name = Packets terminated
Field Data type Name = Unsigned32
Field Name = DLL MIC failures
Field Data type Name = Unsigned32
Field Name = NL MIC failures
Field Data type Name = Unsigned32
Field Name = CRC errors
Field Data type Name = Unsigned32
Field Name = Packets missed
Field Data type Name = Unsigned32
Field Name = Nonce counter missed
Field Data type Name = Unsigned32
Field Name = Upstream latency standard deviation
Field Data type Name = Time
Field Name = Downstream average latency
Field Data type Name = Time
Field Name = Downstream latency standard deviation
Field Data type Name = Time
Field Name = Upstream availability
Field Data type Name = Time
Field Name = Downstream availability
Field Data type Name = Time
Field Name = Maximum queue
Field Data type Name = Unsigned32
Field Name = Average queue
Field Data type Name = Float32
Field Name = Connection status
Field Data type Name = Bit Field
Field Name = Health status
Field Data type Name = Bit Field
Field Name = Session counter
Field Data type Name = Unsigned8

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7.4.2.6.7 Read network device identity using nickname

7.4.2.6.7.1 Service overview

This service reads the identity information of the device with matching Device nickname from the gateway.

7.4.2.6.7.2 Request parameters

Numeric Identifier = 841
Additional Identifier
Name = Device_nickname
Data type = Unsigned16

7.4.2.6.7.3 Response parameters

Numeric Identifier = 841
Additional Identifier
Name = Device_nickname
Data type = Unsigned16

7.4.2.6.7.4 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 841
Variable Name = Device identity
Number of Fields = 2
List of Fields
Field Name = Unique ID
Field Data type Name = Unique ID
Field Name = Long_tag
Field Data type Name = Latin-1
Octet Length = 32

7.4.2.6.8 Write network device's scheduling flags

7.4.2.6.8.1 Service overview

This service allows user to request special consideration for a device when the network manager is creating schedules.

7.4.2.6.8.2 Request parameters

Numeric Identifier = 842
Additional Identifier
Name = Unique ID
Data type = Unique ID

7.4.2.6.8.3 Response parameters

Numeric Identifier = 842
Additional Identifier
Name = Unique ID
Data type = Unique ID

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7.4.2.6.8.4 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 842
Variable Name = Scheduling flags
Data type Name = Bit Field

7.4.2.6.9 Read network device's scheduling flags

7.4.2.6.9.1 Service overview

This service reads the network device attributes that a network manager may consider when creating schedules.

7.4.2.6.9.2 Request parameters

Numeric Identifier = 843
Additional Identifier
Name = Unique ID
Data type = Unique ID

7.4.2.6.9.3 Response parameters

Numeric Identifier = 843
Additional Identifier
Name = Unique ID
Data type = Unique ID

7.4.2.6.9.4 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 843
Variable Name = Scheduling flags
Data type Name = Bit Field

7.4.2.6.10 Read network constraints

7.4.2.6.10.1 Service overview

This service reads the current setting of the network management strategy and the number of request / response messages per 10 s.

7.4.2.6.10.2 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 844
Variable Name = Network constraints
Number of Fields = 2
List of Fields
Field Name = Optimization flags
Field Data type Name = Bit Field
Field Name = Message pair count
Field Data type Name = Unsigned8

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7.4.2.6.11 Write network constraints

7.4.2.6.11.1 Service overview

This service writes the current setting of the network management strategy and the number of request / response messages per 10 s.

7.4.2.6.11.2 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 845
Variable Name = Network constraints
Number of Fields = 2
List of Fields
Field Name = Optimization flags
Field Data type Name = Bit Field
Field Name = Message pair count
Field Data type Name = Unsigned8

7.4.2.6.12 Read network statistics

7.4.2.6.12.1 Service overview

This service reads overall network health statistics.

7.4.2.6.12.2 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 846
Variable Name = Network statistics
Number of Fields = 8
List of Fields
Field Name = Throughput
Field Data type Name = Float32
Field Name = Utilization
Field Data type Name = Float32
Field Name = Availability
Field Data type Name = Float32
Field Name = Latency
Field Data type Name = Time
Field Name = Latency standard deviation
Field Data type Name = Time
Field Name = Packet error rate
Field Data type Name = Float32
Field Name = Dropped packets
Field Data type Name = Unsigned32
Field Name = Unsuccessful joins
Field Data type Name = Unsigned32

7.4.2.6.13 Transfer network list to white list

7.4.2.6.13.1 Service overview

This service copies the network list to the white list.

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7.4.2.6.13.2 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 847
Variable Name = Count
Data type name = Unsigned16

7.4.2.6.14 Generate key

7.4.2.6.14.1 Service overview

This service is used by an application to get a random key from the security manager.

7.4.2.6.14.2 Request parameters

Numeric Identifier = 848
Additional Identifier
Field Name = Value
Field Data type = Unsigned8

7.4.2.6.14.3 Response parameters

Numeric Identifier = 848
Additional Identifier
Field Name = Value
Field Data type = Unsigned8

7.4.2.6.14.4 Response variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 848
Variable Name = Key
Data type Name = Security Key

7.4.2.6.15 Read device join key

7.4.2.6.15.1 Service overview

This command reads a new random join key for the specified device.

7.4.2.6.15.2 Request parameters

Numeric Identifier = 849
Additional Identifier
Field Name = Value
Field Data type = Unsigned8
Name = Unique ID
Data type = Unique ID

7.4.2.6.15.3 Response parameters

Numeric Identifier = 849
Additional Identifier
Field Name = Value
Field Data type = Unsigned8

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Name = Unique ID
Data type = Unique ID

7.4.2.6.15.4 Response variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 849
Variable Name = Key
Data type Name = Security Key

7.4.2.6.16 Write device join key

7.4.2.6.16.1 Service overview

This command writes the specified join key to the identified device.

7.4.2.6.16.2 Variable model

Numeric Identifier = 850
Variable Name = Value
Variable type Name = Unique ID
Variable Name = Key
Data type Name = Security Key

7.4.2.6.17 Change key now

7.4.2.6.17.1 Service overview

This service is instructs the security manager to change the keys (Network, Join or Sessions) in the specified device.

7.4.2.6.17.2 Request parameters

Numeric Identifier = 851
Additional Identifier
Field Name = Value
Field Data type = Unsigned8
Field Name = Change key flags
Field Data type = Bit Field
Field Name = Unique ID
Field Data type = Unique ID

7.4.2.6.17.3 Response parameters

Numeric Identifier = 851
Additional Identifier
Field Name = Value
Field Data type = Unsigned8
Field Name = Change key flags
Field Data type = Bit Field
Field Name = Unique ID
Field Data type = Unique ID

7.4.2.6.17.4 Response variable model

CLASS: **Simple VARIABLE**

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ATTRIBUTES:

Numeric Identifier = 851
Variable Name = Change time
Data type Name = Time

7.4.2.6.18 Read stale data setpoints

7.4.2.6.18.1 Service overview

This command is used by an application to read the stale data timer and counter setpoint.

7.4.2.6.18.2 Variable model

Numeric Identifier = 852
Variable Name = Stale data timer
Variable type Name = Float32
Variable Name = Stale data count setpoint
Data type Name = Unsigned8

7.4.2.6.19 Write stale data timer

7.4.2.6.19.1 Service overview

This command is used by an application to write the stale data timer.

7.4.2.6.19.2 Variable model

Numeric Identifier = 853
Variable Name = Stale data timer
Variable type Name = Float32

7.4.2.6.20 Write stale data count setpoint

7.4.2.6.20.1 Service overview

This command is used by an application to write the stale data count setpoint.

7.4.2.6.20.2 Variable model

Numeric Identifier = 854
Variable Name = Stale data count
Variable type Name = Unsigned8

7.4.2.6.21 Read session extended

7.4.2.6.21.1 Service overview

This service reads the entries in the session table from a gateway or network manager.

7.4.2.6.21.2 Request parameters

Numeric Identifier = 855
Additional Identifier
Name = Session index

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Data type = Unsigned16

7.4.2.6.21.3 Response parameters

Numeric Identifier = 855
Additional Identifier
Name = Session index
Data type = Unsigned16

7.4.2.6.21.4 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 855
Variable Name = Session
Number of Fields = 6
List of Fields
Field Name = Session count
Field Data type Name = Unsigned8
Field Name = Session type
Field Data type Name = Enumeration
Field Name = Peer nickname
Field Data type Name = Unsigned16
Field Name = Peer unique id
Field Data type Name = Unique ID
Field Name = Peer nonce counter
Field Data type Name = Unsigned32
Field Name = Device nonce counter
Field Data type Name = Unsigned32

7.4.2.6.22 Read device suspend settings

7.4.2.6.22.1 Service overview

This command is reads the current suspension settings from a device.

7.4.2.6.22.2 Variable model

Numeric Identifier = 856
Variable Name = Suspend time
Variable type Name = Time
Variable Name = Resume time
Data type Name = Time

7.4.2.6.23 Read security level advertised

7.4.2.6.23.1 Service overview

This command is used to read the security level supported by the network manager.

7.4.2.6.23.2 Variable model

Numeric Identifier = 857
Variable Name = Security level
Variable type Name = Enumeration

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7.4.2.6.24 Reset availability statistics

7.4.2.6.24.1 Service overview

This command instructs the gateway to reset the availability statistics.

7.4.2.6.24.2 Variable model

Numeric Identifier = 858
Variable Name = Unique ID
Variable type Name = Unique ID

7.4.2.6.25 Read active advertising status

7.4.2.6.25.1 Service overview

This command returns the current advertising settings.

7.4.2.6.25.2 Variable model

Numeric Identifier = 859
Variable Name = Advertising shed time
Variable type Name = Time
Variable Name = Advertising period
Variable type Name = Time

7.4.2.6.26 Read join key mode

7.4.2.6.26.1 Service overview

This command reads the join key mode currently employed by the network manager.

7.4.2.6.26.2 Variable model

Numeric Identifier = 860
Variable Name = Join key mode
Variable type Name = Enumeration

7.4.2.6.27 Write join key mode

7.4.2.6.27.1 Service overview

This command writes the join key mode currently employed by the network manager.

7.4.2.6.27.2 Variable model

Numeric Identifier = 861
Variable Name = Join key mode
Variable type Name = Enumeration

7.4.2.6.28 Read timetable by id

7.4.2.6.28.1 Service overview

This service reads the timetable specified by the Timetable ID.

7.4.2.6.28.2 Request parameters

Numeric Identifier = 862

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Additional Identifier
Name = Timetable ID
Data type = Unsigned8

7.4.2.6.28.3 Response parameters

Numeric Identifier = 862
Additional Identifier
Name = Timetable ID
Data type = Unsigned8

7.4.2.6.28.4 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 862
Variable Name = Timetable table entry
Number of Fields = 5
List of Fields
Field Name = Request flags
Field Data type Name = Bit Field
Field Name = Application domain
Field Data type Name = Enumeration
Field Name = Nickname
Field Data type Name = Unsigned16
Field Name = Period
Field Data type Name = Time
Field Name = Route ID
Field Data type Name = Unsigned8

7.4.2.7 Network management configuration services

7.4.2.7.1 Disconnect device

7.4.2.7.1.1 Service overview

This service allows the network manager to force a device off the network.

7.4.2.7.1.2 Request parameters

CLASS: **Qualified Action**
ATTRIBUTES:
Numeric Identifier = 960
Variable name = Disconnect cause
Data type name = Enumeration

7.4.2.7.1.3 Response parameters

CLASS: **Qualified Action**
ATTRIBUTES:
Numeric Identifier = 960
Variable name = Disconnect cause
Data type name = Enumeration

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7.4.2.7.2 Write network key

7.4.2.7.2.1 Service overview

This service writes the network key in a network device.

7.4.2.7.2.2 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 961
Variable Name = Network key
Number of Fields = 2
List of Fields
Variable Name = Join_key
Data type Name = Security key
Field Name = Key change time
Field Data type Name = Unsigned40

7.4.2.7.3 Write device nickname

7.4.2.7.3.1 Service overview

This service writes a network device's nickname.

7.4.2.7.3.2 Variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 962
Variable Name = Device nickname
Data type Name = Unsigned16

7.4.2.7.4 Write session

7.4.2.7.4.1 Service overview

This service writes the session parameters required to establish a session between the destination (of this request) device and the peer device specified in the request.

7.4.2.7.4.2 Request variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 963
Variable Name = Session entry
Number of Fields = 7
Field Name = Session_type
Field Data type Name = Enumeration
Field Name = Peer_nickname
Field Data type Name = Unsigned16
Field Name = Peer_unique_ID
Field Data type Name = Unique ID
Field Name = Peer_nonce_counter
Field Data type Name = Unsigned32
Field Name = Session_key
Field Data type Name = Security key

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Field Name = Reserved
Field Data type Name = Unsigned8
Field Name = Session change time
Field Data type Name = Unsigned40

7.4.2.7.4.3 Response variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 963
Variable Name = Session entry
Number of Fields = 7
Field Name = Session_type
Field Data type Name = Enumeration
Field Name = Peer_nickname
Field Data type Name = Unsigned16
Field Name = Peer_unique_ID
Field Data type Name = Unique ID
Field Name = Peer_nonce_counter
Field Data type Name = Unsigned32
Field Name = Session_key
Field Data type Name = Security key
Field Name = Session count
Field Data type Name = Unsigned8
Field Name = Session change time
Field Data type Name = Unsigned40

7.4.2.7.5 Delete session

7.4.2.7.5.1 Service overview

This service deletes an end-to-end session in a network device.

7.4.2.7.5.2 Request parameters

CLASS: **Qualified Action**
ATTRIBUTES:
Numeric Identifier = 964
Variable name = Session_type
Data type name = Enumeration
Qualifier Name = Peer_nickname
Data type Name = Unsigned16

7.4.2.7.5.3 Response parameters

CLASS: **Qualified Action**
ATTRIBUTES:
Numeric Identifier = 964
Variable name = Session_type
Data type name = Enumeration
Qualifier Name = Peer_nickname
Data type Name = Unsigned16

7.4.2.7.5.4 Response variable model

CLASS: **Simple VARIABLE**

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ATTRIBUTES:
Numeric Identifier = 964
Variable Name = Session count
Data type Name = Unsigned8

7.4.2.7.6 Write superframe

7.4.2.7.6.1 Service overview

This service writes or modifies a Superframe in a network device.

7.4.2.7.6.2 Request variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 965
Variable Name = Superframe entry
Number of Fields = 5
Field Name = Superframe_ID
Field Data type Name = Unsigned8
Field Name = Num_Slots
Field Data type Name = Unsigned16
Field Name = Superframe mode
Field Data type Name = Bit Field
Field Name = Reserved
Field Data type Name = Unsigned8
Field Name = Superframe change time
Field Data type Name = Unsigned40

7.4.2.7.6.3 Response variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 965
Variable Name = Superframe entry
Number of Fields = 5
Field Name = Superframe_ID
Field Data type Name = Unsigned8
Field Name = Num_Slots
Field Data type Name = Unsigned16
Field Name = Superframe mode
Field Data type Name = Bit Field
Field Name = Superframe count
Field Data type Name = Unsigned8
Field Name = Superframe change time
Field Data type Name = Unsigned40

7.4.2.7.7 Delete superframe

7.4.2.7.7.1 Service overview

This service deletes a superframe in a network device.

7.4.2.7.7.2 Request parameters

CLASS: **Qualified Action**

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ATTRIBUTES:
Numeric Identifier = 966
Variable name = Superframe_ID
Data type name = Enumeration

7.4.2.7.7.3 Response parameters

CLASS: Qualified Action
ATTRIBUTES:
Numeric Identifier = 966
Variable name = Superframe_ID
Data type name = Enumeration

7.4.2.7.7.4 Response variable model

CLASS: Simple VARIABLE
ATTRIBUTES:
Numeric Identifier = 966
Field Name = Superframe count
Field Data type Name = Unsigned8

7.4.2.7.8 Write link

7.4.2.7.8.1 Service overview

This service adds a link assignment to a network device.

7.4.2.7.8.2 Request variable model

CLASS: STRUCTURE VARIABLE
ATTRIBUTES:
Numeric Identifier = 967
Variable Name = Link entry
Number of Fields = 6
Field Name = Superframe_ID
Field Data type Name = Unsigned8
Field Name = Slot
Field Data type Name = Unsigned16
Field Name = Channel_Offset
Field Data type Name = Unsigned8
Field Name = Neighbor
Field Data type Name = Unsigned16
Field Name = Link options
Field Data type Name = Bit Field
Field Name = Link_type
Field Data type Name = Enumeration

7.4.2.7.8.3 Response variable model

CLASS: STRUCTURE VARIABLE
ATTRIBUTES:
Numeric Identifier = 967
Variable Name = Link entry
Number of Fields = 7
Field Name = Superframe_ID
Field Data type Name = Unsigned8

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Field Name = Slot
Field Data type Name = Unsigned16
Field Name = Channel_Offset
Field Data type Name = Unsigned8
Field Name = Neighbor
Field Data type Name = Unsigned16
Field Name = Link options
Field Data type Name = Bit Field
Field Name = Link_type
Field Data type Name = Enumeration
Field Name = Link count
Field Data type Name = Unsigned16

7.4.2.7.9 Delete link

7.4.2.7.9.1 Service overview

This service deletes a Link assignment in a network device.

7.4.2.7.9.2 Request parameters

CLASS: **Qualified Action**
ATTRIBUTES:
Numeric Identifier = 968
Variable name = Superframe_ID
Data type name = Enumeration
Qualifier Name = Slot
Data type Name = Unsigned16
Qualifier Name = Neighbor
Data type Name = Unsigned16

7.4.2.7.9.3 Response parameters

CLASS: **Qualified Action**
ATTRIBUTES:
Numeric Identifier = 968
Variable name = Superframe_ID
Data type name = Enumeration
Qualifier Name = Slot
Data type Name = Unsigned16
Qualifier Name = Neighbor
Data type Name = Unsigned16

7.4.2.7.9.4 Response variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 968
Field Name = Link count
Field Data type Name = Unsigned16

7.4.2.7.10 Write graph connection

7.4.2.7.10.1 Service overview

This service adds a graph connection assignment to a network device.

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7.4.2.7.10.2 Request variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 969
Variable Name = Connection entry
Number of Fields = 2
Field Name = Graph_ID
Field Data type Name = Unsigned16
Field Name = Neighbor_nickname
Field Data type Name = Unsigned16

7.4.2.7.10.3 Response variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 969
Variable Name = Connection entry
Number of Fields = 3
Field Name = Graph_ID
Field Data type Name = Unsigned16
Field Name = Neighbor_nickname
Field Data type Name = Unsigned16
Field Name = Connection count
Field Data type Name = Unsigned16

7.4.2.7.11 Delete graph connection

7.4.2.7.11.1 Service overview

This service deletes a graph connection assignment in a network device.

7.4.2.7.11.2 Request parameters

CLASS: **Qualified Action**
ATTRIBUTES:
Numeric Identifier = 970
Variable name = Graph_ID
Data type name = Unsigned16
Qualifier Name = Neighbor_nickname
Data type Name = Unsigned16

7.4.2.7.11.3 Response parameters

CLASS: **Qualified Action**
ATTRIBUTES:
Numeric Identifier = 970
Variable name = Graph_ID
Data type name = Unsigned16
Qualifier Name = Neighbor_nickname
Data type Name = Unsigned16

7.4.2.7.11.4 Delete response variable model

CLASS: **Simple VARIABLE**
ATTRIBUTES:
Numeric Identifier = 970

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Field Name = Connection count
Field Data type Name = Unsigned16

7.4.2.7.12 Write neighbor attribute flag

7.4.2.7.12.1 Service overview

This service sets attributes of a neighbor to a network device.

7.4.2.7.12.2 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 971
Variable sub index Not present
Variable Name = Neighbor attribute
Number of Fields = 2
Field Name = Neighbor_nickname
Field Data type Name = Unsigned16
Field Name = Neighbor flags
Field Data type Name = Bit Field

7.4.2.7.13 Write network suspend

7.4.2.7.13.1 Service overview

This service puts the entire network in a "quiet", non-transmitting state. The command may be sent to all devices on the network or an individual device based on the addressing used.

7.4.2.7.13.2 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 972
Variable sub index Not present
Variable Name = Network suspend
Number of Fields = 2
Field Name = Suspend time
Field Data type Name = Unsigned40
Field Name = Resume time
Field Data type Name = Unsigned40

7.4.2.7.14 Write timetable

7.4.2.7.14.1 Service overview

This service adds new Timetable to a network device. The network device may start using this Service after processing this command.

7.4.2.7.14.2 Request variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 973
Variable Name = Timetable entry
Number of Fields = 6
Field Name = Timetable_ID

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Field Data type Name = Unsigned8
Field Name = Timetable_type
Field Data type Name = Bit Field
Field Name = Application domain
Field Data type Name = Enumeration
Field Name = Peer_nickname
Field Data type Name = Unsigned16
Field Name = Service_duration
Field Data type Name = Time
Field Name = Route_ID
Field Data type Name = Unsigned8

7.4.2.7.14.3 Response variable model

CLASS: STRUCTURE VARIABLE
ATTRIBUTES:
Numeric Identifier = 973
Variable Name = Timetable entry
Number of Fields = 7
Field Name = Timetable_ID
Field Data type Name = Unsigned8
Field Name = Timetable_type
Field Data type Name = Bit Field
Field Name = Application domain
Field Data type Name = Enumeration
Field Name = Peer_nickname
Field Data type Name = Unsigned16
Field Name = Service_duration
Field Data type Name = Time
Field Name = Route_ID
Field Data type Name = Unsigned8
Field Name = Timetable count
Field Data type Name = Unsigned8

7.4.2.7.15 Write route

7.4.2.7.15.1 Service overview

This service sets or modifies a route for a particular Service in a network device.

7.4.2.7.15.2 Request variable model

CLASS: STRUCTURE VARIABLE
ATTRIBUTES:
Numeric Identifier = 974
Variable Name = Route entry
Number of Fields = 3
Field Name = Route_ID
Field Data type Name = Unsigned8
Field Name = Destination_nickname
Field Data type Name = Unsigned16
Field Name = Graph_ID
Field Data type Name = Unsigned16

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7.4.2.7.15.3 Variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 974
Variable Name = Route entry
Number of Fields = 4
Field Name = Route_ID
Field Data type Name = Unsigned8
Field Name = Destination_nickname
Field Data type Name = Unsigned16
Field Name = Graph_ID
Field Data type Name = Unsigned16
Field Name = Route count
Field Data type Name = Unsigned8

7.4.2.7.16 Delete route

7.4.2.7.16.1 Service overview

This service deletes a Route entry in a network device.

7.4.2.7.16.2 Request parameters

CLASS: **Simple Variable Action**
ATTRIBUTES:
Numeric Identifier = 975
Variable Name = Route_ID
Data type Name = Unsigned8

7.4.2.7.16.3 Response parameters

CLASS: **Simple Variable Action**
ATTRIBUTES:
Numeric Identifier = 975
Variable Name = Route_ID
Data type Name = Unsigned8

7.4.2.7.16.4 Response variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 975
Field Name = Route count
Field Data type Name = Unsigned8
Field Name = Source route count
Field Data type Name = Unsigned8

7.4.2.7.17 Write source route

7.4.2.7.17.1 Service overview

This service writes a Source route in a network device. Broadcast addresses are not legal address values in this request and are not be included in Source routes or the requests or responses for this command.

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7.4.2.7.17.2 Request variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 976
Variable Name = Source route entry
Number of Fields = 3
List of Fields
Field Name = Route_ID
Field Data type Name = Unsigned8
Field Name = Hop count
Field Data type Name = Unsigned8
Field Name = Hop list
Field Data type Name = Array of Hop

CLASS: **Data type**
ATTRIBUTES:
Data type Name = Array of Hop
Format = ARRAY
Number of Array Elements = value of Hop count
Array Element Data type = Unsigned16

7.4.2.7.17.3 Response variable model

CLASS: **STRUCTURE VARIABLE**
ATTRIBUTES:
Numeric Identifier = 976
Variable Name = Source route entry
Number of Fields = 4
List of Fields
Field Name = Route_ID
Field Data type Name = Unsigned8
Field Name = Hop count
Field Data type Name = Unsigned8
Field Name = Hop list
Field Data type Name = Array of Hop
Field Name = Source route count
Field Data type Name = Unsigned8

7.4.2.7.18 Delete source route

7.4.2.7.18.1 Service overview

This service deletes a source route entry in a network device.

7.4.2.7.18.2 Request parameters

CLASS: **Simple Variable Action**
ATTRIBUTES:
Numeric Identifier = 977
Variable Name = Route_ID
Data type Name = Unsigned8

7.4.2.7.18.3 Response parameters

CLASS: **Simple Variable Action**

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ATTRIBUTES:

Numeric Identifier	= 977
Variable Name	= Route_ID
Data type Name	= Unsigned8
Variable Name	= Source route count
Data type Name	= Unsigned8

7.4.2.7.19 Write status counter mode

7.4.2.7.19.1 Service overview

This service is used to configure the device to use saturating status counters or roll-over counters.

7.4.2.7.19.2 Variable model

Numeric Identifier	= 978
Variable Name	= Counter mode
Variable type Name	= Enumeration

7.4.2.7.20 Write security level supported

7.4.2.7.20.1 Service overview

This service allows the network manager to change the security level included in advertisements generated by the device.

7.4.2.7.20.2 Variable model

Numeric Identifier	= 979
Variable Name	= Security level
Variable type Name	= Enumeration

7.4.3 ARs

7.4.3.1 Application relationship ASE

7.4.3.1.1 Overview

ARs are composed of a set of endpoints of compatible classes. One endpoint of each AR has to be Master class and the other end has to be Slave class. Each device can have only one instance of a Slave class AREP.

A device can use more than one Master class AREP to communicate with several Slave class AREPs. The user at Master class AREP provides the identification of the Slave class AREP as a parameter in the request primitive.

7.4.3.1.2 Master class AREP

7.4.3.1.2.1 Formal model

ASE:	**AR ASE**
CLASS:	Master
CLASS ID:	Not used
PARENT CLASS:	Top
ATTRIBUTES:	
(m) Attribute:	Address

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SERVICES:

1	(m)	OpsService:	AR-Get Attribute
2	(m)	OpsService:	AR-Set Attribute

7.4.3.1.2.2 Attributes

Address
This attribute specifies the network address of master device.

7.4.3.1.3 Slave class AREP

7.4.3.1.3.1 Formal model

ASE:			**AR ASE**
CLASS:			Slave
CLASS ID:			Not used
PARENT CLASS:			Top
ATTRIBUTES:			
(m)	Physical layer type		Wireless
(m)	Attribute:		Nickname
(m)	Attribute:		Unique ID
SERVICES:			
1	(m)	OpsService:	AR-Get Attribute
2	(m)	OpsService:	AR-Set Attribute

7.4.3.1.3.2 Attributes

Nickname
This attribute specifies the network address of Slave device. The device responds only to this address in an Identify frame received from a Master device.

Unique ID
This attribute is used to form the network address of Slave device. The device responds only to this address in all frames received from a Master device. An all zero value of this attribute shall be reserved as Broadcast address.

7.4.3.1.4 Application relationship ASE service specifications

7.4.3.1.4.1 Overview

This subclause contains the definition of the services that are unique to this ASE. The services are

- AR Get Attribute and
- AR Set Attribute.

7.4.3.1.4.2 AR-Get attribute service

7.4.3.1.4.2.1 Overview

This confirmed service is used to read the value of attributes of an AREP locally.

7.4.3.1.4.2.2 Service parameters

The service parameters for the AR Get Attribute Service are shown in Table 73.

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Table 73 – AR get attributes service parameters

Parameter name	Req	Cnf
Argument	M	
Attribute index	M	
Result (+)		S
Value		C
Result (-)		S
Status		C
NOTE The method by which a confirm primitive is correlated with its corresponding preceding request primitive is a local matter.		

Argument
The argument carries the parameters of the service request.

Attribute index
This parameter identifies the attribute.

Result (+)
This selection type parameter indicates that the request succeeded.

Value
This parameter is returned with the requested attribute value if the request succeeded.

Result (-)
This selection type parameter indicates that the request failed.

Status
If the request failed, Status is returned indicating the reason for failure. The possible values are: Illegal attribute index, Unknown value.

7.4.3.1.4.3 AR Set attributes service

7.4.3.1.4.3.1 Overview

This confirmed service is used to set the current value of attributes of an AREP locally.

7.4.3.1.4.3.2 Service parameters

The service parameters for the AR Set Attribute Service are shown in Table 74.

Table 74 – AR set attributes service parameters

Parameter name	Req	Cnf
Argument	M	
Attribute index	M	
Value	M	
Result		
Status		M
NOTE The method by which a confirm primitive is correlated with its corresponding preceding request primitive is a local matter.		

Argument
The argument carries the parameters of the service request.

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Attribute index
This parameter identifies the attribute to be updated.

Value
This parameter holds the new attribute value.

Status
As a result of the request, Status is returned indicating OK or the reason for failure. The possible values are: OK, Illegal attribute index, Illegal value.

7.4.3.2 Void

NOTE To retain the structure of IEC 61158-6-x series that specifies additional ARs, this an empty subclause to fulfill the ISO/IEC Directives Part 2 requirements not to have an isolated subclause.

7.4.4 Summary of classes

This subclause contains a summary of the defined Classes. Table 75 provides a summary of the classes.

Table 75 – Class summary

ASE	Class
Virtual field device	VFD
Data type	Fixed Length Data type
	String Data type
Variable	Simple Variable
	Structure variable

7.4.5 Permitted services by AREP role

Table 76 and Table 77 define the valid combinations of services and AREP class (which service Application protocol data units (APDU) and AREP with the specified class can send or receive).

Table 76 – Confirmed services by AREP class

Services	Master		Slave	
	req	cnf	Ind	rsp
VFD ASE				
Identify	X	X	X	X
Variable ASE				
Read service – all	X	X	X	X
Write service – all	X	X	X	X

Table 77 – Unconfirmed services by AREP class

Services	Slave	Master
	req	ind
Variable ASE		
Information report	X	X

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8 Application layer protocol specification – Type 20 elements

8.1 General

This document specifies the wireless Application layer protocol of Type 20 in addition to the wired Application layer protocol of Type 20 specified in IEC 61158-6-20.

8.2 Abstract syntax

The abstract syntax of Application protocol data unit (APDU) is combined with their transfer syntax and is specified in 8.3.

8.3 Transfer syntax

8.3.1 Common APDU fields

8.3.1.1 Command number field

The Command number is the Numeric Identifier of Read (7.4.2.2.3.3), Write (7.4.2.2.3.4), Information report (7.4.2.2.3.5) or Action (7.4.2.3.4) service. It identifies the type of service and the object in the Slave that has to be accessed or action that has to be performed. It is Unsigned16 extended Command number. Commands 0 to 255 are zero filled to form the 16-bit command number (for example Command 9 is transmitted as 0x0009). Command 31 is reserved and shall not be used in the request.

8.3.1.2 Octet count field

This field represents the number of octets in the all of fields that follow this field. The data type of this field is Unsigned8 and its value can be 0 to 255. If the value of this field is zero, then this is the last field in the APDU.

8.3.1.3 Response code field

Response code field is Enumeration data type and it indicates either the successful completion of the requested command, or completion of the requested command with a warning or an error in performing the requested command, as shown in Table 78. Some of the values depend upon the value of Command field. Each service-specific APDU structure shows the response code values assigned to that service. A device is required to use these values. The device can respond with an unused value as long it indicates a condition that is not defined in this standard.

Table 78 – Response code values

Value	Class	Definition
0	Success	Command (read or Write) was executed properly
1 – 127	Warning	Command (Write) was executed with the deviation as described in response (for example a value was set to the nearest legal value)
1 – 127	Error	Command execution was not properly completed and the Response code indicates the reason (for example the device is in Write Protect mode)
1 – 127	Reserved	A code may be reserved for future use by this standard protocol. A device is not permitted to return reserved value

The response code values that are common to all commands and the behavior of the responding device for those codes are specified in Annex E.

8.3.1.4 Application process status

This field is provided by the FAL user. Its data type is one octet long Bit Field. It is not associated with the completion of any command. This field shall have at least following status:

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a) Configuration changed – an operation was performed that changed the device's configuration, and

b) More status available – more status information is available via another Read Command.

If “Configuration changed” is ‘1’, then the client should read other variables from the server, if necessary and then use “Reset configuration changed flag” service to reset this status bit.

If “More status available” is ‘1’, then the client should use “Read additional device status” service to get the information not included in the “Application process status”.

8.3.1.5 Extended status

This field indicates the VFD status. The possible values of this parameter are shown in Table 79. Its data type is one octet long Bit Field. It is not associated with the completion of any command.

Table 79 – Extended status values

Code	Value	Description
0x01	Maintenance required	The VFD requires maintenance, although it has not malfunctioned.
0x02	Device variable alert	One or more of the “Device variables” are in an Alarm or Warning state.
0x04	Critical power failure	The available power is becoming critically low; used by devices that operate from stored power

8.3.1.6 Value field

The Value field is the user data which is transferred between application layer and its user. The ALE assembles it from the parameters of a service primitive or parses it into parameters of a service primitive. Its structure depends upon the type of APDU.

8.3.1.7 Formats of APDU structures

The sending application layer prepares an APDU to transfer it to the receiving application layer. It uses the parameters from the service primitives to do so. There are several formats of the APDU:

- request APDU from Master to Slave device,
- normal response from Slave to Master device, and
- command error response from Slave to Master device.

The common formats for APDU structures are specified in 8.3.2. The formats for service-specific APDU structures are specified in 8.3.3, 8.3.4, 8.3.5 and 8.3.6.

The “Command number” field is in included in the request and response both. The requester does not have to store the request APDU to associate it with the response APDU.

8.3.2 Common APDU structure

8.3.2.1 Request APDU from master to slave device

All APDU have a common structure as shown in Figure 41.

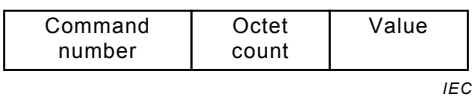

Figure 41 – Request APDU format from master to slave

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For a Read service, Value field is either Null or a Variable Sub Index and for an array type of variable, it may include number of elements to be read. For a Write service, Value field is Variable Sub Index, if required followed by the value that has to be written to the Slave objects identified by the Command. The ALE assembles it from the parameters of a service primitive. Its structure depends upon the service-specific APDU.

8.3.2.2 Normal response APDU from slave to master device

Figure 42 shows the format of the application layer fields that are used for an error-free response from Slave to Master.

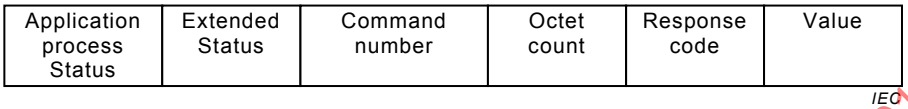

Figure 42 – Normal response APDU format from slave to master

The Slave sends this APDU in response to a request from Master. The value of Command number field in this APDU is identical to the Command number field in the corresponding request APDU.

The Octet count is number of octets in Value field plus one. The minimum value of Octet count field is one (1).

If the response is for a Read request, then Value field is used for the value of the objects that are read from Slave device. If the response is for a Write request, then this field is used for the value of the objects that were written in the Slave device. In the response to the Write request, it is same as the value received in the request, unless the value received was not permitted and the server wrote a different value. In that case, it is the value written in the Slave device.

The Master shall issue only one command to one Slave until that Slave sends the response or the request times out and becomes invalid (see 7.4.2.2.3.2 and 7.4.2.3.2).

8.3.2.3 Command error APDU from slave to master device

Figure 43 shows the format of the application layer fields that are used for a response from Slave to Master, when there is an error in executing the command. The Value field does not exist.

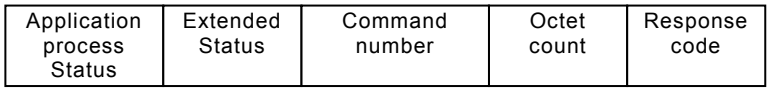

Figure 43 – Command error response APDU format from slave to master

The responding device sends this APDU in response to a request from Master. The value of Command number field in this APDU is identical to the Command number field in the corresponding request APDU.

The Octet count field is set to one (1).

Command 31 is reserved and any response to a Command 31 request shall be an error code "Command Not Implemented".

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8.3.2.4 Information report APDU from slave to master device

The Information report and data publishing uses the response APDU defined in 8.3.2.2. The publishing is setup to use one of the command numbers (see 8.3.3.33). Other information report command numbers are specified in service-specific APDU subclauses.

8.3.2.5 Command aggregation

This standard allows multiple commands and associated data to be transported in a single request and response APDU. The command aggregation is especially useful when reading device configurations. The aggregated command APDU is shown in Figure 44. The "Command #n Request" field is same as the request APDU as shown in Figure 41. The "Command #n Response" field is the same the response APDU as shown in Figure 42 and Figure 43, except that the "Application process status" and "Extended status" fields are used only once in the beginning and these are not part of "Command #1 Response" to "Command #n Response" fields.

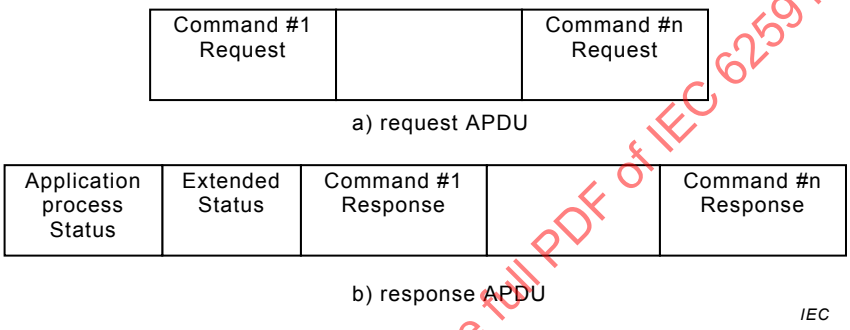

Figure 44 – Aggregated command APDU

If the device has been configured to publish more than one messages (see 8.3.3.33), it can combine these into one message using command aggregation, except that "Publish data Message 0" shall never be aggregated.

Whenever possible, the Type 20 compliant field device shall aggregate multiple pending "Publish data Message" into one transaction using Information report request. If the multiple "Publish data Message" does not fit into a single transaction, then these can be sent in separate transactions.

General requirements for aggregating commands are as following.

- If a device receives an aggregated request APDU, then it shall provide response to all "Command" fields in the request in one aggregated response APDU.
- Command with a number in the range of 0x0300 to 0x03FF shall be aggregated only with another command in this range.
- A read command can be aggregated with write command.

NOTE 1 The mixing of read and write commands in one aggregation is permitted, but it is not recommended.

- The network management configuration APDU (see 8.3.6) shall not be aggregated with any other types. Network management configuration request is acknowledged transaction containing write command that modifies network behavior.

NOTE 2 The commands do not have dependency on each other. It implies that the commands can be aggregated. For example several read commands can be aggregated in one transaction. Some restrictions may be imposed in the requirements for specific commands. The protocol does not put any other restriction on the command restriction. A host application (FAL-user) for example device calibration may prevent command aggregation.

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8.3.3 Device application service-specific APDU structures

8.3.3.1 Identify FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.1.

8.3.3.2 Read primary variable FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.2.

8.3.3.3 Read loop current and percent of range FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.3.

8.3.3.4 Read dynamic variables and loop current FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.4.

8.3.3.5 Write loop configuration FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.5.

8.3.3.6 Read loop configuration FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.6.

8.3.3.7 Read dynamic variable families classifications FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.7.

8.3.3.8 Read device variables with status FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.8.

8.3.3.9 Read message FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.9.

8.3.3.10 Read tag, descriptor and date FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.10.

8.3.3.11 Read primary variable transducer information FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.11.

8.3.3.12 Read device information FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.12.

8.3.3.13 Read final assembly number FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.13.

8.3.3.14 Write message FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.14.

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8.3.3.15 Write tag, descriptor and date FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.15.

8.3.3.16 Write final assembly number FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.16.

8.3.3.17 Read long tag FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.17.

8.3.3.18 Write long tag FAL PDU

This Command is specified in IEC 61158-6-20:2014, 5.3.18.

8.3.3.19 Reset configuration changed flags FAL PDU

8.3.3.19.1 Request primitive

The value of Command is thirty-eight (38); the value of Octet count field is two (2) and Value field is as shown in Table 80.

Table 80 – Reset configuration changed flags value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Configuration change counter	Total number of configuration changes

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8.3.3.19.2 Response primitive

The Value field of response is shown in Table 80. The Response code values are shown in Table 81.

Table 81 – Reset configuration changed flag command specific Response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
6	Error	Device-specific command error
7	Error	In write protect mode
9	Error	Configuration change counter mismatch
16	Error	Access restricted

8.3.3.19.3 Procedure at responding device

A field device shall contain “Configuration changed” bits separately for each Master – primary and the secondary and the gateway. All “Configuration changed” bits shall be set to ‘1’ when any configuration item in the field device is modified. This command shall reset the “Configuration changed” bit to ‘0’, which is associated with the Master device issuing this command. That bit shall stay at ‘0’ value, until another change is made to the device's configuration. The value of this bit shall be maintained even if power is removed from the device or a device reset is performed. “Configuration changed” bit of the “Application process status” octet for the Master device not issuing this command is unaffected by this command and remains set to ‘1’ until the other Master device issues this command.

Upon receiving this command the device shall compare the Configuration change counter received in this command with the current value of this parameter in the device. If they do not match then the device shall return "Configuration Change Counter Mismatch" and not reset the “Configuration changed” bit.

8.3.3.20 Perform self test FAL PDU

8.3.3.20.1 Request primitive

The value of Command is forty-one (41); the value of Octet count field is zero (0) and Value field is null.

8.3.3.20.2 Response primitive

The Value field of response is null. The Response code values are shown in Table 82.

Table 82 – Perform self test command specific Response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command error
16	Error	Access restricted
32	Error	Busy

8.3.3.20.3 Procedure at responding device

This command initiates the self test function in the device. The execution of this command may take a relatively long time to complete. During the self test the field device shall continue to communicate. However, it is allowed to respond ‘Busy’ to all commands received during this interval.

The Loop Current may not reflect the process while the self test is executing. A Master shall not generate spurious error messages or disconnect from a device while the self test is in progress in that device.

8.3.3.21 Perform device reset FAL PDU

8.3.3.21.1 Request primitive

The value of Command is forty-two (42); the value of Octet count field is zero (0) and Value field is null.

8.3.3.21.2 Response primitive

The Value field of response is null. The Response code values are shown in Table 83.

Table 83 – Perform device reset command specific Response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command error
16	Error	Access restricted
32	Error	Busy

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8.3.3.21.3 Procedure at responding device

The device shall respond to this command immediately and within the slave time out and then reset itself. This is equivalent to cycling the power off and then back on to the device.

The execution of this command may take a relatively long period of time to complete. The device may not respond to subsequent commands until the reset is complete. The device may not respond while it in the process of reset. This may look like communications with the device is lost. A Master shall not generate spurious error messages or disconnect from the device while the reset is in progress in that device.

8.3.3.22 Read additional device status FAL PDU

8.3.3.22.1 Request primitive

The value of Command is forty-eight (48); the value of Octet count field is zero (0) and Value field is null.

8.3.3.22.2 Response primitive

The Value field of response is shown in Table 84. The Response code values are shown in Table 85.

Table 84 – Read additional device status value field

Octet offset	Data type	Parameter name	Description
0	Bit Field (total of 6)	Device specific status 0	Manufacturer and device type specific status
6	Bit Field	Extended status	Extended operational status of the VFD
7	Bit Field	Device operating mode	Operational mode of the device
8	Bit Field	Standardized status 0	Status of the device as specified in Table F.8
9	Bit Field	Standardized status 1	Status of the device as specified in Table F.9
10	Bit Field	Analog channel saturated	Status of the analog channel as specified in Table F.6
11	Bit Field	Standardized status 2	Status of the device as specified in Table F.10
12	Bit Field	Standardized status 3	Status of the device as specified in Table F.11
13	Bit Field	Analog channel fixed	Status of the analog channel as specified in Table F.7
14	Bit Field (1 to 11)	Device specific status 1	Manufacturer and device type specific status
NOTE The Device specific status 0 and Device specific status 1 can be either Bit Field or Enumeration data types.			

Table 85 – Read additional device status command specific Response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command error
8	Warning	Update in progress
16	Error	Access Restricted

8.3.3.22.3 Procedure at responding device

If the device is able to respond to the request, but the status information is pending the completion of a command that requires a relatively long time to complete, then Response

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code value of “Update in progress” shall be returned. The Client should retry the request after a delay.

Else, the device shall respond indicating ‘Success’ and include all Value fields supported by the device's implementation of Command 48 in the response.

The Response Value fields returned are truncated after the last status octet supported by the device. All devices shall support at least octet numbers 0 to 8 including “Extended status”, Device operating mode and Standardized status 0. If the device supports more than one Analog channel, then octet numbers 9 to 13 shall also be returned.

8.3.3.23 Reset more status available FAL PDU

8.3.3.23.1 Request primitive

The value of Command is forty-eight (48); the value of Octet count field is nine (9) to twenty-five (25) depending upon the device implementation. The Value field is as shown in Table 86.

Table 86 – Read additional device status value field

Octet offset	Data type	Parameter name	Description
0	Bit Field (total of 6)	Device specific status 0	Manufacturer and device type specific status
6	Bit Field	Extended status	Extended operational status of the VFD
7	Bit Field	Device operating mode	Operational mode of the device
8	Bit Field	Standardized status 0	Status of the device as specified in Table F.8
9	Bit Field	Standardized status 1	Status of the device as specified in Table F.9
10	Bit Field	Analog channel saturated	Status of the analog channel as specified in Table F.6
11	Bit Field	Standardized status 2	Status of the device as specified in Table F.10
12	Bit Field	Standardized status 3	Status of the device as specified in Table F.11
13	Bit Field	Analog channel fixed	Status of the analog channel as specified in Table F.7
14	Bit Field (1 to 11)	Device specific status 1	Manufacturer and device type specific status
NOTE The Device specific status 0 and Device specific status 1 can be either Bit Field or Enumeration data types.			

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8.3.3.23.2 Response primitive

The Value field of response is shown in Table 86. The Response code values are shown in Table 87.

Table 87 – Read additional device status command specific Response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command error
8	Warning	Update in progress
16	Error	Access Restricted

8.3.3.23.3 Procedure at responding device

If the device is able to respond to the request, but the status information is pending the completion of a command that requires a relatively long time to complete, then Response code value of “Update in progress” shall be returned. The Client should retry the request after a delay.

Else, it shall compare the received values to the current values contained in the device. If there is an exact match then the “More status available” bit corresponding to the requesting device (primary master, secondary master or gateway) shall be reset to ‘0’. If there is not an exact match or too few octets are received then the “More status available” bit shall remain unchanged. If the request contains more Value fields than supported by the device, then these extra fields shall be ignored. The device shall always send the current values of Value fields in the response.

The Response Value fields returned are truncated after the last status octet supported by the device. All devices shall support at least octet numbers 0 to 8 including “Extended status”, Device operating mode and Standardized status 0. If the device supports more than one Analog channel, then octet numbers 9 to 13 shall also be returned.

8.3.3.24 Read device variable information FAL PDU

8.3.3.24.1 Request primitive

The value of Command is fifty-four (54); the value of Octet count field is one (1). The Value field is as shown in Table 88.

Table 88 – Read device variable information value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Variable code	Variable for which information is requested

8.3.3.24.2 Response primitive

The Value field of response is shown in Table 89. The Response code values are shown in Table 90.

Table 89 – Read device variable information response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Variable code	Code received in request at Value field
1	Unsigned24	Transducer serial number	Value of Transducer Serial Number
4	Enumeration	Transducer unit	Code for Transducer Limits and Minimum Span Units
5	Float32	Upper transducer limit	Value of Upper Transducer Limit variable
9	Float32	Lower transducer limit	Value of Lower Transducer Limit variable
13	Float32	Damping value	Damping constant for the transducer value
17	Float32	Minimum span	Value of Minimum Span variable
21	Enumeration	Device variable classification	Function performed by the device variable as specified in Table F.5
22	Enumeration	Device variable family	Device family as specified in Table F.4
23	Time	Update period	The maximum period between Device variable updates

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Table 90 – Read device variable information command specific Response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too Few data octets received
6	Error	Device-specific command error
16	Error	Access restricted
32	Error	Busy

8.3.3.24.3 Procedure at responding device

If there no transducer for the selected Deice variable, then the device shall set Transducer serial number to zero, set other Float32 parameters to "0x7F, 0xA0, 0x00, 0x00", and Transducer units parameters to "250" (not used) when they are not applicable.

If the Device variable classification is not supported by this Device variable then the device shall return "0" (not implemented). If the Device variable family is not supported by the Device variable then the device shall return "250" (not used).

The device shall update the Device variable at least once in the interval indicated by the Update period.

8.3.3.25 Write device variable FAL PDU

8.3.3.25.1 Request primitive

The value of Command is seventy-nine (79); the value of Octet count field is eight (8) and Value field is as shown in Table 91.

Table 91 – Write device variable value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Variable code	Variable for which values have to be written
1	Enumeration	Device variable command	Command to be executed as specified in Table F.3
2	Engineering unit	Device variable unit	Measurement unit of the variable
3	Float32	Device variable value	Variable value to be written
7	Bit Field	Device variable status	Variable status to be written

8.3.3.25.2 Response primitive

The Value field of response is shown in Table 91. The Response code values are shown in Table 92.

Table 92 – Write device variable command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received

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Value	Class	Description
6	Error	Device-specific Command Error
7	Error	In write protect mode
8	Warning	Device family status bit not set
10	Error	Invalid Device variable code
16	Error	Access Restricted
17	Error	Invalid Device variable index; the Device variable does not exist in the device
18	Error	Invalid Units code
19	Error	Device variable index not allowed for this command
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

8.3.3.25.3 Procedure at responding device

The Write Device variable command controls the operation of the device either forcing the engineering value, or allowing normal operation. For Device variables automatically calculated by the field device, normal operation shall be resumed when power is removed from the device and re-applied to it, or upon completing a device reset.

A field device shall start a DR (delayed response), if the change in the Device variable's value exceeds the rate-of-change limit. This DR shall continue until the new value can be reached. While the Device variable remains forced, Response code 8 – "Update failure" shall be returned, whenever the forced value is read by a client. This signals the master to detect this condition. Forcing a Device variable value may affect bits in the “Application process status” octet.

Host application should not use Device family status bits for Device variables not supporting a Device family (i.e., the field device always reset these bits in this case).

The Device variable unit code received with this command does not affect the Device variable units of the field device. The Device variable value shall be returned in the same units as received.

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8.3.3.26 Read Sub-Device Identity Summary

8.3.3.26.1 Request primitive

The value of Command is eighty four (84); the value of Octet count field is two (2) and Value field is null.

8.3.3.26.2 Response primitive

The Value field of response is shown in Table 93. The Response code values are shown in Table 94.

Table 93 – Read Sub-Device Identity Summary value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Sub-device Index	Index 0 returns the I/O System Identity; the Card and Channel should be ignored in Host Applications

2	Unsigned8	I/O Card	
3	Unsigned8	Channel	
4	Unsigned16	Manufacturer ID	
6	Unsigned16	Expanded Device Type Code	
8	Unsigned24	Device ID	
11	Unsigned8	Universal command revision level	
12	Latin-1	Long Tag	To be stored in the device
44	Unsigned8	Device revision	
45	Enumeration	Device Profile	If the sub-device does not return Device Profile in its Command 0 response then I/O system shall return “Process Automation Device”
46	Enumeration	Private Label Distributor Code	See IEC 61158-6-20:2014, Table 6

Table 94 – Read Sub-Device Identity Summary command specific response codes

Value	Class	Description
0	Success	No error
1		Undefined
2	Error	Invalid selection
3		Undefined
5	Error	Too few data bytes received
6	Error	Device-specific command error
7		Undefined
8	Warning	Duplicate ID
9 – 127		Undefined

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8.3.3.26.3 Procedure at responding device

The device shall respond with the internal time at which the request was received.

8.3.3.27 Read real-time clock FAL PDU

8.3.3.27.1 Request primitive

The value of Command is ninety (90); the value of Octet count field is zero (0) and Value field is null.

8.3.3.27.2 Response primitive

The Value field of response is shown in Table 95. The Response code values are shown in Table 96.

Table 95 – Read real-time clock value field

Octet offset	Data type	Parameter name	Description
0	Date	Date	Current date
3	Time	Current time	Current time of day
7	Date	Date last set	Date clock last set

10	Time	Time last set	Time clock last set
14	Bit Field	RTC flags	RTC flags as specified in Table F.18

Table 96 – Read real-time clock command specific response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command error

8.3.3.27.3 Procedure at responding device

The device shall respond with the internal time at which the request was received. If the clock has not been set then the last time set shall be initialized to midnight (00:00) 01 January, 1900.

8.3.3.28 Write publish data period FAL PDU

8.3.3.28.1 Request primitive

The value of Command is one hundred and three (103); the value of Octet count field is nine (9) and Value field is as shown in Table 97.

Table 97 – Write publish data period value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Publish data message ref	Reference to one set of publish data in all read and write requests and responses for that set
1	Time	Update period	The duration between two successive publication of the specified data, if the trigger conditions in Command 104 are met
5	Time	Maximum update period	The duration between two successive publication of the specified data, if the trigger conditions in Command 104 are not met
NOTE The value returned in the response data octets reflects the value actually used by the device.			

8.3.3.28.2 Response primitive

The Value field of response is shown in Table 97. The Response code values are shown in Table 98.

Table 98 – Write publish data period command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
6	Error	Device-specific command Error
7	Error	In write protect mode
8	Warning	Update times adjusted
9	Error	Invalid Device variable code
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated

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Value	Class	Description
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

8.3.3.28.3 Procedure at responding device

This request selects the minimum and maximum update period of a Publish data message. The minimum time shall be less than or equal to the maximum time. Only following values of Update period parameter are allowed:

0,100 s,

0,250 s,

0,500 s,

1 s,

2 s,

4 s,

8 s,

16 s,

32 s, and

any value from 60 to 3 600 s.

Field devices shall correct settings differing from these values to the nearest allowed value and indicate "Update times adjusted" in its response code. The default value of Update period parameter is 60 s.

If multiple Publish data messages are enabled and they all coincide within the same time, then these are aggregated together using Command 78 to form one APDU. The Publish data messages with the highest priority will be concatenated first up to the maximum number of octets that the respective transport layer allows. The Publish data message with the lower reference number has the higher priority over the Publish data message with the higher reference number. The “Application process status” event has lower priority than the Publish data messages and has higher priority than Command 48 event.

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8.3.3.29 Write publish data trigger FAL PDU

8.3.3.29.1 Request primitive

The value of Command is one hundred and four (104); the value of Octet count field is eight (8) and Value field is as shown in Table 99.

Table 99 – Write publish data trigger field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Publish data message ref	Reference to one set of publish data in all read and write requests and responses for that set
1	Enumeration	Trigger mode	Trigger mode selection code as specified in Table F.12
2	Enumeration	Device variable classification	Function performed by the device variable as specified in Table F.5
3	Engineering unit	Device variable unit	Measurement unit of the variable
4	Float32	Trigger level	Window or the level that is used to trigger the publishing
NOTE The value returned in the response data octets reflects the value actually used by the device.			

8.3.3.29.2 Response primitive

The Value field of response is shown in Table 99. The Response code values are shown in Table 100.

Table 100 – Write publish data trigger command specific response codes

Value	Class	Description
0	Success	No error
3	Error	Parameter value to be written is larger than permitted
4	Error	Parameter value to be written is smaller than permitted
5	Error	Too few data octets received
6	Error	Device-specific command Error
7	Error	In write protect mode
8	Warning	Set to the nearest possible value
9	Error	Invalid Publish data message ref
11	Error	Invalid Device variable classification
12	Error	Invalid units code
13	Error	Invalid publish data trigger mode selection code
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

8.3.3.29.3 Procedure at responding device

Unless otherwise configured by this request, a Publish data message shall assume a Trigger mode of "Continuous" and a Trigger value of 0,00. Furthermore, if a device specific command is specified as the publish command then this request shall return "Access restricted" and shall use the default value of "Continuous" for Trigger mode.

These trigger modes allow the device to be configured to defer the publishing of the Publish data message beyond the Update period specified in Command 103 (see Table 97). In all cases, the Publish data message shall be triggered when the Maximum update time in Command 103 (see Table 97) is exceeded. The trigger source is specified and is normally the first process value returned as response to the command as shown in Table 101. The command number for Publish data message is specified in 8.3.3.33.

Table 101 – Publish data message trigger source

Command	Reference	Trigger source
1	8.3.3.2	Primary Variable value
2	8.3.3.3	Primary Variable in percent of range
3	8.3.3.4	Primary Variable
9	8.3.3.8	Device variable for slot 0

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When in "Windowed" mode, the Trigger value shall be a positive number and is the symmetric window around the last communicated value. Figure 45 illustrates the Publish data message being published after the window was exceeded.

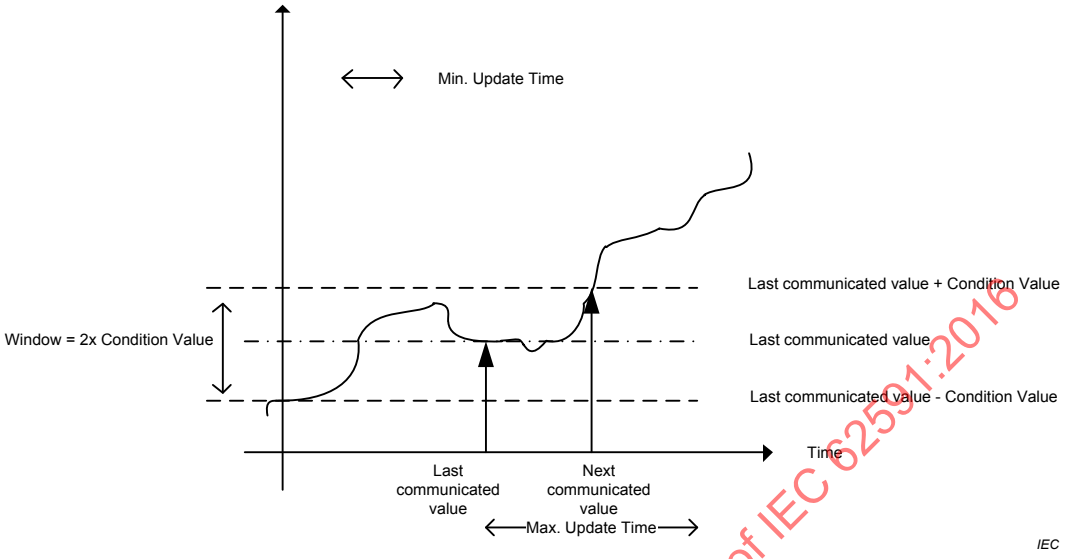

Figure 45 – Windowed trigger mode

Figure 46 illustrates that even if the value does not deviate beyond the window a Publish Data Message is still published when the Max Update Period is exceeded.

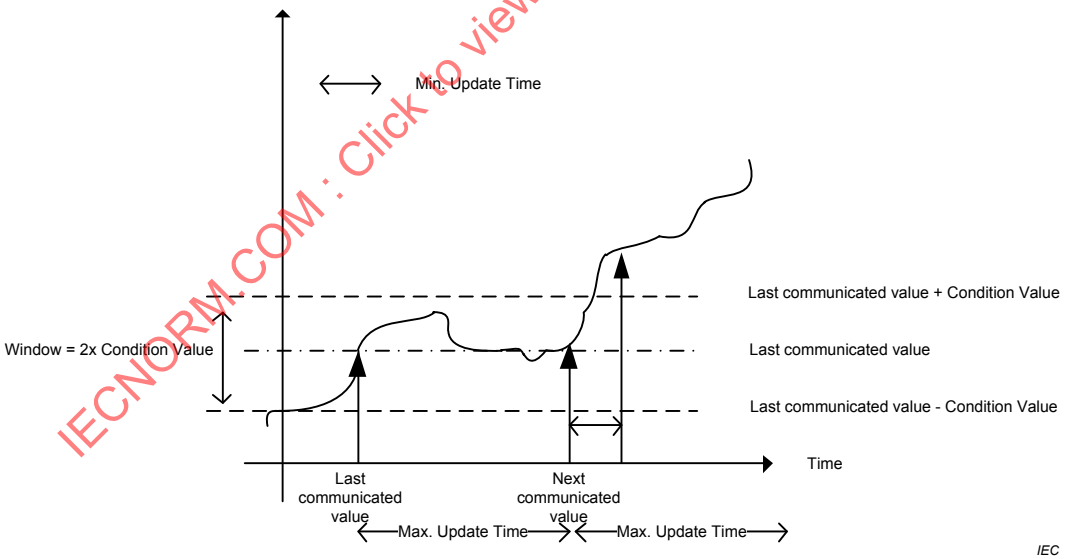

Figure 46 – Windowed trigger mode with maximum update time expired

In "Rising" mode, the Publish Data Message shall be published when the source value is above the threshold established by the trigger value. Figure 47 shows that the update time changes once the limit is exceeded. Publish Data messages are published at the rate indicated by the Update period as long as the source value remains above the trigger value. If the value falls below the trigger value, the update time shall be the Maximum update period.

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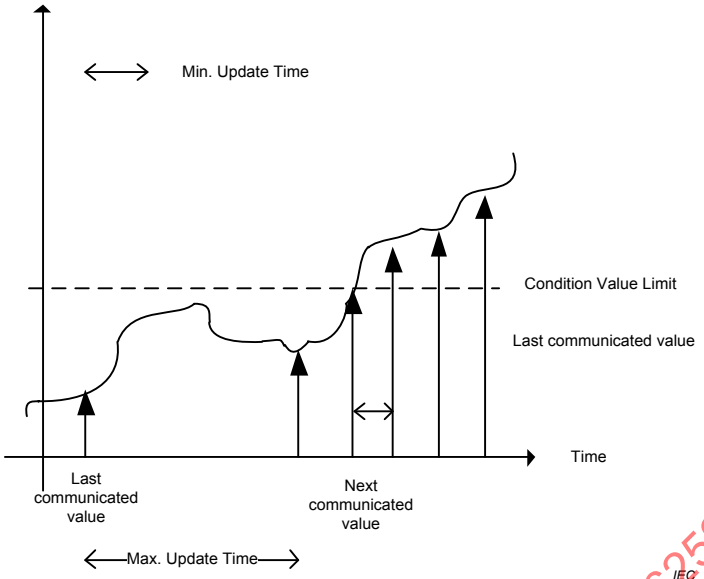

Figure 47 – Level trigger mode

In "Falling" mode is similar to "Rising" mode, the Publish Data Message shall be published when the source value is below the threshold established by the trigger value.

8.3.3.30 Read publish data mode configuration FAL PDU

8.3.3.30.1 Request primitive

The value of Command is one hundred and five (105); the value of Octet count field is zero (0) or one (1). If the request has one octet, then the request Value field is shown in Table 102.

Table 102 – Read publish data mode configuration request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Publish data message ref	This is used to refer to one set of publish data in all read and write requests and responses for that set

8.3.3.30.2 Response primitive

The Value field of response is shown in Table 103. The Response code values are shown in Table 104.

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Table 103 – Read publish data mode configuration response value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Publish data mode control	Publish data mode control code as specified in Table F.2
1	Unsigned8	Command number expansion	31 (0x1F) or LSB of the Publish data command number – see Note
2	Unsigned8	Device variable code 0	Device variable code assigned to Slot 0
3	Unsigned8	Device variable code 1	Device variable code assigned to Slot 1
4	Unsigned8	Device variable code 2	Device variable code assigned to Slot 2
5	Unsigned8	Device variable code 3	Device variable code assigned to Slot 3
6	Unsigned8	Device variable code 4	Device variable code assigned to Slot 4
7	Unsigned8	Device variable code 5	Device variable code assigned to Slot 5
8	Unsigned8	Device variable code 6	Device variable code assigned to Slot 6
9	Unsigned8	Device variable code 7	Device variable code assigned to Slot 7
10	Unsigned8	Publish data message ref	Reference to one set of publish data in all read and write requests and responses for that set
11	Unsigned8	Max publish count	Maximum number of Publish data messages supported by the device
12	Unsigned16	Extended command number	Extended command number (see 8.3.2.2)
14	Time	Update period	The duration between two successive publication of the specified data, if the trigger conditions in Command 104 are met
18	Time	Maximum update period	The duration between two successive publication of the specified data, if the trigger conditions in Command 104 are not met
22	Enumeration	Trigger mode	Trigger mode selection code as specified in Table F.12
23	Enumeration	Device variable classification	Function performed by the device variable as specified in Table F.5
24	Engineering unit	Device variable unit	Measurement unit of the variable
25	Float32	Trigger level	Window or the level that is used to trigger the publishing
NOTE If the request has one octet, then this parameter is set to 31.			

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Table 104 – Read publish data mode configuration command specific response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command Error
9	Error	Invalid Publish data message ref
32	Error	Busy – a delayed response could not be started

8.3.3.30.3 Procedure at responding device

If the device receives a Request without data octets, it shall return the configuration of Publish data message ‘0’ and the LSB of the publish command number shall be returned in response data octet one (1).

If a slot is not configured to transmit a Device variable, that slot shall return "250" (not used) as Device variable code. If command 9 is to be published, then that slot's Device variable code shall meet the requirements according to command 9 (see 8.3.3.8).

If a device implements this Publish data mode, then it shall support at least three Publish data sets i.e. the minimum value of Max publish count shall be three (3).

8.3.3.31 Flush delayed responses FAL PDU

8.3.3.31.1 Request primitive

The value of Command is one hundred and six (106); the value of Octet count field is zero (0) and Value field is null.

8.3.3.31.2 Response primitive

The Value field of response is null. The Response code values are shown in Table 105.

Table 105 – Flush delayed responses command specific Response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command error
8	Warning	All but running delayed responses flushed
16	Error	Access restricted
32	Error	Busy

8.3.3.31.3 Procedure at responding device

This command clears all pending delayed responses for the Master that issued the command. Delayed responses currently running that cannot be interrupted or aborted may be completed. If this is the case, then the Slave shall respond with “All but running delayed responses flushed”.

Devices should support a minimum of two DR buffers (one for each Master). If only one DR buffer is supported then this command shall flush the DR buffer even if it is in use by the other Master that did not send the flush request.

8.3.3.32 Write publish data device variables FAL PDU

8.3.3.32.1 Request primitive

The value of Command is one hundred and seven (107); the value of Octet count field is either (5), or nine (9) and Value field is as shown in Table 106.

Table 106 – Write publish data mode configuration value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Device variable code 0	Device variable code assigned to Slot 0
1	Unsigned8	Device variable code 1	Device variable code assigned to Slot 1
2	Unsigned8	Device variable code 2	Device variable code assigned to Slot 2
3	Unsigned8	Device variable code 3	Device variable code assigned to Slot 3
4	Unsigned8	Device variable code 4	Device variable code assigned to Slot 4
5	Unsigned8	Device variable code 5	Device variable code assigned to Slot 5
6	Unsigned8	Device variable code 6	Device variable code assigned to Slot 6
7	Unsigned8	Device variable code 7	Device variable code assigned to Slot 7
8	Unsigned8	Publish data message ref	Reference to one set of publish data in all read and write requests and responses for that set
NOTE The value returned in the response data octets reflects the value actually used by the device.			

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8.3.3.32.2 Response primitive

The Value field of response is shown in Table 106. The Response code values are shown in Table 107.

Table 107 – Write publish data device variables command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
6	Error	Device-specific command Error
7	Error	In write protect mode
8	Warning	Publish data condition conflict
9	Error	Invalid Publish data message ref
16	Error	Access restricted

8.3.3.32.3 Procedure at responding device

The Device variables codes received in the request shall be used by a publishing device for a Command 9 or 33 in Publish data mode. The master shall always send either five (5) or nine (9) data octets in the request. If any of the Device variables codes starting with slot 1 is ‘250’ (not used), then the Command 9 or Command 33 response shall be truncated starting with the first slot that has a value of ‘250’ (not used). For command 33 only first four slots shall be used. If the request has only five (5) data octets, then Device variables code for slots 4 to 7 shall be set to ‘250’ (not used).

If the Trigger mode (see Table 99) for the Publish data message ref in this request is non-zero and the trigger source's Device variable classification does not match the new Device variable code assigned to Slot 0, then the value from this request shall be accepted and Response code "Publish data condition conflict" shall be returned; the field device shall correct the classification, unit codes, set Trigger mode to publish continuously at the Update period until it receives another Command 104.

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8.3.3.33 Write publish data mode command number FAL PDU

8.3.3.33.1 Request primitive

The value of Command is one hundred and eight (108); the value of Octet count field is either three (3) as shown in Table 108 or one (1) as shown in Table 109.

Table 108 – Write publish data mode command number value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Publish command number	16-bit Command Number of the response message to be transmitted in Publish data mode
2	Unsigned8	Publish data message ref	Reference to one set of publish data in all read and write requests and responses for that set
NOTE The value returned in the response data octets reflects the value actually used by the device.			

Table 109 – Write publish data mode command number value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Publish command number	8-bit Command Number of the response message to be transmitted in Publish data mode
NOTE The value returned in the response data octets reflects the value actually used by the device.			

8.3.3.33.2 Response primitive

The Value field of response is shown in Table 108 and Table 109. The Response code values are shown in Table 110.

Table 110 – Write publish data mode command number command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
6	Error	Device-specific command Error
7	Error	In write protect mode
8	Warning	Publish data condition conflict
9	Error	Invalid Publish data message ref
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

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8.3.3.33.3 Procedure at responding device

The permitted values for Publish command number are {1, 2, 3, 9, 33, and 48}. All devices shall support all of these values except 33. If the device implements the optional command 33, then it shall also support this value of Publish command number. If a field device receives only one data octet in the request, it shall assume the value of Publish data message ref is ‘0’; and it shall treat the request as a single octet command number and respond with only a single octet in the response.

If the Trigger mode (see Table 99) for the Publish data message ref in this request is non-zero and the trigger source's Device variable classification does not match the command number in this request, then the value from this request shall be accepted and Response code "Publish data condition conflict" shall be returned; the field device shall correct the classification, unit codes, set Trigger mode to publish continuously at the Update period until it receives another Command 104.

After the publishing is enabled (see 8.3.3.34), the device shall publish the response to “Publish command number” using Information report service.

8.3.3.34 Write publish data mode control FAL PDU

8.3.3.34.1 Request primitive

The value of Command is one hundred and nine (109); the value of Octet count field is either one (1) – the first field, or two (2) – both fields, as shown in Table 111.

Table 111 – Write publish data mode control value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Publish data mode control	Publish data mode control code as specified in Table F.2
1	Unsigned8	Publish data message ref	Reference to one set of publish data in all read and write requests and responses for that set

8.3.3.34.2 Response primitive

The Value field of response is shown in Table 111. The Response code values are shown in Table 112.

Table 112 – Write publish data mode control command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
6	Error	Device-specific command Error
7	Error	In write protect mode
8	Warning	Update period increased
9	Error	Insufficient bandwidth
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

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8.3.3.34.3 Procedure at responding device

This command is used to enable or disable the Publish data mode for devices. This command affects data-link layer operation. All data-link layer requirements for entering and exiting Publish Data mode shall be met.

If the request is for enabling the publishing, then the responding device shall perform the following procedure.

- If the responding device does not have capacity currently scheduled for publishing the data set specified for Publish data message ref, then it shall respond with “DR initiated”.
- The device shall send “Request timetable FAL PDU” request (see 8.3.4.31.1) to the network manager for publishing data. The network manager is expected to send response to “Request timetable FAL PDU” with “DR initiated” and to start processing the request. The network manager then:
  - allocates the network resources for the publish service;

– if required, sends “Write superframe FAL PDU” request (see 8.3.6.6.1) to set up a superframe; and

– sends “Write link FAL PDU” request (see 8.3.6.8.1) to set up a Link within the superframe.

NOTE 1 The network manager also sends request to other network devices to add superframe and Link for publishing.

- In most cases, the network manager sets up links in an existing superframe to satisfy this request. Once the network has been configured, the network manager returns a response to the “Request timetable FAL PDU” indicating that the request has been completed.
- After receiving this response the device shall send a response indicating success.
- If the response from the network manager to the “Request timetable FAL PDU” indicates that the request cannot be met, then the device shall respond indicating “Insufficient bandwidth”.
- If the responding device has sufficient capacity currently scheduled for publishing the data set specified for Publish data message ref, then the device shall send a response indicating success.

If the request is for disabling the publishing then the responding device shall perform the following procedure.

- The responding device shall respond with “Success”.
- The device shall send “Delete timetable FAL PDU” request (see 8.3.4.33.1) to the network manager. The network manager is expected to start processing the request. The network manager then:

  – de-allocates the network resources for the publish service;

  – sends “Delete link FAL PDU” request (see 8.3.6.9.1) to remove the Link from the superframe; and

  – if required, sends “Delete superframe FAL PDU” request (see 8.3.6.7.1) to remove the superframe.

NOTE 2 The network manager also sends request to other network devices to delete superframe and Link that was used for publishing.

- Once the network resources have been de-allocated, the network manager returns a response to “Request timetable FAL PDU” indicating that the request has been completed.

If the device is denied the required network capacity to publish, it shall set the bit "Capacity denied" in the Standardized status (see 8.3.3.22.2 – command 48).

If there is only one octet in the request, then:

- If the device is build according to this standard and the value of this field is neither ‘0’ nor ‘1’, then the device shall respond with “Too few data octets received”;
- Else, the device shall assume that Publish data message ‘0’ is being activated or deactivated for publishing.

8.3.3.35 Read event notification summary FAL PDU

8.3.3.35.1 Request primitive

The value of Command is one hundred and fifteen (115); the value of Octet count field is one (1) as shown in Table 113.

Table 113 – Read event notification summary request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Event	This is used to refer to one set of event data in all read and write

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		number ref	requests and responses for that set

8.3.3.35.2 Response primitive

The Value field of response is shown in Table 114. The Response code values are shown in Table 115.

Table 114 – Read event notification summary response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Event number ref	Reference to one set of event data in all read and write requests and responses for that set
1	Unsigned8	Maximum event count	Maximum number of Event data messages supported by the device
2, bit 7	Bit Field	Event status	Event status as specified in Table F.14 – bits 7-4 at octet offset 2
2, bit 3	Bit Field	Event notification control	Event notification control code as specified in Table F.13 – bits 3-0 at octet offset 2
3	Time	Event occurrence time	Time when first unacknowledged event was triggered; 0xFFFFFFFF if no pending event
7	Time	Event notification retry time	Even notification retry time
11	Time	Maximum update time	Maximum update time
15	Time	Event de-bounce interval	Event de-bounce interval
19	Bit Field	Device status mask	Bits included in device status
20	Array of Bit Field (1 to 26)	Event mask	The concatenation of the mask for triggering on bits set to '1' in "Application process status" and command 48 response

Table 115 – Read event notification summary command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
6	Error	Device-specific command Error

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8.3.3.35.3 Procedure at responding device

This command reads the configuration of the Event notification. If the device supports fewer than maximum number of status fields described in command 48 responses (see Table 84), then the response to this request shall include Event mask for only those fields that are supported by the device.

8.3.3.36 Write event notification bit mask FAL PDU

8.3.3.36.1 Request primitive

The value of Command is one hundred and sixteen (116); the value of Octet count field is three (3) to twenty-eight (28) as shown in Table 116.

Table 116 – Write event notification bit mask value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Event number ref	Reference to one set of event data in all read and write requests and responses for that set
1	Bit Field	Device status mask	Bits included in device status
2	Array of Bit Field (1 to 26)	Event mask	The concatenation of the mask for triggering on bits set to '1' in "Application process status" and command 48 response

8.3.3.36.2 Response primitive

The Value field of response is shown in Table 116. The Response code values are shown in Table 117.

Table 117 – Write event notification bit mask command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
6	Error	Device-specific command Error
7	Error	In write protect mode
16	Error	Access restricted

8.3.3.36.3 Procedure at responding device

This command sets the Event mask that is used to trigger an Event notification. For each bit set to '1' in the Event mask, any change in the corresponding "Application process status" or Command 48 response value triggers an event notification. If the number of Event mask fields in the request is smaller than the Event mask fields supported by the device, then unspecified mask bits shall be considered as '0'.

The device shall retain Event mask through a device reset, self test or the power being removed and reapplied.

8.3.3.37 Write event notification timing FAL PDU

8.3.3.37.1 Request primitive

The value of Command is one hundred and seventeen (117); the value of Octet count field is thirteen (13) and Value field is as shown in Table 118.

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Table 118 – Write event notification timing value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Event number ref	Reference to one set of event data in all read and write requests and responses for that set
1	Time	Event notification retry time	Even notification retry time
5	Time	Maximum update time	Maximum update time
9	Time	Event de-bounce interval	Event de-bounce interval
NOTE The value returned in the response data octets reflects the value actually used by the device.			

8.3.3.37.2 Response primitive

The Value field of response is shown in Table 118. The Response code values are shown in Table 119.

Table 119 – Write event notification timing command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
6	Error	Device-specific command Error
7	Error	In write protect mode
8	Warning	Update time or de-bounce interval adjusted
9	Error	Invalid event notification timing request
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

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8.3.3.37.3 Procedure at responding device

This command sets the timing parameters for event notification. If the Event notification retry time is not less than or equal to the maximum update time, then the device shall adjust it. If necessary, the devices shall correct other timing values received in the request and respond with “Update time or de-bounce interval adjusted”.

The Event de-bounce interval sets the minimum time duration over which the status bit shall remain changed (i.e., the time the event shall persist) in a device before the Event notification is sent. The device shall scan for possible events at least twice during one Event de-bounce interval.

If there was no event generated during a Maximum update time, the device shall publish the Command 119 response one time to the gateway using Information report request.

The device shall retain Event notification timing parameters through a device reset, self test or the power being removed and reapplied.

8.3.3.38 Write event notification control FAL PDU

8.3.3.38.1 Request primitive

The value of Command is one hundred and eighteen (118); the value of Octet count field is two (2) as shown in Table 120.

Table 120 – Write event notification control value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Event number ref	Reference to one set of event data in all read and write requests and responses for that set
1	Bit Field	Event notification control	Event notification control code as specified in Table F.13

8.3.3.38.2 Response primitive

The Value field of response is shown in Table 120. The Response code values are shown in Table 121.

Table 121 – Write event notification control command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
6	Error	Device-specific command Error
7	Error	In write protect mode
8	Warning	Update times adjusted
9	Error	Invalid event notification timing request
14	Warning	Update time uncertain – only allowed when not connected to the network
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated – only allowed when enabling events in a device connected to a network according to this standard
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

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8.3.3.38.3 Procedure at responding device

This command is used to enable or disable Event notification. If a Type 20 compliant field device joins the network and is denied the required capacity for Event notification, it shall set the bit ‘Capacity denied’ in the Standardized status 3, see Table F.11. Capacity can be denied due to Publish data or Event notification demands.

The device shall retain Event notification mode control through a device reset, self test or the power being removed and reapplied.

8.3.3.39 Write event notification acknowledgement FAL PDU

8.3.3.39.1 Request primitive

The value of Command is one hundred and nineteen (119); the value of Octet count field is either one (1) or eight (8) to thirty-three (33) as shown in Table 122. If there is only one octet then it shall be Event number ref.

Table 122 – Write event notification acknowledgement value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Event number ref	Reference to one set of event data in all read and write requests and responses for that set
1	Time	Event occurrence time	Time when first unacknowledged event was triggered; '-1' when no events are pending
5	Unsigned16	Configuration change counter	Configuration change counter
7	Bit Field	Application process status	Application process status (see 8.3.1.4)
8	Array of Bit Field (1 to 25)	Additional device status	Command 48 data, see Note
NOTE Contains latched data and may not match current Command 48 response data.			

8.3.3.39.2 Response primitive

The Value field of response is shown in Table 122. The Response code values are shown in Table 123.

Table 123 – Write event notification acknowledgement command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received; generated only if the event number is not in the request data
6	Error	Device-specific command Error
8	Warning	Not all events cleared
16	Error	Access restricted

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8.3.3.39.3 Procedure at responding device

This command is used to acknowledge the Event notification. The device shall compare parameters values in the received acknowledgement to the current values for the same parameters in the device – Event occurrence time, Configuration change counter, "Application process status", and Additional device status. If all parameter values are equal, then the device shall respond with "Success" and clear the Event Status (see Table 114) bits to '0'. Since there may be multiple time-stamped bit transitions, the command shall only clear the oldest one. If not all bits are cleared to '0', then the device shall respond with "Not all events cleared". Although, this is a write command, but it shall not be affected by any write protect mechanism. It is essential that Event notifications can be cleared at any time.

The command is truncated after the last octet received when setting the Event mask (see Command 116 in 8.3.3.36). If any octets beyond those provided in Command 116 are

received in this command request, they shall be ignored and not returned in the command response. The latest values for “Application process status”, the Configuration change counter and the Command 48 response octets are always included in the Command 119.

This command may be issued with only the Event number ref in the request data. If this occurs, the device shall return the current latched event data as shown in Table 122 and shall not clear the Event Status bits to ‘0’.

The device shall store at least three (3) response messages (the current event being published using Command 119 and 2 more that are buffered). It is highly recommended that five (5) transitions be buffered. It is not necessary to save these through power cycles.

8.3.4 Layer management service specific APDU structures

8.3.4.1 Write Join_key FAL PDU

8.3.4.1.1 Request primitive

The value of Command is seven hundred and sixty-eight (768); the value of Octet count field is one (1) and value field is as shown in Table 124.

Table 124 – Write Join_key value field

Octet offset	Data type	Parameter name	Description
0	Security key	Join_key	This is 128-bit network key that is used for security

8.3.4.1.2 Response primitive

The Value field of response is shown in Table 124. The Response code values are shown in Table 125.

Table 125 – Write Join_key command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
6	Error	Device-specific command Error
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict
65	Error	Key change failed

8.3.4.1.3 Procedure at responding device

This command modifies the devices Join_key. The command may be issued by the network manager or entered via a local maintenance tool (for example a handheld). This command shall be accepted if received at any time from the network manager or via the local maintenance port. If received from any other source then the device shall respond with "Access Restricted".

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8.3.4.2 Read join status FAL PDU

8.3.4.2.1 Request primitive

The value of Command is seven hundred and sixty-nine (769); the value of Octet count field is zero (0) and Value field is null.

8.3.4.2.2 Response primitive

The Value field of response is shown in Table 126. The Response code values are shown in Table 127.

Table 126 – Read join status value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Wireless mode	Wireless mode as specified in Table F.27; the upper four bits shall be set to zero.
1	Bit Field	Join status	This 2-octet enumeration indicates join status as specified in Table F.28
3	Unsigned8	Neighbors	Number of available neighbors. The number of neighbors detected by the device.
4	Unsigned8	Advertising packets	Number of Advertising packets received
5	Unsigned8	Max_join_retries	Number of join attempts; too many join attempts results in the device considering the join failed
6	Time	Join_rsp_time	The amount of time since the last join request was sent
10	Time	Search time	The amount of time listening for first advertisement

Table 127 – Read join status command specific response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command Error

8.3.4.2.3 Procedure at responding device

This command allows a host system or handheld device to monitor a field device as it transitions through the joining process according to Clause A.2. If the device is not able to join the network, then the response to this command provides diagnostics assistance to an instrument technician or service person.

8.3.4.3 Write active_search_shed_time FAL PDU

8.3.4.3.1 Request primitive

The value of Command is seven hundred and seventy (770); the value of Octet count field is four (4) and value field is as shown in Table 128.

Table 128 – Write Active_search_shed_time request value field

Octet offset	Data type	Parameter name	Description
0	Time	Active_search_shed_time	Time duration for which the active search is enabled during join procedure

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8.3.4.3.2 Response primitive

The Value field of response is shown in Table 129. The Response code values are shown in Table 130.

Table 129 – Write Active_search_shed_time response value field

Octet offset	Data type	Parameter name	Description
0	Time	Active_search_shed_time	Time duration for which the active search is enabled during join procedure
4	Time	Advertise_time	Interval at which Advertise DLPDUs are transmitted
8	Unsigned8	Neighbors	Number of neighbors advertising in addition to this device

Table 130 – Write Active_search_shed_time command specific response codes

Value	Class	Description
0	Success	No error
3	Error	Passed parameter larger than permitted
4	Error	Passed parameter smaller than permitted
5	Error	Too few data octets received
6	Error	Device-specific command Error
8	Warning	Set to the nearest possible value
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict
65	Error	Request declined (for example operator overridden)

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8.3.4.3.3 Procedure at responding device

This command requests active and fast search – see A.2.3.2. Generally, this is received by a network device from a local maintenance tool (for example a handheld) and is propagated to the network manager. The network manager is expected to configure or turn on fast advertising in the device and one or more of its neighbors.

8.3.4.4 Write join mode configuration FAL PDU

8.3.4.4.1 Request primitive

The value of Command is seven hundred and seventy-one (771); the value of Octet count field is six (6) and value field is as shown in Table 131.

Table 131 – Write Join mode configuration value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Join mode	Join mode as specified in Table F.36
1	Time	Active_search_shed_time	Time duration for which the active search is enabled during join procedure
5	Unsigned8	max_join_retries	Maximum number of join retries

8.3.4.4.2 Response primitive

The Value field of response is shown in Table 131. The Response code values are shown in Table 132.

Table 132 – Write Join mode configuration command specific response codes

Value	Class	Description
0	Success	No error
3	Error	Passed parameter larger than permitted
4	Error	Passed parameter smaller than permitted
5	Error	Too few data octets received
6	Error	Device-specific command Error
7	Error	In write protect mode
8	Warning	Set to the nearest possible value
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict
65	Error	Request declined

8.3.4.4.3 Procedure at responding device

This command allows a host system or handheld device to force a field device into active join mode. The device shall stay in the active search mode for at least the Active_search_shed_time – see A.2.3.2. After this time has expired, the device may go into Deep Sleep or Ultra Low Power mode.

8.3.4.5 Read Join mode configuration FAL PDU

8.3.4.5.1 Request primitive

The value of Command is seven hundred and seventy-two (772); the value of Octet count field is zero (0) and Value field is null.

8.3.4.5.2 Response primitive

The Value field of response is shown in Table 133. The Response code values are shown in Table 134.

Table 133 – Read Join mode configuration response value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Join mode	Join mode as specified in Table F.36
1	Time	Active_search_shed_time	Time duration for which the active search is enabled during join procedure
5	Unsigned8	max_join_retries	Maximum number of join retries

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Table 134 – Read Join mode configuration command specific response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command Error
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started

8.3.4.5.3 Procedure at responding device

This command reads the Join mode and Active_search_shed_time.

8.3.4.6 Write network_ID FAL PDU

8.3.4.6.1 Request primitive

The value of Command is seven hundred and seventy-three (773); the value of Octet count field is two (2) and value field is as shown in Table 135.

Table 135 – Write network_ID value field request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	network_ID	Network identifier as defined in 3.2.72

8.3.4.6.2 Response primitive

The Value field of response is shown in Table 136. The Response code values are shown in Table 137.

Table 136 – Write network_ID value field response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	new network_ID	This is the new network identifier as defined in 3.2.72
2	Unsigned16	current network_ID	This is the current network identifier as defined in 3.2.72

Table 137 – Write network_ID command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
6	Error	Device-specific command Error
7	Error	In write protect mode
8	Warning	Network_ID change pending; new value shall be used for next join or upon restarting the network.
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict
65	Error	Invalid network_ID

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8.3.4.6.3 Procedure at responding device

This command configures the device to recognize the proper network_ID. If this command was not issued by the network manager or via the maintenance port, then the device shall respond with "Access Restricted".

If the device is not connected to the network, then the network_ID is changed immediately. The device should enter power save mode and wait for the join mode configuration command before beginning to actively search for the network.

Else, the new network_ID shall be used for next join process.

8.3.4.7 Read network_ID FAL PDU

8.3.4.7.1 Request primitive

The value of Command is seven hundred and seventy-four (774); the value of Octet count field is zero (0) and Value field is null.

8.3.4.7.2 Response primitive

The Value field of response is shown in Table 138. The Response code values are shown in Table 139.

Table 138 – Read network_ID value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	new Network_ID	New network identifier as defined in 3.2.72
2	Unsigned16	current Network_ID	Current network identifier as defined in 3.2.72

Table 139 – Read network_ID command specific response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command Error
8	Warning	Network identifier change pending
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started

8.3.4.7.3 Procedure at responding device

This command reads the current setting of the network_ID from the device.

8.3.4.8 Write network_tag FAL PDU

8.3.4.8.1 Request primitive

The value of Command is seven hundred and seventy-five (775); the value of Octet count field is thirty-two (32) and Value field is as shown in Table 140.

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Table 140 – Write Network_tag value field

Octet offset	Data type	Parameter name	Description
0 – 31	Latin-1	Network_tag	Long Tag to be stored in the device

8.3.4.8.2 Response primitive

The Value field of response is shown in Table 140. The Response code values are shown in Table 141.

Table 141 – Write Network_tag command specific Response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
6	Error	Device-specific command Error
7	Error	In write protect mode
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

8.3.4.8.3 Procedure at responding device

This command writes the tag for the network. The Network_tag is a proxy for the network_ID, so that the network can be identified in a text form at the application level.

8.3.4.9 Read network_tag FAL PDU

8.3.4.9.1 Request primitive

The value of Command is seven hundred and seventy-six (776); the value of Octet count field is zero (0) and Value field is null.

8.3.4.9.2 Response primitive

The Value field of response is shown in Table 142. The Response code values are shown in Table 143.

Table 142 – Read Network_tag response value field

Octet offset	Data type	Parameter name	Description
0 – 31	Latin-1	Long_tag	Long Tag stored in the device

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Table 143 – Read Network_tag command-specific response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command Error
16	Error	Access restricted
32	Error	Busy

8.3.4.10 Read wireless device capabilities FAL PDU

8.3.4.10.1 Request primitive

The value of Command is seven hundred and seventy-seven (777); the value of Octet count field is zero (0) and Value field is null.

8.3.4.10.2 Response primitive

The Value field of response is shown in Table 144. The Response code values are shown in Table 145.

Table 144 – Read wireless device capabilities value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Power source	Upper 4-bits (7-4) represent the wireless capability as specified in Table F.39 Lower 4-bits (3-0) represent the Power Source as specified in Table F.20
1	Float32	Peak packet rate	Peak packets per second
5	Time	Load duration	Duration at peak packet load before power drained
9	Time	Recovery time	Time to recover from power drain
13	Integer8	Good RSL	RSL (Received Signal Level in dB) threshold for 'good' connection
14	Time	Min Keep_alive_time	Minimum required Keep_alive_time
18	Unsigned16	Neighbor count	Maximum number of neighbors
20	Unsigned16	Packet buffer	Maximum number of packet buffers

Table 145 – Read wireless device capabilities command specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

8.3.4.10.3 Procedure at responding device

This PDU is used by the network manager to determine operational characteristics of a network device. The network manager is expected to use Peak packet rate and Recovery time to accommodate rechargeable or power scavenging devices.

Battery operated devices shall be able to sustain the peak packet rate for the specified lifetime of the device. The Load duration shall be at least one hour. If this parameter is not applicable, then its value shall be set to twenty-four hours.

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While the device is recovering from the power drain, it shall be able to route one packet per second. If this parameter is not applicable, then its value shall be set to zero.

8.3.4.11 Read battery life FAL PDU

8.3.4.11.1 Request primitive

The value of Command is seven hundred and seventy-eight (778); the value of Octet count field is zero (0) and Value field is null.

8.3.4.11.2 Response primitive

The Value field of response is shown in Table 146. The Response code values are shown in Table 147.

Table 146 – Read battery life response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Battery life	Battery Life remaining in days

Table 147 – Read battery life command-specific response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command Error
32	Error	Busy

8.3.4.11.3 Procedure at responding device

This PDU is used to determine the current state of the battery in a network device. If the device does not have a battery or other energy storage component, then the device may return 0xFFFF as the value of Battery life.

Careful design analysis of long-term battery performance is recommended to properly implement this command.

8.3.4.12 Report device health FAL PDU

8.3.4.12.1 Request primitive

There is no request primitive for this Command.

8.3.4.12.2 Response primitive

The value of Command is seven hundred and seventy-nine (779); the Value field of response is shown in Table 148. The Response code values are shown in Table 149.

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Table 148 – Report device health response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Packets generated	Number of packets generated by this device
2	Unsigned16	Packets terminated	Number of packets terminated by this device
4	Unsigned8	DLL MIC failures	Number of DLL MAC MIC failures detected
5	Unsigned8	NL MIC failures	Number of NL (session) MIC failures detected
6	Enumeration	Power status	Power Status as specified by in Table F.33
7	Unsigned8	CRC errors	Number of CRC errors detected
8	Unsigned8	Packets missed	Number of packets detected as missing
9	Unsigned8	Maximum buffer queue	Maximum buffer queue length since report last published
10	Float32	Average buffer queue	Average buffer queue length over time (rolling average)
14	Time	Average latency	Average latency of all packets from the gateway and network manager since last join
18	Time	Variance of latency	Variance of latency of all packets from the gateway and network manager since last join
22	Unsigned32	Packets received	Number of packets received
26	Unsigned32	Packets late or lost	Number of late or lost packets
30	Unsigned8	Unknown session	Number of packets with unknown session

Table 149 – Report device health command specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

8.3.4.12.3 Procedure at responding device

This PDU is used by the field device to publish communication related counters as Information report. These counters shall be reset only just prior to the device joining the network. After that the counters shall be incremented and roll-over to zero upon overflow. Packets missed value is incremented for each zero in Nonce counter history that underflows.

This command shall be rejected with a response code of access restricted if the device is not joined to the network.

The device shall publish the report device health using Command level priority as information report.

8.3.4.13 Read neighbor health list FAL PDU

8.3.4.13.1 Request primitive

The value of Command is seven hundred and eighty (780); the value of Octet count field is two (2) and Value field is shown in Table 150.

Table 150 – Read neighbor health list request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Table index	Neighbor table index
1	Unsigned8	Entry count	Number of neighbor entries to be read

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8.3.4.13.2 Response primitive

The Value field of response is shown in Table 151. The Response code values are shown in Table 152.

Table 151 – Read neighbor health list response value field

Octet offset[a]	Data type	Parameter name	Description
0	Unsigned8	Table index	Neighbor table index
1	Unsigned8	Entry count	Number of neighbor entries in the response
2	Unsigned8	Neighbor count	Total number of neighbors linked or not in the neighbor table
3	Unsigned16	Neighbor_nickname	Nickname of neighbor as defined in 3.2.74
5	Bit Field	Neighbor flags	Neighbor Flags as specified in Table F.34
6	Integer8	Average_RSL	Average RSL (received signal level in dBm) since last report
7	Unsigned16	Packets_transmitted	Number of packets transmitted to this neighbor
9	Unsigned16	Missed_ACK_packets	Failed transmission to this neighbor – number of packets expecting an ACK and none received
11	Unsigned16	Packets_received	Number of packets received from this neighbor
13..			

[a] The fields from octet number 3 to 12 are repeated as many times as the value of Neighbor count.

Table 152 – Read neighbor health list command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
8	Warning	Set to the nearest possible value
16	Error	Access restricted

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8.3.4.13.3 Procedure at responding device

This command reads the entries in the Neighbor table from the network device. Neighbors with links to device are expected at the beginning of the list and neighbors without links at the end. The neighbor table is a list with entries being deleted as a neighbor stops communication or added as a new neighbor is detected. Table index and Entry count change following addition or deletion of a neighbor. Therefore, if the parameter(s) in the request are invalid, the device shall respond with the nearest valid value of the parameter(s) and send the response code “Set to the nearest possible value”.

The device shall send this response to a read request. The device shall publish the neighbor health list using Command level priority as information report. The publishing period is set by configuring “Health report” time using Command 795 (see 8.3.4.27).

Packet counters shall be reset only just prior to the device joining the network. After that the counters shall be incremented and roll-over to zero upon overflow.

This PDU is also used by the field device to publish neighbor health as Information report.

8.3.4.14 Read device nickname FAL PDU

8.3.4.14.1 Request primitive

The value of Command is seven hundred and eight-one (781); the value of Octet count field is zero (0) and Value field is null.

8.3.4.14.2 Response primitive

The Value field of response is shown in Table 153. The Response code values are shown in Table 154.

Table 153 – Read device nickname response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Device nickname	Nickname of the device as defined in 3.2.74

Table 154 – Read device nickname command-specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

8.3.4.14.3 Procedure at responding device

This command reads a network device's Nickname (short address).

8.3.4.15 Read session list FAL PDU

8.3.4.15.1 Request primitive

The value of Command is seven hundred and eighty-two (782); the value of Octet count field is two (2) and Value field is shown in Table 155.

Table 155 – Read session list request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Table index	Session table index
1	Unsigned8	Entry count	Number of session entries to be read (shall be set to 1)

8.3.4.15.2 Response primitive

The Value field of response is shown in Table 156. The Response code values are shown in Table 157.

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Table 156 – Read session list response value field

Octet offset[a]	Data type	Parameter name	Description
0	Unsigned8	Table index	Session table index
1	Unsigned8	Entry count	Number of session entries in the response
2	Unsigned8	Session count	Total number of active sessions
3	Enumeration	Session_type	Session_type as specified in Table F.24
4	Unsigned16	Peer_nickname	Nickname of the correspondent device
6	Unique ID	Peer_unique_ID	Unique ID of correspondent device as defined in 3.2.105
11	Unsigned32	Peer_nonce_counter	Largest nonce counter value received from the correspondent device
15	Unsigned32	My_nonce_counter	Nonce counter for packets sourced by the device
19..			

[a] The fields from octet number 3 to 18 are repeated as many times as the value of Session count.

Table 157 – Read session list command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
8	Warning	Set to the nearest possible value
16	Error	Access restricted

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8.3.4.15.3 Procedure at responding device

This command reads the entries in the Session table from the network device. The Session table is a list with entries being deleted or added. Session index and Entry count change following addition or deletion of a session. Therefore, if the parameter(s) in the request are invalid, the device shall respond with the nearest valid value of the parameter(s) and send the response code “Set to the nearest possible value”.

8.3.4.16 Read superframe list FAL PDU

8.3.4.16.1 Request primitive

The value of Command is seven hundred and eighty-three (783); the value of Octet count field is two (2) and Value field is shown in Table 158.

Table 158 – Read superframe list request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Table index	Superframe table index
1	Unsigned8	Entry count	Number of superframe entries to be read (shall be set to 1)

8.3.4.16.2 Response primitive

The Value field of response is shown in Table 159. The Response code values are shown in Table 160.

Table 159 – Read superframe list response value field

Octet offset[a]	Data type	Parameter name	Description
0	Unsigned8	Table index	Superframe table index
1	Unsigned8	Entry count	Number of superframe entries in the response
2	Unsigned8	Superframe count	Total number of active superframes
3	Unsigned8	Superframe_ID	Identification number assigned to the superframe
4	Unsigned16	Num_Slots	Number of slots in this superframe i.e. size of superframe
6	Bit Field	Superframe mode	Superframe mode flags as specified in Table F.23
7..			

[a] The fields from octet number 3 to 6 are repeated as many times as the value of Superframe count.

Table 160 – Read superframe list command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid Section
5	Error	Too few data octets received
8	Warning	Set to the nearest possible value
16	Error	Access restricted

8.3.4.16.3 Procedure at responding device

This command reads the entries in the superframe table from the network device. The superframe table is a list with entries being deleted or added. Superframe index and Entry count change following addition or deletion of a superframe. Therefore, if the parameter(s) in the request are invalid, the device shall respond with the nearest valid value of the parameter(s) and send the response code “Set to the nearest possible value”.

8.3.4.17 Read link list FAL PDU

8.3.4.17.1 Request primitive

The value of Command is seven hundred and eighty-four (784); the value of Octet count field is three (3) and Value field is shown in Table 161.

Table 161 – Read link list request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Table index	Link table index
2	Unsigned8	Entry count	Number of Link entries to be read (shall be set to 1)

8.3.4.17.2 Response primitive

The Value field of response is shown in Table 162. The Response code values are shown in Table 163.

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Table 162 – Read link list response value field

Octet offset[a]	Data type	Parameter name	Description
0	Unsigned16	Table index	Link table index
2	Unsigned8	Entry count	Number of Link entries in the response
3	Unsigned16	Link count	Total number of active Links
5	Unsigned8	Link_ID	Identification number assigned to this Link
6	Unsigned16	Slot	Slot number in superframe assigned to this link
8	Unsigned8	Channel_Offset	Initial frequency hopping channel offset
9	Unsigned16	Neighbor_nickname	Nickname of neighbor for this link, or 0xFFFF if broadcast link
11	Bit Field	Link options	Link options as specified in Table F.22
12	Enumeration	Link_type	Link_type as specified in Table F.21
13..			
[a] The fields from octet number 5 to 12 are repeated as many times as the value of Link count.			

Table 163 – Read link list command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
8	Warning	Set to the nearest possible value
16	Error	Access restricted

8.3.4.17.3 Procedure at responding device

This command reads the entries in the Link table from the network device. The Link table is a list with entries being deleted or added. Link index and Entry count change following addition or deletion of a Link. Therefore, if the parameter(s) in the request are invalid, the device shall respond with the nearest valid value of the parameter(s) and send the response code “Set to the nearest possible value”.

8.3.4.18 Read graph list FAL PDU

8.3.4.18.1 Request primitive

The value of Command is seven hundred and eighty-five (785); the value of Octet count field is one (1) and Value field is shown in Table 164.

Table 164 – Read graph list request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Table index	Graph table index

8.3.4.18.2 Response primitive

The Value field of response is shown in Table 165. The Response code values are shown in Table 166.

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Table 165 – Read graph list response value field

Octet offset[a]	Data type	Parameter name	Description
0	Unsigned8	Table index	Graph table index
1	Unsigned8	Graph count	Total number of graphs currently configured
2	Unsigned16	Graph_ID	Identification number assigned to this Graph
4	Unsigned8	Neighbor count	Number of neighbors specified for this Graph_ID
5	Unsigned16	Neighbor_nickname	Nickname of neighbor for this graph
7..			
[a] The fields from octet number 5 to 6 are repeated as many times as the value of Neighbor count.			

Table 166 – Read graph list command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
8	Warning	Set to the nearest possible value
16	Error	Access restricted

8.3.4.18.3 Procedure at responding device

This command reads one item in the Graph table from the network device. The index is for reference only and the referenced graph may change, if a graph before it on the list is deleted. Therefore, if the parameter in the request is invalid, the device shall respond with the nearest valid value of the parameter and send the response code “Set to the nearest possible value”.

8.3.4.19 Read neighbor attribute flag FAL PDU

8.3.4.19.1 Request primitive

The value of Command is seven hundred and eighty-six (786); the value of Octet count field is two (2) and Value field is shown in Table 167.

Table 167 – Read neighbor attribute flag request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Neighbor_nickname	Nickname of neighbor as defined in 3.2.74

8.3.4.19.2 Response primitive

The Value field of response is shown in Table 168. The Response code values are shown in Table 169.

Table 168 – Read neighbor attribute flag response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Neighbor_nickname	Nickname of neighbor as defined in 3.2.74
2	Bit Field	Neighbor flags	Neighbor attributes as specified in Table F.34

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Table 169 – Read neighbor attribute flag command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	Unknown Neighbor_nickname

8.3.4.19.3 Procedure at responding device

This command reads the attributes of a neighbor from the network device.

8.3.4.20 Read neighbor signal level FAL PDU

8.3.4.20.1 Request primitive

The value of Command is seven hundred and eighty-seven (787); the value of Octet count field is two (2) and Value field is shown in Table 170.

Table 170 – Read neighbor signal level request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Table index	Neighbor table index
1	Unsigned8	Entry count	Number of neighbor entries to be read

8.3.4.20.2 Response primitive

The Value field of response is shown in Table 171. The Response code values are shown in Table 172.

Table 171 – Read neighbor signal level response value field

Octet offset[a]	Data type	Parameter name	Description
0	Unsigned8	Table index	Neighbor table index
1	Unsigned8	Entry count	Number of neighbor entries in the response
2	Unsigned8	Neighbor count	Total number of neighbors
3	Unsigned16	Neighbor_nickname	Nickname of neighbor as defined in 3.2.74
5	Integer8	Average_RSL	Average RSL (received signal level in dBm) of neighbor
6..			
[a] The fields from octet number 3 to 5 are repeated as many times as the value of Neighbor count.			

Table 172 – Read neighbor signal level command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
8	Warning	Set to the nearest possible value
16	Error	Access restricted

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8.3.4.20.3 Procedure at responding device

This command reads the signal level in the Neighbor table from the network device. The neighbor table is a list with entries being deleted as a neighbor stops communication or added as a new neighbor is detected. Table index and Entry count change following addition or deletion of a neighbor. Therefore, if the parameter(s) in the request are invalid, the device shall respond with the nearest valid value of the parameter(s) and send the response code “Set to the nearest possible value”. The list contains all neighbors.

The device shall send this response to a read request. In addition, the device shall publish the Neighbor signal level using "Command " level priority as Information report. The neighbors communicated in this manner are the discovered but not linked neighbors. The publishing period is set by configuring “Health report” time using Command 795 (see 8.3.4.27).

8.3.4.21 Report path down alarm FAL PDU

8.3.4.21.1 Request primitive

There is no request primitive for this service. The value of Command is seven hundred and eighty-eight (788).

8.3.4.21.2 Response primitive

The Value field of response is shown in Table 173. The Response code values are shown in Table 174.

Table 173 – Report path down alarm response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Neighbor_nickname	Nickname of neighbor as defined in 3.2.74

Table 174 – Report path down alarm command specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

8.3.4.21.3 Procedure at responding device

If the device cannot communicate with one of its neighbor for a time exceeding Path_fail_time, it shall publish the path down alarm response using "Command" level priority as Information report. The Path_fail_time is configured by Command 795 (see 8.3.4.27).

8.3.4.22 Report source route failed alarm FAL PDU

8.3.4.22.1 Request primitive

There is no request primitive for this service. The value of Command is seven hundred and eighty-nine (789).

8.3.4.22.2 Response primitive

The Value field of response is shown in Table 175. The Response code values are shown in Table 176.

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Table 175 – Report source route failed alarm response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Unreachable neighbor	Nickname of unreachable neighbor in the source route
2	Unsigned32	NL MIC	Network layer MIC from the NPDU that failed routing

Table 176 – Report source route failed alarm command specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

8.3.4.22.3 Procedure at responding device

If the device detects a source route failure, it shall publish the source route failed alarm response using "Command" level priority as Information report.

8.3.4.23 Report graph route failed alarm FAL PDU

8.3.4.23.1 Request primitive

There is no request primitive for this service. The value of Command is seven hundred and eighty-ninety (790).

8.3.4.23.2 Response primitive

The Value field of response is shown in Table 177. The Response code values are shown in Table 178.

Table 177 – Report graph route failed alarm response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Graph_ID	Graph_ID of the failed route

Table 178 – Report graph route failed alarm command specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

8.3.4.23.3 Procedure at responding device

If the device detects a graph route failure, it shall publish the graph route failed alarm response using "Command" level priority as Information report.

8.3.4.24 Report transport layer failed alarm FAL PDU

8.3.4.24.1 Request primitive

There is no request primitive for this service. The value of Command is seven hundred and ninety-one (791).

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8.3.4.24.2 Response primitive

The Value field of response is shown in Table 179. The Response code values are shown in Table 180.

Table 179 – Report transport layer failed alarm response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Unreachable peer	Nickname of unreachable peer in the end-to-ends transport layer

Table 180 – Report transport layer failed alarm command specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

8.3.4.24.3 Procedure at responding device

If the device detects a session failure, it shall publish the transport layer connection failed alarm response using "Command" level priority as Information report.

8.3.4.25 Write UTC time mapping FAL PDU

8.3.4.25.1 Request primitive

The value of Command is seven hundred and ninety-three (793); the value of Octet count field is seven (7) and value field is as shown in Table 181.

Table 181 – Write UTC time mapping value field

Octet offset	Data type	Parameter name	Description
0	Date	Date	Date
3	Time	Time of day	Time of day

8.3.4.25.2 Response primitive

The Value field of response is shown in Table 181. The Response code values are shown in Table 182.

Table 182 – Write UTC time mapping command specific response codes

Value	Class	Description
0	Success	No error
3	Error	Passed parameter too large
5	Error	Too few data octets received
9	Error	Invalid date code detected
16	Error	Access restricted

8.3.4.25.3 Procedure at responding device

This command sets the date and time received in the request as the instance in time when the ASN zero started. The date and time in the request can be UTC time or local time or any other

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time that the requester uses. If this command was not issued by the network manager, then the device shall respond with "Access Restricted".

8.3.4.26 Read UTC time mapping FAL PDU

8.3.4.26.1 Request primitive

The value of Command is seven hundred and ninety-four (794); the value of Octet count field is zero (0) and Value field is null.

8.3.4.26.2 Response primitive

The Value field of response is shown in Table 183. The Response code values are shown in Table 184.

Table 183 – Read UTC time mapping response value field

Octet offset	Data type	Parameter name	Description
0	Date	Date	Date
3	Time	Time of day	Time of day

Table 184 – Read UTC time mapping command specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

8.3.4.26.3 Procedure at responding device

This command reads the time when the ASN zero started, as set in the network device.

8.3.4.27 Write timer interval FAL PDU

8.3.4.27.1 Request primitive

The value of Command is seven hundred and ninety-five (795); the value of Octet count field is five (5) and value field is as shown in Table 185.

Table 185 – Write timer interval value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Timer_type	Timer type as specified in Table F.19
1	Unsigned32	Interval	Timer interval in ms

8.3.4.27.2 Response primitive

The Value field of response is shown in Table 185. The Response code values are shown in Table 186.

Table 186 – Write timer interval command specific response codes

Value	Class	Description
0	Success	No error

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Value	Class	Description
3	Error	Passed parameter larger than permitted by the device
4	Error	Passed parameter smaller than permitted by the device
5	Error	Too few data octets received
6	Error	Device-specific command Error
8	Warning	Set to the nearest possible value
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict
65	Error	Invalid Timer_type

8.3.4.27.3 Procedure at responding device

This command sets the time interval for the timer specified by Timer_type in a network device.

8.3.4.28 Read timer interval FAL PDU

8.3.4.28.1 Request primitive

The value of Command is seven hundred and ninety-six (796); the value of Octet count field is one (1) and Value field is shown in Table 187.

Table 187 – Read timer interval request value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Timer_type	Timer type as specified in Table F.19

8.3.4.28.2 Response primitive

The Value field of response is shown in Table 188. The Response code values are shown in Table 189.

Table 188 – Read timer interval response value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Timer_type	Timer type as specified in Table F.19
1	Unsigned32	Interval	Timer interval in ms

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Table 189 – Read timer interval command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
6	Error	Device-specific command Error
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
65	Error	Invalid Timer_type

8.3.4.28.3 Procedure at responding device

This command reads the time interval for the timer specified by Timer_type from a network device.

8.3.4.29 Write radio power output FAL PDU

8.3.4.29.1 Request primitive

The value of Command is seven hundred and ninety-seven (797); the value of Octet count field is one (1) and Value field is as shown in Table 190.

Table 190 – Write radio power output value field

Octet offset	Data type	Parameter name	Description
0	Integer8	Output power	Transmit power in dBm

8.3.4.29.2 Response primitive

The Value field of response is shown in Table 190. The Response code values are shown in Table 191.

Table 191 – Write radio power output command specific response codes

Value	Class	Description
0	Success	No error
3	Error	Passed parameter larger than permitted
4	Error	Passed parameter smaller than permitted
5	Error	Too few data octets received
6	Error	Device-specific command Error
7	Error	In write protect mode
8	Warning	Set to the nearest possible value
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

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8.3.4.29.3 Procedure at responding device

This command sets the radio power output for a device or gateway. If the device cannot accept the exact value sent from the application, it shall set it to the nearest value it can and shall respond with "Set to the nearest possible value". Every device shall support at least following -10 dBm, 0 dBm and +10 dBm values. If the responding device is connected to the network, and if this command was not issued by the network manager, then the device shall respond with "Access Restricted". Else, if the responding device is not connected to the network, and if this command was not received via the maintenance port, then the device shall respond with "Access Restricted".

8.3.4.30 Read radio power output FAL PDU

8.3.4.30.1 Request primitive

The value of Command is seven hundred and ninety-eight (798); the value of Octet count field is zero (0) and Value field is null.

8.3.4.30.2 Response primitive

The Value field of response is shown in Table 192. The Response code values are shown in Table 193.

Table 192 – Read radio power output response value field

Octet offset	Data type	Parameter name	Description
0	Integer8	Output power	Transmit power in dBm

Table 193 – Read radio power output command specific response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command Error
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started

8.3.4.30.3 Procedure at responding device

This command reads the radio power output from a device or gateway.

8.3.4.31 Request timetable FAL PDU

8.3.4.31.1 Request primitive

The value of Command is seven hundred and ninety-nine (799); the value of Octet count field is ten (10) and value field is as shown in Table 194.

Table 194 – Request TimeTable value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Timetable_ID	Timetable identifier supplied by and specific to requesting device; the value shall be in the range of 0x00 – 0x7F
1	Bit Field	Timetable_type	Timetable request flags as specified in Table F.15
2	Enumeration	Application_domain	Application domain as specified in Table F.16
3	Unsigned16	Peer_nickname	Nickname of the peer with which the Timetable is requested
5	Time	Service_duration	If Intermittent service, then latency else, (cyclical communications) period

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8.3.4.31.2 Response primitive

The Value field of response is shown in Table 195. The Response code values are shown in Table 196.

Table 195 – Response TimeTable value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Timetable_ID	Timetable identifier supplied by and specific to requesting device; the value shall be in the range of 0x00 – 0x7F
1	Bit Field	Timetable_type	Timetable request flags as specified in Table F.15
2	Enumeration	Application_domain	Application domain as specified in Table F.16
3	Unsigned16	Peer_nickname	Nickname of the peer with which the Timetable is requested
5	Time	Service_duration	If Intermittent service, then latency else, (cyclical communications) period
9	Unsigned8	Route_ID	Route identifier for this Timetable

Table 196 – Request TimeTable command specific response codes

Value	Class	Description
0	Success	No error
4	Error	Passed parameter smaller than permitted
5	Error	Too few data octets received
6	Error	Device-specific command Error
8	Warning	Set to the nearest possible value
14	Warning	Communication bandwidth supplied significantly less than requested (i.e. reduced more than setting to nearest value)
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict
65	Error	Timetable request denied
66	Error	Unknown Timetable_type
67	Error	Unknown Application_domain
68	Error	Unknown Peer_nickname
69	Error	Invalid Timetable_ID

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8.3.4.31.3 Procedure at responding device

This command shall be used by a wireless device to add a Timetable to another wireless device with specified bandwidth and latency characteristics. Error free response to this command indicates that the network manager has accepted the request and it will attempt to process the request. The Timetable_ID is unique only within the requesting device.

On a heavily utilized network the network manager may decline requests for communication bandwidth or provide significantly less bandwidth than requested. When this occurs the device shall set the "Capacity Denied" status in Standardized status 3 (see Table F.11) and the "More status available" bit in the “Application process status” octet. When the bandwidth

provided is less than (but greater than zero) desired the device shall continue requesting the bandwidth it needs once per health reporting interval.

If the device receives a "Write Timetable" (see Command 973) on the same Timetable_ID while awaiting a response to this command, the device shall reject the new “Write Timetable” command.

Host applications may send this command to the gateway to request additional bandwidth for communication with the specified device.

8.3.4.32 Read timetable list FAL PDU

8.3.4.32.1 Request primitive

The value of Command is eight hundred (800); the value of Octet count field is two (2) and Value field is shown in Table 197.

Table 197 – Read TimeTable list request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Table index	Timetable table index
1	Unsigned8	Entry count	Number of Timetable entries to be read

8.3.4.32.2 Response primitive

The Value field of response is shown in Table 198. The Response code values are shown in Table 199.

Table 198 – Read TimeTable list response value field

Octet offset[a]	Data type	Parameter name	Description
0	Unsigned8	Table index	Timetable table index
1	Unsigned8	Entry count	Number of Timetable entries in the response (shall be 1)
2	Unsigned8	Timetable count	Total number of active Timetables
3	Unsigned8	Timetable_ID	Timetable identifier of the entry
4	Bit Field	Timetable_type	Timetable request flags as specified in Table F.15
5	Enumeration	Application_domain	Application domain as specified in Table F.16
6	Unsigned16	Peer_nickname	Nickname of the peer with which the service is established
8	Time	Service_duration	If Intermittent service, then latency else, (cyclical communications) period
12	Unsigned8	Route_ID	Route identifier for this Timetable
13..			

[a] The fields from octet number 3 to 12 are repeated as many times as the value of Timetable count.

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Table 199 – Read TimeTable list command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid Selection
5	Error	Too few data octets received
6	Error	Device-specific command Error
8	Warning	Set to the nearest possible value
16	Error	Access Restricted

8.3.4.32.3 Procedure at responding device

This command reads the entries in the Timetable table from the network device. The Timetable table is a list with entries being deleted or added. Timetable index and Entry count change following addition or deletion of a Timetable. Therefore, if the parameter(s) in the request are invalid, the device shall respond with the nearest valid value of the parameter(s) and send the response code “Set to the nearest possible value”. If the Timetable index is larger than the maximum of Timetable currently in the device then the device shall return the last entry and set the response code to "Set to nearest possible value". The ‘Entry count’ shall be set to a valid value and the "Set to nearest possible value" response code returned.

8.3.4.33 Delete timetable FAL PDU

8.3.4.33.1 Request primitive

The value of Command is eight hundred and one (801); the value of Octet count field is two (2) and value field is as shown in Table 200.

Table 200 – Delete TimeTable request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Timetable_ID	Timetable identifier specific to the device
1	Enumeration	Reason	Reason for Timetable deletion as specified in Table F.25

8.3.4.33.2 Response primitive

The Value field of response is shown in Table 201. The Response code values are shown in Table 202.

Table 201 – Delete TimeTable response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Timetable_ID	Timetable identifier specific to the device
1	Enumeration	Reason	Reason for Timetable deletion as specified in Table F.25
2	Unsigned8	Timetable count	Total number of active Timetables remaining

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Table 202 – Delete TimeTable command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	Entry not found
66	Error	Invalid reason Code
67	Error	Reason code rejected, Timetable not deleted
68	Error	Delete not allowed – requestor not Timetable owner

8.3.4.33.3 Procedure at responding device

This command notifies a device of Timetable deletion. The delete operation may be caused by peer's request or because of network manager's decision. Only the creator of the Timetable can delete a Timetable. If the owner of the Timetable does not generate this command, the respondent shall reject the command and return the "Delete not allowed" response code.

8.3.4.34 Read route list FAL PDU

8.3.4.34.1 Request primitive

The value of Command is eight hundred and two (802), the value of Octet count field is two (2) and Value field is shown in Table 203.

Table 203 – Read route list request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Table index	Route table index
1	Unsigned8	Entry count	Number of route entries to be read (shall be set to 1)

8.3.4.34.2 Response primitive

The Value field of response is shown in Table 204. The Response code values are shown in Table 205.

Table 204 – Read route list response value field

Octet offset[a]	Data type	Parameter name	Description
0	Unsigned8	Table index	Route table index
1	Unsigned8	Entry count	Number of route entries in the response
2	Unsigned8	Route count	Total number of routes currently configured
3	Unsigned8	Routes remaining	Number of unused Route entries in the device
4	Unsigned8	Route_ID	Route identifier for this entry
5	Unsigned16	Destination nickname	Nickname of the route destination device
7	Unsigned16	Graph_ID	Graph_ID for this route
9	Unsigned8	Source route flag	Source route attached to this route – 1: Yes, 0: No
10..			
[a] The fields from octet number 3 to 9 are repeated as many times as the value of Route count.			

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Table 205 – Read route list command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
8	Warning	Set to the nearest possible value
16	Error	Access restricted

8.3.4.34.3 Procedure at responding device

This command reads the entries in the Route table from the network device. The Route table is a list with entries being deleted or added. Route index and Entry count change following addition or deletion of a Route. Therefore, if the parameter(s) in the request are invalid, the device shall respond with the nearest valid value of the parameter(s) and send the response code “Set to the nearest possible value”.

8.3.4.35 Read source route FAL PDU

8.3.4.35.1 Request primitive

The value of Command is eight hundred and three (803); the value of Octet count field is one (1) and Value field is shown in Table 206.

Table 206 – Read source route request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Route_ID	Route identifier for which source route has to be read

8.3.4.35.2 Response primitive

The Value field of response is shown in Table 207. The Response code values are shown in Table 208.

Table 207 – Read source route response value field

Octet offset[a]	Data type	Parameter name	Description
0	Unsigned8	Route_ID	Route identifier for which source route has to be read
1	Unsigned8	Hop count	Number of hops in this route
2	Unsigned16	Hop	Nickname for hop entry 0
4..			

[a] The fields from octet number 2 to 3 are repeated as many times as the value of Hop count.

Table 208 – Read source route command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection (bad Route_ID)
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	Entry not found (no Source route associated with Route_ID)

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8.3.4.35.3 Procedure at responding device

This command reads the contents of a particular Source route. Broadcast addresses are not legal address values in Source routes and shall not be included in any response for this command.

8.3.4.36 Read CCA mode FAL PDU

8.3.4.36.1 Request primitive

The value of Command is eight hundred and four (804); the value of Octet count field is zero (0) and Value field is null.

8.3.4.36.2 Response primitive

The Value field of response is shown in Table 209. The Response code values are shown in Table 210.

Table 209 – Read CCA mode response value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	CCA Mode	Clear Channel Assessment mode per Table F.40

Table 210 – Read CCA mode command specific response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command Error
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started

8.3.4.36.3 Procedure at responding device

This command reads Clear Channel Assessment (CCA) mode from a network device.

8.3.4.37 Write CCA mode FAL PDU

8.3.4.37.1 Request primitive

The value of Command is eight hundred and five (805); the value of Octet count field is one (1) and Value field is as shown in Table 211. The coding follows the IEEE 802.15.4:2011 coding. To leverage the extended range of CCA modes the NM should be upgraded. Once upgraded the NM will be able to utilize extended codings for new devices while at the same time maintaining backward compatibility with older devices. The NM will be able use its to knowledge of the version of the device or to select CCA modes or it can use the response code. If a value other than 0 or 1 is sent to an older device, the device will respond with Response Code 2 ("Invalid Selection"). Consequently, because of the use of RC's, the NM can adapt as needed. The coding is compliant with the IEEE 802.15.4 coding.

Table 211 – Write CCA mode value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	CCA Mode	Clear Channel Assessment mode per Table F.40

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8.3.4.37.2 Response primitive

The Value field of response is shown in Table 211. The Response code values are shown in Table 212.

Table 212 – Write CCA mode command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection for example, invalid CCA mode
5	Error	Too few data octets received
6	Error	Device-specific command Error
8	Warning	Set to nearest value
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started.
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

8.3.4.37.3 Procedure at responding device

This command writes the Clear Channel Assessment (CCA) mode in a network device. If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

8.3.4.38 Read handheld superframe FAL PDU

8.3.4.38.1 Request primitive

The value of Command is eight hundred and six (806); the value of Octet count field is zero (0) and Value field is null.

8.3.4.38.2 Response primitive

The Value field of response is shown in Table 213. The Response code values are shown in Table 214.

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Table 213 – Read handheld superframe response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Superframe_ID	Identification number assigned to the superframe
1	Unsigned16	Num_Slots	Number of slots in this superframe i.e. size of superframe
3	Bit Field	Superframe mode	Superframe mode flags as specified in Table F.23

Table 214 – Read handheld superframe command specific response codes

Value	Class	Description
0	Success	No error
9	Error	No handheld superframe
16	Error	Access restricted

8.3.4.38.3 Procedure at responding device

This command is used to determine if the handheld superframe in a network device is enabled.

8.3.4.39 Write handheld superframe FAL PDU

8.3.4.39.1 Request primitive

The value of Command is eight hundred and seven (807); the value of Octet count field is two (2) and Value field is as shown in Table 215.

Table 215 – Write handheld superframe value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Superframe_ID	Identification number assigned to the superframe
1	Bit Field	Superframe mode	Superframe mode flags as specified in Table F.23

8.3.4.39.2 Response primitive

The Value field of response is shown in Table 215. The Response code values are shown in Table 216.

Table 216 – Write handheld superframe command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection (for example invalid superframe mode)
5	Error	Too few data octets received
16	Error	Access restricted

8.3.4.39.3 Procedure at responding device

This command allows a handheld device to request that a network device enable the handheld superframe, so that maintenance can be done. The handheld superframe is used between a network device and a handheld device specifically for maintenance purposes.

8.3.4.40 Read packet hop-to-live FAL PDU

8.3.4.40.1 Request primitive

The value of Command is eight hundred and eight (808); the value of Octet count field is zero (0) and Value field is null.

8.3.4.40.2 Response primitive

The Value field of response is shown in Table 217. The Response code values are shown in Table 218.

Table 217 – Read packet hop-to-live response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Hop-to-live	Currently configured value of Hop-to-live

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Table 218 – Read packet hop-to-live command specific response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command Error
16	Error	Access restricted

8.3.4.40.3 Procedure at responding device

This command reads the current value of Hop-to-live configured for a network device.

8.3.4.41 Write packet hop-to-live FAL PDU

8.3.4.41.1 Request primitive

The value of Command is eight hundred and nine (809); the value of Octet count field is one (1) and Value field is as shown in Table 219.

Table 219 – Write packet hop-to-live value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Hop-to-live	Hop-to-live value

8.3.4.41.2 Response primitive

The Value field of response is shown in Table 219. The Response code values are shown in Table 220.

Table 220 – Write packet hop-to-live command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
6	Error	Device-specific command Error
8	Warning	Set to the nearest value
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

8.3.4.41.3 Procedure at responding device

This command writes the Hop-to-live value in a network device. If the Hop-to-live value received in the request is less than eight (8), then this value shall be changed to eight (8) and the response code “Set to the nearest value” shall be returned. If this command is received from any source other than the network manager, then the device shall reject this request with the response code of “Access Restricted”. This command is available via the maintenance port while not connected to the network.

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8.3.4.42 Read Join_priority FAL PDU

8.3.4.42.1 Request primitive

The value of Command is eight hundred and ten (810); the value of Octet count field is zero (0) and Value field is null.

8.3.4.42.2 Response primitive

The Value field of response is shown in Table 221. The Response code values are shown in Table 222.

Table 221 – Read Join_priority response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Join_priority	Join_priority at which the device shall advertise; lower number indicates a better choice for joining

Table 222 – Read Join_priority command specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

8.3.4.42.3 Procedure at responding device

This command reads the current value of Join_priority from a network device.

8.3.4.43 Write Join_priority FAL PDU

8.3.4.43.1 Request primitive

The value of Command is eight hundred and eleven (811); the value of Octet count field is one (1) and Value field is as shown in Table 223.

Table 223 – Write Join_priority value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Join_priority	Join_priority at which the device shall advertise; lower number indicates a better choice for joining

8.3.4.43.2 Response primitive

The Value field of response is shown in Table 223. The Response code values are shown in Table 224.

Table 224 – Write Join_priority command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
8	Warning	Set to the nearest value
16	Error	Access restricted

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8.3.4.43.3 Procedure at responding device

This command writes the Join_priority value in a network device. If the Join_priority value received in the request is more than fifteen (15), then this value shall be changed to fifteen (15) and the response code “Set to the nearest value” shall be returned. If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

8.3.4.44 Read receive Priority_threshold FAL PDU

8.3.4.44.1 Request primitive

The value of Command is eight hundred and twelve (812); the value of Octet count field is zero (0) and Value field is null.

8.3.4.44.2 Response primitive

The Value field of response is shown in Table 225. The Response code values are shown in Table 226.

Table 225 – Read receive Priority_threshold response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Priority_threshold	The lowest priority DLPDU to be accepted from another device

Table 226 – Read receive Priority_threshold command specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

8.3.4.44.3 Procedure at responding device

This command reads the current value of Receive Priority_threshold from a network device.

8.3.4.45 Write receive Priority_threshold FAL PDU

8.3.4.45.1 Request primitive

The value of Command is eight hundred and thirteen (813); the value of Octet count field is one (1) and Value field is as shown in Table 227.

Table 227 – Write receive Priority_threshold value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Priority_threshold	The lowest priority DLPDU to be accepted from another device

8.3.4.45.2 Response primitive

The Value field of response is shown in Table 227. The Response code values are shown in Table 228.

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Table 228 – Write receive Priority_threshold command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
8	Warning	Set to the nearest value
16	Error	Access restricted

8.3.4.45.3 Procedure at responding device

This command writes the Receive Priority_threshold value in a network device. The permitted values for this parameter are zero (0) to three (3). If any other value is received in the request, then the device shall set the parameter value to '3' and return the response "Set to the nearest value". If this command is received from any source other than the network manager, then the device shall reject this request with a response code of "Access Restricted".

8.3.4.46 Read device list FAL PDU

8.3.4.46.1 Request primitive

The value of Command is eight hundred and fourteen (814); the value of Octet count field is four (4) and Value field is shown in Table 229.

Table 229 – Read device list request value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Device code	Device list code as specified in Table F.30
1	Unsigned8	Entry count	Number of device entries to be read
2	Unsigned16	Table index	Device table starting index

8.3.4.46.2 Response primitive

The Value field of response is shown in Table 230. The Response code values are shown in Table 231.

Table 230 – Read device list response value field

Octet offset[a]	Data type	Parameter name	Description
0	Enumeration	Device code	Device list code as specified in Table F.30
1	Unsigned8	Entry count	Number of device entries in the response
2	Unsigned16	Table index	Device table starting index
4	Unsigned16	Device count	Total number of device entries in the table
6	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4
11..			
[a] The fields from octet number 6 to 10 are repeated as many times as the value of Device count.			

Table 231 – Read device list command specific response codes

Value	Class	Description
0	Success	No error

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Value	Class	Description
2	Error	Invalid selection i.e. Device list code not supported
5	Error	Too few data octets received
8	Warning	Set to the nearest possible value
16	Error	Access restricted

8.3.4.46.3 Procedure at responding device

A network device may maintain several Device tables with a list of devices. The currently supported Device tables are the lists indicated in Table F.30, for example, 'Active list', 'White list' and 'Black list'. This command reads the entries in the Device table for the type of list specified by Device code in the request. The Device table is a list of devices with entries being deleted or added. Device index and Entry count change following addition or deletion of a device. Therefore, if the Entry count or Table index parameter(s) in the request are invalid, the device shall respond with the nearest valid value of the parameter(s) and send the response code "Set to the nearest possible value".

The gateway and network manager shall maintain Device table for 'Active list' and support this command. The network manager should maintain Device table for 'White list' and 'Black list'. All network devices should maintain Device table for 'Black list'. If a network device does not maintain Device table for 'Black list' and the "device code" in request is for 'Black list', then it shall respond to this command with "Invalid selection".

8.3.4.47 Add device list entry FAL PDU

8.3.4.47.1 Request primitive

The value of Command is eight hundred and fifteen (815); the value of Octet count field is six (6) and Value field is shown in Table 232.

Table 232 – Add device list entry request value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Device code	Device list code as specified in Table F.30
1	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4

8.3.4.47.2 Response primitive

The Value field of response is shown in Table 233. The Response code values are shown in Table 234.

Table 233 – Add device list entry response value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Device code	Device list code as specified in Table F.30
1	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4
6	Unsigned16	Device count	Total number of entries remaining unconfigured or unused in the Device table

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Table 234 – Add device list entry command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection i.e. Device list code not supported
5	Error	Too few data octets received
6	Error	Device specific command error
7	Error	In write protect mode
8	Warning	Device already in list
16	Error	Access restricted
65	Error	No more entries available
66	Error	Device list conflict

8.3.4.47.3 Procedure at responding device

This command adds a device in the Device table for the type of list specified by Device code. The Device table for 'Active list' cannot be modified by this command. If the request tries to add a device that is in the 'Active list' to 'Black list', then the device shall reject the request and respond with "Device list conflict".

8.3.4.48 Delete device list entry FAL PDU

8.3.4.48.1 Request primitive

The value of Command is eight hundred and sixteen (816); the value of Octet count field is six (6) and Value field is shown in Table 235.

Table 235 – Delete device list entry request value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Device code	Device list code as specified in Table F.30
1	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4

8.3.4.48.2 Response primitive

The Value field of response is shown in Table 236. The Response code values are shown in Table 237.

Table 236 – Delete device list entry response value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Device code	Device list code as specified in Table F.30
1	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4
6	Unsigned16	Device count	Total number of entries remaining in the Device table

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Table 237 – Delete device list entry command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection i.e. Device list code not supported
5	Error	Too few data octets received
6	Error	Device specific command error
7	Error	In write protect mode
16	Error	Access restricted
66	Error	Device list conflict

8.3.4.48.3 Procedure at responding device

This command deletes a device in the Device table for the type of list specified by Device code in a gateway or network manager. If the device is being deleted from 'Active list', then the network manager shall reroute the traffic and disconnect the device. If the Unique ID is set to zero then the complete list content is flushed.

8.3.4.49 Read channel blacklist FAL PDU

8.3.4.49.1 Request primitive

The value of Command is eight hundred and seventeen (817); the value of Octet count field is zero (0) and Value field is null.

8.3.4.49.2 Response primitive

The Value field of response is shown in Table 238. The Response code values are shown in Table 239.

Table 238 – Read channel blacklist response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Channel count	Number of bits in current channel map array; this depends on the physical layer (for example for 2,4 GHz O-QPSK DSSS the array is 16-bits long i.e., 2-octets)
1 – n	Bit Field	Current channel map	Current channel map array; this is an array of bits starting with the least significant bit (bit 0 in octet 0) and adding octets as necessary until all bits are accounted for. Each bit corresponds to a channel. If the bit is '1', the channel will be used
n+1–2n	Bit Field	Pending channel map	Pending channel map array. Each bit corresponds to a channel. If the bit is '1', the channel will be used after the next restart of the network

The number of octets in channel map depends upon the total number of channels available in the physical layer.

Table 239 – Read channel blacklist command specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

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8.3.4.49.3 Procedure at responding device

This command reads the current channel blacklist and the blacklist that shall be used after the next restart.

8.3.4.50 Write channel blacklist FAL PDU

8.3.4.50.1 Request primitive

The value of Command is eight hundred and eighteen (818); the value of Octet count field is variable and Value field is shown in Table 240.

Table 240 – Write channel blacklist value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Channel count	Number of bits in new channel map array
1 – n	Bit Field	Pending channel map	Pending channel map array; this is an array of bits starting with the least significant bit (bit 0 in octet 0) and adding octets as necessary until all bits are accounted for. Each bit corresponds to a channel. If the bit is '1', the channel will be used after the next restart of the gateway or network manager

The number of octets in channel map depends upon the total number of channels available in the physical layer.

8.3.4.50.2 Response primitive

The Value field of response is shown in Table 240. The Response code values are shown in Table 241.

Table 241 – Write channel blacklist command specific response codes

Value	Class	Description
0	Success	No error
3	Error	Parameter value to be written is larger than permitted – number of bits exceeds maximum value
5	Error	Too few data octets received
6	Error	Device-specific command Error
7	Error	In write protect mode
16	Error	Access restricted
65	Error	Invalid frequency channel bits (for example channel 16 for 2,4 GHz according to IEEE 802.15.4 physical layer)

8.3.4.50.3 Procedure at responding device

This command writes the pending channel map, which is the blacklist to the gateway. This channel map shall come into effect only after the gateway and the network manager are restarted.

8.3.4.51 Read back-off exponent FAL PDU

8.3.4.51.1 Request primitive

The value of Command is eight hundred and nineteen (819); the value of Octet count field is zero (0) and Value field is null.

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8.3.4.51.2 Response primitive

The Value field of response is shown in Table 242. The Response code values are shown in Table 243.

Table 242 – Read back-off exponent response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Max_backoff_exp	The maximum value that can be assumed for the back-off exponent used in shared slots

Table 243 – Read back-off exponent command specific response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command Error
16	Error	Access restricted

8.3.4.51.3 Procedure at responding device

This command reads the current value of Max_backoff_exp from a network device.

8.3.4.52 Write back-off exponent FAL PDU

8.3.4.52.1 Request primitive

The value of Command is eight hundred and twenty (820); the value of Octet count field is one (1) and Value field is as shown in Table 244.

Table 244 – Write back-off exponent value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Max_backoff_exp	The maximum value that can be assumed for the back-off exponent used in shared slots

8.3.4.52.2 Response primitive

The Value field of response is shown in Table 244. The Response code values are shown in Table 245.

Table 245 – Write back-off exponent command specific response codes

Value	Class	Description
0	Success	No error
3	Error	Passed parameter larger than permitted
4	Error	Passed parameter smaller than permitted
5	Error	Too few data octets received
6	Error	Device-specific command Error
8	Warning	Set to the nearest value
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated

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Value	Class	Description
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

8.3.4.52.3 Procedure at responding device

This command writes the Max_backoff_exp value in a network device. If the Max_backoff_exp value received in the request is not one of the values in the set {4, 5, 6, 7}, then this value shall be changed to four (4) and the response code “Set to the nearest value” shall be returned. If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

8.3.4.53 Write network access mode FAL PDU

8.3.4.53.1 Request primitive

The value of Command is eight hundred and twenty-one (821); the value of Octet count field is one (1) and Value field is as shown in Table 246.

Table 246 – Write network access mode value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Network access mode	Network access mode code as specified in Table F.31

8.3.4.53.2 Response primitive

The Value field of response is shown in Table 246. The Response code values are shown in Table 247.

Table 247 – Write network access mode command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
6	Error	Device-specific command Error
7	Error	In write protect mode
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

8.3.4.53.3 Procedure at responding device

This command writes the network access mode value in a network device. This can be used to restrict the access to the network. All devices shall support values ‘0’ and ‘4’ for this parameter.

NOTE The network access mode does not substitute the check for the device’s credentials such as Join_key, tag or Device ID. The network access mode provides additional checks.

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8.3.4.54 Read network access mode FAL PDU

8.3.4.54.1 Request primitive

The value of Command is eight hundred and twenty-two (822); the value of Octet count field is zero (0) and Value field is null.

8.3.4.54.2 Response primitive

The Value field of response is shown in Table 248. The Response code values are shown in Table 249.

Table 248 – Read network access mode response value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Network access mode	Network access mode code as specified in Table F.31

Table 249 – Read network access mode command specific response codes

Value	Class	Description
0	Success	No error
6	Error	Device-specific command Error
16	Error	Access restricted
32	Error	Busy – a delayed response could not be started

8.3.4.54.3 Procedure at responding device

This command reads the current value of network access mode from a network device.

8.3.4.55 Request session FAL PDU

8.3.4.55.1 Request primitive

The value of Command is eight hundred and twenty-three (823); the value of Octet count field is two (2) and value field is as shown in Table 250.

Table 250 – Request Session request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Peer_nickname	Nickname of the peer with which the session is requested

8.3.4.55.2 Response primitive

The Value field of response is shown in Table 251. The Response code values are shown in Table 252.

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Table 251 – Request Session response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Peer_nickname	Nickname of the peer with which the session is requested
2	Unsigned32	Peer_nonce_counter	Largest nonce counter value received from the correspondent device
6	Security key	Join_key	This is 128-bit network key that is used for security

Table 252 – Request Session command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	Unknown Peer
66	Error	Field device has insufficient capacity to support another session

8.3.4.55.3 Procedure at responding device

This command requests a unicast session from a handheld to a device. Only authorized devices shall be granted a session.

8.3.5 Gateway and network manager specific APDU structures

8.3.5.1 Read network device identity using unique ID FAL PDU

8.3.5.1.1 Request primitive

The value of Command is eight hundred and thirty-two (832); the value of Octet count field is five (5) and Value field is shown in Table 253.

Table 253 – Read network device identity request value field

Octet offset	Data type	Parameter name	Description
0	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4

8.3.5.1.2 Response primitive

The Value field of response is shown in Table 254. The Response code values are shown in Table 255.

Table 254 – Read network device identity response value field

Octet offset	Data type	Parameter name	Description
0	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4
5	Unsigned16	Device nickname	Nickname of the device as defined in 3.2.74
7 – 38	Latin-1	Long_tag	Long Tag stored in the device

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Table 255 – Read network device identity command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received

8.3.5.1.3 Procedure at responding device

This command reads the identity information of the device with matching Unique ID from the gateway.

8.3.5.2 Read device's neighbor health FAL PDU

8.3.5.2.1 Request primitive

The value of Command is eight hundred and thirty-three (833); the value of Octet count field is seven (7) and Value field is shown in Table 256.

Table 256 – Read device's neighbor health request value field

Octet offset	Data type	Parameter name	Description
0	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4
5	Unsigned8	Table index	Neighbor table index
6	Unsigned8	Entry count	Number of neighbor entries to be read (shall be 1)

8.3.5.2.2 Response primitive

The Value field of response is shown in Table 257. The Response code values are shown in Table 258.

Table 257 – Read device's neighbor health response value field

Octet offset[a]	Data type	Parameter name	Description
0	Unique ID	Unique ID	Unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4
5	Unsigned8	Table index	Neighbor table index
6	Unsigned8	Entry count	Number of neighbor entries in the response
7	Unsigned16	Neighbor_nickname	Nickname of neighbor as defined in 3.2.74
9	Integer8	Average_RSL	Average RSL (received signal level in dBm) received at this device from this neighbor
10	Unsigned32	Packets_transmitted	Number of packets transmitted to this neighbor
14	Unsigned32	Missed_ACK_packets	Failed transmission to this neighbor – number of packets expecting an ACK and none received
18	Unsigned32	Packets_received	Number of packets received from this neighbor
22	Bit Field	Neighbor flags	Neighbor flags as described in Table F.34
23..			

[a] The fields from octet number 7 to 22 are repeated as many times as the value of neighbor count.

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Table 258 – Read device's neighbor health command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
8	Warning	Set to the nearest possible value
16	Error	Access restricted
65	Error	Invalid neighbor table index

8.3.5.2.3 Procedure at responding device

This command reads from the gateway, information regarding the quality of the connection to each active neighbor or potential neighbor for the device specified in the request. The gateway can find the number of neighbors for the device by sending "Read device list FAL PDU" request (see 8.3.4.46). The requesting application can use this service to build the graph and quality of the network.

8.3.5.3 Read network topology information FAL PDU

8.3.5.3.1 Request primitive

The value of Command is eight hundred and thirty-four (834); the value of Octet count field is seven (7) and Value field is shown in Table 259.

Table 259 – Read network topology information request value field

Octet offset	Data type	Parameter name	Description
0	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4
5	Unsigned16	Table index	Graph table index

8.3.5.3.2 Response primitive

The Value field of response is shown in Table 260. The Response code values are shown in Table 261.

Table 260 – Read network topology information response value field

Octet offset[a]	Data type	Parameter name	Description
0	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4
5	Unsigned16	Table index	Graph table index
7	Unsigned16	Graph count	Total number of graphs
9	Unsigned16	Graph_ID	Identification number assigned to this Graph
11	Unsigned16	Neighbor count	Number of neighbors
13	Unsigned16	Neighbor	Nickname of neighbor for this graph
15..			

[a] The fields from octet number 13 to 14 are repeated as many times as the value of Neighbor count.

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Table 261 – Read network topology information command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
65	Error	Invalid graph table index

8.3.5.3.3 Procedure at responding device

This command reads one item in the Graph table for the specified network device from the gateway. The gateway can find the number of graphs for the device by using 'Read graph list' FAL PDU (see 8.3.4.18). The requesting application can use this service to build the graph of the network.

8.3.5.4 Read publish data message list FAL PDU

8.3.5.4.1 Request primitive

The value of Command is eight hundred and thirty-five (835); the value of Octet count field is five (5) and Value field is shown in Table 262.

Table 262 – Read publish data message list request value field

Octet offset	Data type	Parameter name	Description
0	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4

8.3.5.4.2 Response primitive

The Value field of response is shown in Table 263. The Response code values are shown in Table 264.

Table 263 – Read publish data message list response value field

Octet offset[a]	Data type	Parameter name	Description
0	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4
5	Unsigned8	Publish data count	Number of different publish data commands received from this device
6	Unsigned16	Publish command	Command number being published
8	Unsigned32	Packet count	Number of publish data packets received
12..			
[a] The fields from octet number 6 to 11 are repeated as many times as the value of Publish data count.			

Table 264 – Read publish data message list command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received

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8.3.5.4.3 Procedure at responding device

This command reads from the gateway, the publish data message list that the specified device participates in, including number of publish data mode commands that the specified device participates in. The requesting application can use this service to build the list of all publish data mode traffic in the system.

8.3.5.5 Flush cached responses for a device FAL PDU

8.3.5.5.1 Request primitive

The value of Command is eight hundred and thirty-six (836); the value of Octet count field is five (5) and Value field is shown in Table 265.

Table 265 – Flush cached value field

Octet offset	Data type	Parameter name	Description
0	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4

8.3.5.5.2 Response primitive

The Value field of response is shown in Table 265. The Response code values are shown in Table 266.

Table 266 – Flush cached responses command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
16	Error	Access restricted

8.3.5.5.3 Procedure at responding device

This command flushes the cached responses in the gateway, for the specified device.

8.3.5.6 Read network device statistics FAL PDU

8.3.5.6.1 Request primitive

The value of Command is eight hundred and forty (840); the value of Octet count field is five (5) and Value field is shown in Table 267.

Table 267 – Read network device statistics request value field

Octet offset	Data type	Parameter name	Description
0	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4

8.3.5.6.2 Response primitive

The Value field of response is shown in Table 268. The Response code values are shown in Table 269.

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Table 268 – Read network device statistics response value field

Octet offset	Data type	Parameter name	Description
0	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4
5	Unsigned16	Graph count	Number of configured graphs
7	Unsigned16	Superframe count	Number of configured superframes
9	Unsigned16	Link count	Number of configured links
11	Unsigned8	Neighbor count	Number of neighbors (linked and not linked)
12	Time	Upstream latency	Average communication latency from the device to the gateway or network manager
16	Unsigned16	Join count	Number of joins
18	Date	Join date	Date of most recent join
21	Time	Join time	Time in 1/32 of a ms unit from midnight of the date when the device most recently joined the network
25	Unsigned32	Packets generated	Number of packets generated by this device
29	Unsigned32	Packets terminated	Number of packets terminated by this device
33	Unsigned32	DLL MIC failures	Number of DLL MAC MIC failures detected
37	Unsigned32	NL MIC failures	Number of NL (session) MIC failures detected
41	Unsigned32	CRC errors	Number of CRC errors detected
45	Unsigned32	Packets missed	Number of packets detected as missing
49	Unsigned32	Nonce counter missed	Number of Nonce Counter Values not received from the device
53	Time	Upstream latency standard deviation	Standard deviation of latency from the device to the gateway or the network manager
57	Time	Downstream average latency	Average communication latency from the gateway or network manager to the device
61	Time	Downstream latency standard deviation	Standard deviation of latency from the gateway or network manager to the device
65	Time	Upstream availability	Percent availability (node to Gateway or Network Manager)
69	Time	Downstream availability	Percent availability (Gateway or Network Manager to node)
73	Unsigned32	Maximum queue	Maximum packet buffer queue length
75	Float32	Average queue	Average packet buffer queue length (over time)
79	Bit Field	Connection status	Bits 0..2: Wireless Device Connection Status as shown in Table F.41
79	Bit Field	Health status	Bits 4..7: Wireless Device Health Status as shown in Table F.42
80	Unsigned8	Session counter	Number of packets with bad or unknown session received by device. This may indicate a configuration or security problem.

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Table 269 – Read network device statistics command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received

8.3.5.6.3 Procedure at responding device

This command reads the statistics for the specified device from the gateway. The gateway is expected have this information available and shall respond immediately. Packets missed value is incremented for each zero in Nonce counter history that underflows.

8.3.5.7 Read network device identity using nickname FAL PDU

8.3.5.7.1 Request primitive

The value of Command is eight hundred and forty-one (841); the value of Octet count field is two (2) and Value field is shown in Table 270.

Table 270 – Read network device identity request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Device_nickname	Nickname of the device as defined in 3.2.74

8.3.5.7.2 Response primitive

The Value field of response is shown in Table 271. The Response code values are shown in Table 272.

Table 271 – Read network device identity response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Device_nickname	Nickname of the device as defined in 3.2.74
2	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4
7 – 38	Latin-1	Long_tag	Long Tag stored in the device

Table 272 – Read network device identity command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received

8.3.5.7.3 Procedure at responding device

This command reads the identity information of the device with matching Device nickname from the gateway.

8.3.5.8 Write network device's scheduling flags FAL PDU

8.3.5.8.1 Request primitive

The value of Command is eight hundred and forty-two (842); the value of Octet count field is six (6) and Value field is shown in Table 273.

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Table 273 – Write network device's scheduling flags value field

Octet offset	Data type	Parameter name	Description
0	Unique ID	Unique ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4
5	Bit Field	Scheduling flags	Device scheduling flags as specified in Table F.37

8.3.5.8.2 Response primitive

The Value field of response is shown in Table 273. The Response code values are shown in Table 274.

Table 274 – Write network device's scheduling flags command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
6	Error	Device specific command error
7	Error	In write protect mode
8	Warning	Unsupported attribute flag detected. Device attribute Flags set to the nearest possible value
16	Error	Access restricted
9	Error	Invalid attribute flag
65	Error	Unknown Unique ID

8.3.5.8.3 Procedure at responding device

This command allows user to request special consideration for a device when the network manager is creating schedules. This command shall only be supported by gateways and network managers. This information shall not be written to the network device.

8.3.5.9 Read network device's scheduling flags FAL PDU

8.3.5.9.1 Request primitive

The value of Command is eight hundred and forty-three (843); the value of Octet count field is five (5) and Value field is shown in Table 275.

Table 275 – Read network device's scheduling flags request value field

Octet offset	Data type	Parameter name	Description
0	Unique ID	Unique_ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4

8.3.5.9.2 Response primitive

The Value field of response is shown in Table 276. The Response code values are shown in Table 277.

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Table 276 – Read network device's scheduling flags response value field

Octet offset	Data type	Parameter name	Description
0	Unique ID	Unique_ID	The unique identifier assigned to the device as defined in 3.2.105 and described in 6.3.1.2.4
5	Bit Field	Scheduling flags	Device scheduling flags as specified in Table F.37

Table 277 – Read network device's scheduling flags command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received

8.3.5.9.3 Procedure at responding device

This command reads the network device attributes that a network manager may consider when creating schedules. This command shall only be supported by gateways and network managers.

8.3.5.10 Read network constraints FAL PDU

8.3.5.10.1 Request primitive

The value of Command is eight hundred and forty-four (844); the value of Octet count field is zero (0) and Value field is null.

8.3.5.10.2 Response primitive

The Value field of response is shown in Table 278. The Response code values are shown in Table 279.

Table 278 – Read network constraints value field

Octet offset	Data type	Parameter name	Description
0	Bit Field	Optimization flags	Network optimization flags as specified in Table F.38
1	Unsigned8	Message pair count	Number of request / response message pairs that the network manager is permitted to send in 10 s duration

Table 279 – Read network constraints command specific response codes

Value	Class	Description
0	Success	No error

8.3.5.10.3 Procedure at responding device

This command reads the current setting of the network management strategy and the number of request / response messages per 10 s.

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8.3.5.11 Write network constraints FAL PDU

8.3.5.11.1 Request primitive

The value of Command is eight hundred and forty-five (845); the value of Octet count field is two (2) and Value field is shown in Table 280.

Table 280 – Write network constraints value field

Octet offset	Data type	Parameter name	Description
0	Bit Field	Optimization flags	Network optimization flags as specified in Table F.38
1	Unsigned8	Message pair count	Number of request / response message pairs that the network manager is permitted to send in 10 s duration

8.3.5.11.2 Response primitive

The Value field of response is shown in Table 280. The Response code values are shown in Table 281.

Table 281 – Write network constraints command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection (illegal or unsupported strategy)
5	Error	Too few data octets received
6	Error	Device specific command error
7	Error	In write protect mode
8	Warning	Set to the nearest possible value
16	Error	Access restricted

8.3.5.11.3 Procedure at responding device

This command writes the current setting of the network management strategy and the number of request / response messages per 10 s. Minimum value for Number of request / response messages per 10 s is one (1).

8.3.5.12 Read Network Statistics FAL PDU

8.3.5.12.1 Request primitive

The value of Command is eight hundred and forty-six (846); the value of Octet count field is zero (0).

8.3.5.12.2 Response primitive

The Value field of response is shown in Table 282. The Response code values are shown in Table 283.

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Table 282 – Read network statistics response value field

Octet offset	Data type	Parameter name	Description
0	Float32	Throughput	Average number of packets per second communicated from the network manager and gateway
4	Float32	Utilization	Percent network utilization
8	Float32	Availability	Percent availability
12	Time	Latency	Average latency
16	Time	Latency standard deviation	Standard deviation of latency
20	Float32	Packet error rate	Packet error rate
24	Unsigned32	Dropped packets	Number of dropped packets by all devices on the Active list
28	Unsigned32	Unsuccessful joins	The number of join requests received that do not result in the requesting device reaching the Quarantine state.

Table 283 – Read network command specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

8.3.5.12.3 Procedure at responding device

This command summarizes overall network health.

8.3.5.13 Transfer network list to white list FAL PDU

8.3.5.13.1 Request primitive

The value of Command is eight hundred and forty-seven (847); the value of Octet count field is zero (0).

8.3.5.13.2 Response primitive

The Value field of response is shown in Table 284. The Response code values are shown in Table 285.

Table 284 – Transfer network list to white list response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Count	Number of devices copied to the whitelist

Table 285 – Transfer network list to white list command specific response codes

Value	Class	Description
0	Success	No error
6	Error	Device specific command error
7	Error	In write protect mode
16	Error	Access restricted

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8.3.5.13.3 Procedure at responding device

This command copies the network list into the white list. Before the transfer the white list is flushed. After the execution of this command, the white list content will be the same as the network list.

8.3.5.13.4 Procedure at responding device

This command summarizes overall network health.

8.3.5.14 Generate key FAL PDU

8.3.5.14.1 Request primitive

The value of Command is eight hundred and forty-eight (848); the value of Octet count field is one (1) and Value field is shown in Table 286.

Table 286 – Generate key request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Value	Value shall be set to zero (0)

8.3.5.14.2 Response primitive

The Value field of response is shown in Table 287. The Response code values are shown in Table 288.

Table 287 – Generate key response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Value	Value shall be set to zero (0)
1	Security Key	Key	Random security key value

Table 288 – Generate key command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few bytes received
6	Error	Device specific command error
16	Error	Access restricted

8.3.5.14.3 Procedure at responding device

This command is to be used by an application to get a random key from the security manager. Since the application cannot talk directly to the security manager, the gateway is used as a proxy. This key may be used to write a new join key to a device.

8.3.5.15 Read device join key FAL PDU

8.3.5.15.1 Request primitive

The value of Command is eight hundred and forty-nine (849); the value of Octet count field is six (6) and Value field is shown in Table 289.

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Table 289 – Read device join key request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Value	Value shall be set to zero (0)
1	Unique ID	Unique ID	Unique ID of device

8.3.5.15.2 Response primitive

The Value field of response is shown in Table 290. The Response code values are shown in Table 291.

Table 290 – Read device join key response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Value	Value shall be set to zero (0)
1	Unique ID	Unique ID	Unique ID of device
6	Security Key	Key	Random key value

Table 291 – Read device join key command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few bytes received
6	Error	Device specific command error
7	Error	In write protect mode
9	Error	Device active or quarantined
10	Error	Network closed, new device cannot be added
11	Error	Number of network devices cannot be increased
16	Error	Access restricted
32	Error	Busy – a DR could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

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8.3.5.15.3 Procedure at responding device

This command reads a new random join key for the specified device. This command can be used to provision a device prior to it being added to a network. If the device is not already on the white list, then it is added to it. The network list is unaffected (the device is neither added to nor deleted from the network list). This command will return an error if the device is on the Active or Quarantine list. The command will return an error if the network is closed.

8.3.5.16 Write device join key FAL PDU

8.3.5.16.1 Request primitive

The value of Command is eight hundred and fifty (850); the value of Octet count field is twenty-two (22) and Value field is shown in Table 292.

Table 292 – Write device join key

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Value	Value shall be set to zero (0)
1	Unique ID	Unique ID	Unique ID of device
6	Security Key	Security Key	Join key for the selected device

8.3.5.16.2 Response primitive

The Value field of response is shown in Table 292. The Response code values are shown in Table 293.

Table 293 – Write device join key command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few bytes received
6	Error	Device specific command error
7	Error	In write protect mode
9	Error	Device active or quarantined
10	Error	Network closed, new device cannot be added
11	Error	Number of network devices cannot be increased
16	Error	Access restricted
32	Error	Busy – a DR could not be started
33	Error	DR initiated
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

8.3.5.16.3 Procedure at responding device

This command writes the specified join key to the identified device. The security manager may use this command to change the join key associated with a device. The join key for this device will be updated in the network manager. The device will be added to the white list. The device shall be in the Active or Quarantined state for this command to be successful.

8.3.5.17 Change key now FAL PDU

8.3.5.17.1 Request primitive

The value of Command is eight hundred and fifty-one (851); the value of Octet count field is eight (8) and Value field is shown in Table 294.

Table 294 – Change key now request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Value	Value shall be set to zero (0)
1	Bit Field	Change key flags	Change key flags per Table F.43
3	Unique ID	Unique ID	Unique ID of Device. When set to broadcast address (i.e., 0x0000.0x000000) the keys in all devices will be changed.

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8.3.5.17.2 Response primitive

The Value field of response is shown in Table 295. The Response code values are shown in Table 296.

Table 295 – Change key now response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Value	Value shall be set to zero (0)
1	Bit Field	Change key flags	Change key flags per Table F.43
3	Unique ID	Unique ID	Unique ID of Device. When set to broadcast address (i.e., 0x0000.0x000000) the keys in all devices will be changed.
8	Time	Change time	Estimated time to complete key change

Table 296 – Change key now command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few bytes received
6	Error	Device specific command error
7	Error	In write protect mode
9	Error	Unique ID shall be broadcast address to change network key
16	Error	Access restricted
65	Error	Unknown Unique ID

8.3.5.17.3 Procedure at responding device

This command instructs the security manager to change the keys (Network, Join or Sessions) in the specified device. The broadcast address shall be specified to change the network key.

This command shall be immediately responded to and contains the estimated time required to complete the key changes. The record of the device join key shall only be updated after confirming the join key in the device has been successfully updated.

8.3.5.18 Read stale data setpoints FAL PDU

8.3.5.18.1 Request primitive

The value of Command is eight hundred and fifty-two (852); the value of Octet count field is zero (0).

8.3.5.18.2 Response primitive

The Value field of response is shown in Table 297. The Response code values are shown in Table 298.

Table 297 – Change key now response value field

Octet offset	Data type	Parameter name	Description
0	Float32	Stale data timer	The percent of the publish message maximum update time that, when exceeded, cause the stale data count to increment by 1
4	Unsigned8	Stale data count setpoint	The count that, when exceeded, causes the stale data alarm to be signaled. The default value is 3.

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Table 298 – Change key now command specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

8.3.5.18.3 Procedure at responding device

This command is to be used by an application to read the stale data timer and counter setpoint. When the stale data timer expires the stale data count shall be incremented. When the stale count setpoint is exceeded the process data status for the corresponding process variables shall be set to bad and the stale data alarm us set. The stale data count and stale data alarm shall be reset when a publish message is received before the stale data timer expires.

8.3.5.19 Write stale data timer FAL PDU

8.3.5.19.1 Request primitive

The value of Command is eight hundred and fifty-three (853); the value of Octet count field is four (4) and Value field is shown in Table 299.

8.3.5.19.2 Response primitive

The Value field of response is shown in Table 299. The Response code values are shown in Table 300.

Table 299 – Write stale data timer response value field

Octet offset	Data type	Parameter name	Description
0	Float32	Stale data timer	The percent of the publish message maximum update time that, when exceeded, cause the stale data count to increment by 1.

Table 300 – Write stale data timer command specific response codes

Value	Class	Description
0	Success	No error
3	Error	Parameter passed too large
4	Error	Parameter passed too small
5	Error	Too few bytes received
6	Error	Device specific command error
7	Error	In write protect mode
8	Warning	Set to nearest possible value
16	Error	Access restricted
32	Error	DR could not be started
33	Error	DR initiating
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict
65	Error	Unknown Unique ID

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8.3.5.19.3 Procedure at responding device

Writes the percent of the maximum publish period that a published message can be late before the stale data count is incremented.

8.3.5.20 Write stale data count setpoint FAL PDU

8.3.5.20.1 Request primitive

The value of Command is eight hundred and fifty-four (854); the value of Octet count field is one (1) and Value field is shown in Table 301.

Table 301 – Write stale data count request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Stale data count	Stale data count setpoint (defaults to 3). The count that, when exceeded, causes the Stale Data Alarm to be signaled

8.3.5.20.2 Response primitive

The Value field of response is shown in Table 301. The Response code values are shown in Table 302.

Table 302 – Write stale data count command specific response codes

Value	Class	Description
0	Success	No error
3	Error	Passed parameter too large
4	Error	Passed parameter too small
5	Error	Too few bytes received
6	Error	Device specific command error
7	Error	In write protect mode
8	Warning	Set to nearest possible value
16	Error	Access restricted
32	Error	DR could not be started
33	Error	DR initiating
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

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8.3.5.20.3 Procedure at responding device

This command writes the stale count.

8.3.5.21 Read session extended FAL PDU

8.3.5.21.1 Request primitive

The value of Command is eight hundred and fifty-five (855); the value of Octet count field is two (2) and Value field is shown in Table 303.

Table 303 – Read session extended request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Session index	Session index (first value shall always be 0)

8.3.5.21.2 Response primitive

The Value field of response is shown in Table 304. The Response code values are shown in Table 305.

Table 304 – Read session extended response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Session Index	Session table index (first value shall always be 0)
2	Unsigned8	Session count	Number of sessions currently configured (i.e., the number of entries currently residing in the Session Table
3	Enumeration	Session type	Session type per Table F.24
4	Unsigned16	Peer nickname	Peer Device Nickname
6	Unique ID	Peer unique id	Peer Device's Unique ID
11	Unsigned32	Peer nonce counter	Peer Device's Nonce Counter Value
15	Unsigned32	Device nonce counter	The Device's Nonce Counter Value

Table 305 – Read session extended command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few bytes received
8	Warning	Set to nearest possible value
16	Error	Access restricted

8.3.5.21.3 Procedure at responding device

This command allows a host application to retrieve information about sessions from a gateway or network manager. Sessions are addressed by their position in the list of sessions on the device, and do not assume a particular implementation. Session indexes may change following addition or deletion of sessions. "Session Index" may be modified and "Set to nearest value" response code returned.

8.3.5.22 Read device suspend settings FAL PDU

8.3.5.22.1 Request primitive

The value of Command is eight hundred and fifty-six (856); the value of Octet count field is zero (0).

8.3.5.22.2 Response primitive

The Value field of response is shown in Table 306. The Response code values are shown in Table 307.

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Table 306 – Read device suspend settings response value field

Octet offset	Data type	Parameter name	Description
0	Time	Suspend time	Time at which to suspend device (ASN)
5	Time	Resume time	Time at which to resume device (ASN)

Table 307 – Read device suspend settings command specific response codes

Value	Class	Description
0	Success	No error
6	Error	Device specific command error
32	Error	Busy

8.3.5.22.3 Procedure at responding device

This command reads the current suspension settings from a device.

8.3.5.23 Read security level advertised FAL PDU

8.3.5.23.1 Request primitive

The value of Command is eight hundred and fifty-seven (857); the value of Octet count field is zero (0).

8.3.5.23.2 Response primitive

The Value field of response is shown in Table 308. The Response code values are shown in Table 309.

Table 308 – Read security level advertised response value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Security level	Security level supported as documented in Table F.29. Defaults to "Join Keyed".

Table 309 – Read security level advertised command specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

8.3.5.23.3 Procedure at responding device

This command is used to read the security level supported by the network manager. All network managers shall support at least the "Join Keyed" security type.

8.3.5.24 Reset availability statistics FAL PDU

8.3.5.24.1 Request primitive

The value of Command is eight hundred and fifty-eight (858); the value of Octet count field is five (5) and Value field is shown in Table 310.

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Table 310 – Reset availability statistics request value field

Octet offset	Data type	Parameter name	Description
0	Unique ID	Unique ID	Unique ID for device to reset availability statistics for (broadcast address resets availability for entire network).

8.3.5.24.2 Response primitive

The Value field of response is shown in Table 310. The Response code values are shown in Table 311.

Table 311 – Reset availability statistics command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few bytes received
16	Error	Access restricted

8.3.5.24.3 Procedure at responding device

This command instructs the gateway to reset the availability statistics.

8.3.5.25 Read active advertising status FAL PDU

8.3.5.25.1 Request primitive

The value of Command is eight hundred and fifty-nine (859); the value of Octet count field is zero (0).

8.3.5.25.2 Response primitive

The Value field of response is shown in Table 312. The Response code values are shown in Table 313.

Table 312 – Read active advertising status response value field

Octet offset	Data type	Parameter name	Description
0	Time	Advertising shed time	Active Advertising Shed Time. Returns the time remaining before active advertising ceases (or 0x00000000 if active advertising has stopped)
4	Time	Advertising period	Current Advertising Period (median value if response is from Gateway)

Table 313 – Read active advertising status command specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

8.3.5.25.3 Procedure at responding device

This command returns the current advertising settings. When this command is received from a local maintenance tool (e.g., a handheld) the values for the field device are returned. This

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command shall be supported by all gateways. When this command is received by the gateway the median advertising rate for the entire network is returned.

8.3.5.26 Read join key mode FAL PDU

8.3.5.26.1 Request primitive

The value of Command is eight hundred and sixty (860); the value of Octet count field is zero (0).

8.3.5.26.2 Response primitive

The Value field of response is shown in Table 314. The Response code values are shown in Table 315.

Table 314 – Read join key mode response value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Join key mode	Join key mode as per Table F.36

Table 315 – Read join key mode command specific response codes

Value	Class	Description
0	Success	No error
6	Error	Device specific command error
32	Error	Busy (A DR could not be started)

8.3.5.26.3 Procedure at responding device

This command reads the join key mode currently employed by the network manager.

8.3.5.27 Write join key mode FAL PDU

8.3.5.27.1 Request primitive

The value of Command is eight hundred and sixty-one (861); the value of Octet count field is one (1) and Value field is shown in Table 316.

Table 316 – Write join key mode request value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Join key mode	Join key mode as per Table F.36

8.3.5.27.2 Response primitive

The Value field of response is shown in Table 316. The Response code values are shown in Table 317.

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Table 317 – Write join key mode command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few bytes received
6	Error	Device specific command error
7	Error	In write protect mode
16	Error	Access restricted
32	Error	DR could not be started
33	Error	DR initiating
34	Error	DR running
35	Error	DR dead
36	Error	DR conflict

8.3.5.27.3 Procedure at responding device

This command writes the join key mode. This command supports an optional mode where the join key is common to all devices. This allows installations to quickly provision the network and then once the devices are on they can transition the network to a random network wide join key.

8.3.5.28 Read Timetable by ID FAL PDU

8.3.5.28.1 Request primitive

The value of Command is eight hundred and sixty-two (862); the value of Octet count field is eight (8) and Value field is shown in Table 318.

Table 318 – Read Timetable by ID request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Timetable ID	Timetable ID

8.3.5.28.2 Response primitive

The Value field of response is shown in Table 319. The Response code values are shown in Table 320.

Table 319 – Read Timetable by ID response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Timetable ID	Timetable ID
1	Bit Field	Request flags	Timetable Request Flags per Table F.15
2	Enumeration	Application domain	Timetable Application Domain per Table F.16
3	Unsigned16	Nickname	Nickname of the peer with which the Timetable is requested
5	Time	Period	Period (latency if Intermittent flag set)
9	Unsigned8	Route ID	Route ID

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Table 320 – Read Timetable by ID command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few bytes received
6	Error	Device specific command error
16	Error	Access restricted

8.3.5.28.3 Procedure at responding device

This command reads the timetable specified by the Timetable ID. This command shall be rejected with a response code of Access restricted if the device is not joined to the Network.

8.3.6 Network management configuration specific APDU structures

8.3.6.1 Disconnect device FAL PDU

8.3.6.1.1 Request primitive

The value of Command is nine hundred and sixty (960); the value of Octet count field is one (1) and value field is as shown in Table 321.

Table 321 – Disconnect device value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Disconnect cause	Disconnect cause code as specified in Table F.26

8.3.6.1.2 Response primitive

The Value field of response is shown in Table 321. The Response code values are shown in Table 322.

Table 322 – Disconnect device command specific response codes

Value	Class	Description
0	Success	No error
16	Error	Access restricted

8.3.6.1.3 Procedure at responding device

This service allows the network manager to force a device off the network. The receiving device shall go off the network, issue TL-FLUSH request, clear all its network information and rejoin the network. If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

8.3.6.2 Write network key FAL PDU

8.3.6.2.1 Request primitive

The value of Command is nine hundred and sixty-one (961); the value of Octet count field is twenty-one (21) and value field is as shown in Table 323.

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Table 323 – Write network key value field

Octet offset	Data type	Parameter name	Description
0	Security key	Network key	This is 128-bit network key that is used for security
16	Unsigned40	Key change time	Execution ASN time for command; 0 – execute immediately

The transport type for this request shall be Request-broadcast.

8.3.6.2.2 Response primitive

The Value field of response is shown in Table 323. The Response code values are shown in Table 324.

Table 324 – Write network key command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	Key change failed
66	Error	Invalid execution time

8.3.6.2.3 Procedure at responding device

This command writes the network key in a network device. The value field in the request can be truncated after the Key value. If truncated, then the network Key shall become effective immediately. Else, the new key shall become effective at the Key change time received in the request. If the Key change time received in the request is less than the current ASN time the "Invalid execution time" response code shall be returned. If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

8.3.6.3 Write device nickname FAL PDU

8.3.6.3.1 Request primitive

The value of Command is nine hundred and sixty-two (962); the value of Octet count field is two (2) and Value field is as shown in Table 325.

Table 325 – Write device nickname value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Device nickname	Nickname of the device as defined in 3.2.74

8.3.6.3.2 Response primitive

The Value field of response is shown in Table 325. The Response code values are shown in Table 326.

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Table 326 – Write device nickname command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	Invalid device nickname

8.3.6.3.3 Procedure at responding device

This command writes a network device's nickname. If this command is received from any source other than the network manager, then the device shall reject this request with a response code of "Access Restricted".

8.3.6.4 Write session FAL PDU

8.3.6.4.1 Request primitive

The value of Command is nine hundred and sixty-three (963); the value of Octet count field is thirty-two (32) and Value field is shown in Table 327.

Table 327 – Write session request value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Session_type	Session_type as specified in Table F.24
1	Unsigned16	Peer_nickname	Nickname of the correspondent device
3	Unique ID	Peer_unique_ID	Unique ID of correspondent device as defined in 3.2.105
8	Unsigned32	Peer_nonce_counter	Nonce counter value received from the correspondent device
12	Security key	Session_key	This is 128-bit network key that is used for security.
28	Unsigned8	Reserved	Always zero (0) in request
29	Unsigned40	Session change time	Execution ASN time for command; 0 – execute immediately

8.3.6.4.2 Response primitive

The Value field of response is shown in Table 328. The Response code values are shown in Table 329.

Table 328 – Write session response value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Session_type	Session_type as specified in Table F.24
1	Unsigned16	Peer_nickname	Nickname of the correspondent device
3	Unique ID	Peer_unique_ID	Unique ID of correspondent device as defined in 3.2.105
8	Unsigned32	Peer_nonce_counter	Nonce counter value received from the correspondent device
12	Security key	Session_key	This is 128-bit session key that is used for security
28	Unsigned8	Session count	Number of sessions remaining
29	Unsigned40	Session change time	Execution ASN time for command; 0 – execute immediately

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Table 329 – Write session command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	No more entries available
66	Error	Invalid execution time
67	Error	Session_type invalid

8.3.6.4.3 Procedure at responding device

This command writes the session parameters required to establish a session between the destination (of this request) device and the peer device specified in the request. Session is identified by Session_type and Peer_nickname. If this command is modifying an existing session then the Peer_nonce_counter is ignored. The response always includes the values actually used by the device. When a new key is written to the session the old key shall be retained to allow for out-of-order packet reception. The old key shall be discarded after 2 * Max_PDU_age duration from the reception of the request. The value fields in the request can be truncated after the Session_key value. If truncated, then the Session_key shall become effective immediately. If the Session change time received in the request is less than the current ASN time the "Invalid execution time" response code shall be returned. If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

8.3.6.5 Delete session FAL PDU

8.3.6.5.1 Request primitive

The value of Command is nine hundred and sixty-four (964); the value of Octet count field is three (3) and Value field is shown in Table 330.

Table 330 – Delete session request value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Session_type	Session_type as specified in Table F.24
1	Unsigned16	Peer_nickname	Nickname of the correspondent device

8.3.6.5.2 Response primitive

The Value field of response is shown in Table 331. The Response code values are shown in Table 332.

Table 331 – Delete session response value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Session_type	Session_type as specified in Table F.24
1	Unsigned16	Peer_nickname	Nickname of the correspondent device
3	Unsigned8	Session count	Number of sessions remaining

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Table 332 – Delete session command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Too few data octets received
5	Error	Invalid selection
16	Error	Access restricted
65	Error	Session with given peer device does not exist

8.3.6.5.3 Procedure at responding device

This command deletes an end-to-end session in a network device. If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”. Execution of this command shall have no effect on routes, timetables or other tables in the device. This command shall not be used to delete the join session.

8.3.6.6 Write superframe FAL PDU

8.3.6.6.1 Request primitive

The value of Command is nine hundred and sixty-five (965); the value of Octet count field is ten (10) and Value field is shown in Table 333.

Table 333 – Write superframe request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Superframe_ID	Identification number assigned to the superframe
1	Unsigned16	Num_Slots	Number of slots in this superframe i.e. size of superframe
3	Bit Field	Superframe mode	Superframe mode flags as specified in Table F.23
4	Unsigned8	Reserved	Always zero (0) in request
5	Unsigned40	Superframe change time	Execution ASN time for command; 0 – execute immediately

8.3.6.6.2 Response primitive

The Value field of response is shown in Table 334. The Response code values are shown in Table 335.

Table 334 – Write superframe response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Superframe_ID	Identification number assigned to the superframe
1	Unsigned16	Num_Slots	Number of slots in this superframe i.e. size of superframe
3	Bit Field	Superframe mode	Superframe mode flags as specified in Table F.23
4	Unsigned8	Superframe count	Number of superframes remaining
5	Unsigned40	Superframe change time	Execution ASN time for command; 0 – execute immediately

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Table 335 – Write superframe command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	No more entries available
66	Error	Invalid execution time
67	Error	Invalid number of slots
68	Error	Invalid superframe mode

8.3.6.6.3 Procedure at responding device

This command writes or modifies a superframe in a network device. If the device has a superframe with its ID matching the Superframe_ID in the request, then it shall modify the existing superframe. Else, it shall add a new superframe. The device shall make the superframe effective at the superframe change time received in the request. This allows synchronous network-wide operation. If this request is received while a superframe change is pending then the pending modifications shall be overwritten by the new values received in this request.

The value fields in the request can be truncated after the superframe mode value. If truncated, then the superframe shall become effective immediately. If the Superframe change time received in the request is less than the current ASN time the "Invalid execution time" response code shall be returned. If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

8.3.6.7 Delete superframe FAL PDU

8.3.6.7.1 Request primitive

The value of Command is nine hundred and sixty-six (966); the value of Octet count field is one (1) and Value field is shown in Table 336.

Table 336 – Delete superframe request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Superframe_ID	Identification number assigned to the superframe

8.3.6.7.2 Response primitive

The Value field of response is shown in Table 337. The Response code values are shown in Table 338.

Table 337 – Delete superframe response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Superframe_ID	Identification number assigned to the superframe
1	Unsigned8	Superframe count	Number of superframes remaining

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Table 338 – Delete superframe command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	Superframe entry not found

8.3.6.7.3 Procedure at responding device

This command deletes a superframe in a network device. If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”. When executed by the device all links associated with the Superframe shall also be deleted.

8.3.6.8 Write link FAL PDU

8.3.6.8.1 Request primitive

The value of Command is nine hundred and sixty-seven (967); the value of Octet count field is eight (8) and Value field is shown in Table 339.

Table 339 – Write link request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Superframe_ID	Identification number assigned to the superframe
1	Unsigned16	Slot	Slot number in superframe assigned to this link
3	Unsigned8	Channel_Offset	Initial frequency hopping channel offset
4	Unsigned16	Neighbor	Nickname of neighbor for this link, or 0xFFFF if broadcast, discovery, or join link
6	Bit Field	Link options	Link options as specified in Table F.22
7	Enumeration	Link_type	Link_type as specified in Table F.21

8.3.6.8.2 Response primitive

The Value field of response is shown in Table 340. The Response code values are shown in Table 341.

Table 340 – Write link response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Superframe_ID	Identification number assigned to the superframe
1	Unsigned16	Slot	Slot number in superframe assigned to this link
3	Unsigned8	Channel_Offset	Initial frequency hopping channel offset
4	Unsigned16	Neighbor	Nickname of neighbor for this link
6	Bit Field	Link options	Link options as specified in Table F.22
7	Enumeration	Link_type	Link_type as specified in Table F.21
8	Unsigned16	Link count	Total number of Link entries remaining

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Table 341 – Write link command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid Selection e.g., nickname = 0x0000
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	No more Link entries available
66	Error	Link already exists
67	Error	Unknown Superframe_ID
68	Error	Invalid Slot
69	Error	Invalid Link options (for example neither transmit nor receive set)
70	Error	Invalid Channel_Offset
71	Error	Invalid Link_type
72	Error	No more neighbors available

8.3.6.8.3 Procedure at responding device

This command adds a link assignment to a network device. The link is uniquely identified by the combination of following key parameters:

Superframe_ID, Slot, Neighbor.

If the request specifies a Link that already exists, then the device shall reject the request and respond with “Link already exists”. The network manager has to delete an existing link and then write a new link to accomplish a modify operation.

If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

8.3.6.9 Delete link FAL PDU

8.3.6.9.1 Request primitive

The value of Command is nine hundred and sixty-eight (968); the value of Octet count field is five (5) and Value field is shown in Table 342.

Table 342 – Delete link request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Superframe_ID	Identification number assigned to the superframe
1	Unsigned16	Slot	Slot number in superframe assigned to this link
3	Unsigned16	Neighbor	Nickname of neighbor for this link, or 0xFFFF if broadcast link

8.3.6.9.2 Response primitive

The Value field of response is shown in Table 343. The Response code values are shown in Table 344.

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Table 343 – Delete link response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Superframe_ID	Identification number assigned to the superframe
1	Unsigned16	Slot	Slot number in superframe assigned to this link
3	Unsigned16	Neighbor	Nickname of neighbor for this link, or 0xFFFF if broadcast link
5	Unsigned16	Link count	Total number of Link entries remaining

Table 344 – Delete link command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	Link does not exist

8.3.6.9.3 Procedure at responding device

This command deletes a Link assignment in a network device. The link is uniquely identified by the combination of following key parameters:

Superframe_ID, Slot, Neighbor.

If this command is received from any source other than the network manager, then the device shall reject this request with a response code of "Access Restricted".

Execution of this command shall not delete any graph-edge or superframe. Deleting the last link to a neighbor deletes the neighbor from the neighbor table.

8.3.6.10 Write graph connection FAL PDU

8.3.6.10.1 Request primitive

The value of Command is nine hundred and sixty-nine (969); the value of Octet count field is four (4) and Value field is shown in Table 345.

Table 345 – Write graph connection request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Graph_ID	Identification number assigned to this Graph
2	Unsigned16	Neighbor_nickname	Nickname of neighbor for this graph

8.3.6.10.2 Response primitive

The Value field of response is shown in Table 346. The Response code values are shown in Table 347.

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Table 346 – Write graph connection response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Graph_ID	Identification number assigned to this graph
2	Unsigned16	Neighbor_nickname	Nickname of neighbor for this graph
4	Unsigned16	Connection count	Total number of connection entries remaining

Table 347 – Write graph connection command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid Selection e.g., nickname = 0x0000
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	No more Edge entries available
66	Error	Unknown neighbor
67	Error	Can't add connection because superframe is used as graph equivalent

8.3.6.10.3 Procedure at responding device

This command adds a graph connection assignment to a network device. A graph and its connections with an ID less than 256 is specified by a superframe and its transmit links. In that case connections shall be added to the graph by writing a transmit link to new neighbor for that superframe-graph.

If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

8.3.6.11 Delete graph connection FAL PDU

8.3.6.11.1 Request primitive

The value of Command is nine hundred and seventy (970); the value of Octet count field is four (4) and Value field is shown in Table 348.

Table 348 – Delete graph connection request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Graph_ID	Identification number assigned to this Graph
2	Unsigned16	Neighbor_nickname	Nickname of neighbor for this graph

8.3.6.11.2 Response primitive

The Value field of response is shown in Table 349. The Response code values are shown in Table 350.

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Table 349 – Delete graph connection response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Graph_ID	Identification number assigned to this Graph
2	Unsigned16	Neighbor_nickname	Nickname of neighbor for this graph
4	Unsigned16	Connection count	Total number of connection entries remaining

Table 350 – Delete graph connection command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid Selection e.g., nickname = 0x0000
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	Graph connection entry does not exist

8.3.6.11.3 Procedure at responding device

This command deletes a graph connection assignment in a network device.

If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

8.3.6.12 Write neighbor attribute flag FAL PDU

8.3.6.12.1 Request primitive

The value of Command is nine hundred and seventy-one (971); the value of Octet count field is three (3) and Value field is shown in Table 351.

Table 351 – Write neighbor attribute flag value field

Octet offset	Data type	Parameter name	Description
0	Unsigned16	Neighbor_nickname	Nickname of neighbor as defined in 3.2.74
2	Bit Field	Neighbor flags	Neighbor attributes as specified in Table F.34

8.3.6.12.2 Response primitive

The Value field of response is shown in Table 351. The Response code values are shown in Table 352.

Table 352 – Write neighbor attribute command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	Unknown neighbor
66	Error	Invalid neighbor attribute

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8.3.6.12.3 Procedure at responding device

This command sets attributes of a neighbor to a network device.

If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

8.3.6.13 Write network suspend FAL PDU

8.3.6.13.1 Request primitive

The value of Command is nine hundred and seventy-two (972); the value of Octet count field is ten (10) and Value field is shown in Table 353.

Table 353 – Write network suspend value field

Octet offset	Data type	Parameter name	Description
0	Unsigned40	Suspend time	ASN time at which to suspend network
5	Unsigned40	Resume time	ASN time at which to resume network

8.3.6.13.2 Response primitive

The Value field of response is shown in Table 353. The Response code values are shown in Table 354.

Table 354 – Write network suspend command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	Invalid Suspend time
66	Error	Invalid Resume time

8.3.6.13.3 Procedure at responding device

This command is used by the network manager to suspend the operation of one or more devices. The command may be sent to all devices on the network or an individual device based on the addressing used. The receiving device shall go off the network, delete all of the pending transmission requests and clear all its network information. If this command is received while a suspend command is pending then the pending suspend setting shall be overwritten by the values received in this request.

If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

8.3.6.14 Write timetable FAL PDU

8.3.6.14.1 Request primitive

The value of Command is nine hundred and seventy-three (973); the value of Octet count field is ten (10) and Value field is shown in Table 355.

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Table 355 – Write TimeTable request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Timetable_ID	Timetable identifier of the entry; if the network manager is creating a new Timetable then the Timetable_ID shall be in the range of 0x80-0xFF
1	Bit Field	Timetable_type	Timetable request flags as specified in Table F.15
2	Enumeration	Application_domain	Application domain as specified in Table F.16
3	Unsigned16	Peer_nickname	Nickname of the peer with which the Timetable is established
5	Time	Service_duration	If Intermittent service, then latency else, (cyclical communications) period
9	Unsigned8	Route_ID	Route identifier for this Timetable

8.3.6.14.2 Response primitive

The Value field of response is shown in Table 356. The Response code values are shown in Table 357.

Table 356 – Write TimeTable response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Timetable_ID	Timetable identifier of the entry
1	Bit Field	Timetable_type	Timetable request flags as specified in Table F.15
2	Enumeration	Application_domain	Application domain as specified in Table F.16
3	Unsigned16	Peer_nickname	Nickname of the peer with which the Timetable is established
5	Time	Service_duration	If Intermittent service, then latency else, (cyclical communications) period
9	Unsigned8	Route_ID	Route identifier for this Timetable
10	Unsigned8	Timetable count	Total number of Timetable entries remaining

Table 357 – Write TimeTable command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
8	Warning	Set to nearest possible value
16	Error	Access restricted
65	Error	No more Timetable entries available
66	Error	Invalid Timetable_ID
67	Error	Open transaction pending
68	Error	Invalid application domain
69	Error	Unknown correspondent nickname (no session exists)
70	Error	Invalid route ID
71	Error	Correspondent nickname and route correspondent mismatch

8.3.6.14.3 Procedure at responding device

This command adds new Timetable to a network device. The network device may start using this Timetable after processing this command. The network manager may issue this command to restrict or reduce previously allocated bandwidth (for example during a network

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disturbance). When this command is used to reduce previously allocated bandwidth the recipient device shall set the "Capacity Denied" status and the "More status available" bit in the “Application process status” octet, if the bandwidth restriction can result in a process upset/disturbance.

If this command is received while the device is awaiting a response to a “Request Timetable (see Command 799)” on the same Timetable_ID, the device shall respond to this command with an "Open Transaction Pending" error.

If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

8.3.6.15 Write route FAL PDU

8.3.6.15.1 Request primitive

The value of Command is nine hundred and seventy-four (974); the value of Octet count field is five (5) and Value field is shown in Table 358.

Table 358 – Write route request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Route_ID	Route identifier for this entry
1	Unsigned16	Destination_nickname	Nickname of the peer with which the route is established
3	Unsigned16	Graph_ID	Graph_ID for this route

8.3.6.15.2 Response primitive

The Value field of response is shown in Table 359. The Response code values are shown in Table 360.

Table 359 – Write route response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Route_ID	Route identifier for this entry
1	Unsigned16	Destination_nickname	Nickname of the peer with which the route is established
3	Unsigned16	Graph_ID	Graph_ID for this route
5	Unsigned8	Route count	Total number of Route entries remaining

Table 360 – Write route command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	No Route entries available
66	Error	Invalid Peer_nickname
67	Error	Invalid Graph_ID

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8.3.6.15.3 Procedure at responding device

This command sets or modifies a route for a particular service in a network device.

If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

8.3.6.16 Delete route FAL PDU

8.3.6.16.1 Request primitive

The value of Command is nine hundred and seventy-five (975); the value of Octet count field is one (1) and Value field is shown in Table 361.

Table 361 – Delete route request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Route_ID	Route identifier for this entry

8.3.6.16.2 Response primitive

The Value field of response is shown in Table 362. The Response code values are shown in Table 363.

Table 362 – Delete route response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Route_ID	Route identifier for this entry
1	Unsigned8	Route count	Total number of Route entries remaining
2	Unsigned8	Source route count	Number of unconfigured Source-Routes remaining

Table 363 – Delete route command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
16	Error	Access restricted
65	Error	Invalid Route identifier

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8.3.6.16.3 Procedure at responding device

This command deletes a Route entry in a network device.

If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”. If the Route has an attached Source-Route then the Source-Route is also deleted.

8.3.6.17 Write source route FAL PDU

8.3.6.17.1 Request primitive

The value of Command is nine hundred and seventy-six (976); the value of Octet count field is variable and Value field is shown in Table 364.

Table 364 – Write source route request value field

Octet offset[a]	Data type	Parameter name	Description
0	Unsigned8	Route_ID	Route identifier for which source route has to be written
1	Unsigned8	Hop count	Number of hops in this route
2	Unsigned16	Hop	Nickname for hop entry 0
4..			
[a] The fields from octet number 2 to 3 are repeated as many times as the value of Hop count.			

8.3.6.17.2 Response primitive

The Value field of response is shown in Table 365. The Response code values are shown in Table 366.

Table 365 – Write source route response value field

Octet offset[a]	Data type	Parameter name	Description
0	Unsigned8	Route_ID	Route identifier for which source route has to be written
1	Unsigned8	Hop count	Number of hops in this route
2	Unsigned16	Hop	Nickname for hop entry 0
4..n			
n+1	Unsigned8	Source route count	Number of Source route entries remaining
[a] The fields from octet number 2 to 3 are repeated as many times as the value of Hop count.			

Table 366 – Write source route command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
8	Warning	Broadcast addresses deleted in response
16	Error	Access restricted
65	Error	No more entries available
66	Error	Invalid Route identifier
67	Error	Invalid Nickname
68	Error	Invalid Hop count

8.3.6.17.3 Procedure at responding device

This command writes a Source route in a network device. Broadcast addresses are not legal address values in this command and shall not be included in Source routes or the requests or responses for this command.

If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

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8.3.6.18 Delete source route FAL PDU

8.3.6.18.1 Request primitive

The value of Command is nine hundred and seventy-seven (977); the value of Octet count field is one (1) and Value field is shown in Table 367.

Table 367 – Delete source route request value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Route_ID	Route identifier for this entry

8.3.6.18.2 Response primitive

The Value field of response is shown in Table 368. The Response code values are shown in Table 369.

Table 368 – Delete source route response value field

Octet offset	Data type	Parameter name	Description
0	Unsigned8	Route_ID	Route identifier for this entry

Table 369 – Delete source route command specific response codes

Value	Class	Description
0	Success	No error
5	Error	Too few data octets received
16	Error	Access restricted
66	Error	Invalid Route identifier

8.3.6.18.3 Procedure at responding device

This command deletes a source route entry in a network device.

If this command is received from any source other than the network manager, then the device shall reject this request with a response code of “Access Restricted”.

8.3.6.19 Write status counter mode FAL PDU

8.3.6.19.1 Request primitive

The value of Command is nine hundred and seventy-eight (978); the value of Octet count field is one (1) and Value field is shown in Table 370.

Table 370 – Write status counter mode request value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Counter mode	Counter Mode (1=Saturating; 0=Roll-Over Counter)

8.3.6.19.2 Response primitive

The Value field of response is shown in Table 370. The Response code values are shown in Table 371.

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Table 371 – Write status counter mode command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
6	Error	Device specific command error
7	Error	In write protect mode
16	Error	Access restricted
66	Error	Invalid Route identifier

8.3.6.19.3 Procedure at responding device

This command is used to configure the device to use saturating status counters or roll-over counters. When configured for saturating counter the status counters will count up from zero and reset after each health report. If the status counter reaches its maximum possible value (e.g., 255 for one byte counters) then the value will saturate at its maximum. When set for rollover operation the counters never reset. Upon incrementing the status while at the counter's maximum value, the counter will rollover to zero.

Network managers and gateways shall function correctly with status counters configured in either operating mode.

This command shall be accepted if received: at any time from the network manager; or via the local Maintenance Port while not connected to the network. If received from any other source or the Maintenance Port while connected to the Network the device shall return "Access Restricted".

8.3.6.20 Write security level supported FAL PDU

8.3.6.20.1 Request primitive

The value of Command is nine hundred and seventy-nine (979); the value of Octet count field is one (1) and Value field is shown in Table 372.

Table 372 – Write security level supported request value field

Octet offset	Data type	Parameter name	Description
0	Enumeration	Security level	Security Level Supported per Table F.29

8.3.6.20.2 Response primitive

The Value field of response is shown in Table 372. The Response code values are shown in Table 373.

Table 373 – Write security level supported command specific response codes

Value	Class	Description
0	Success	No error
2	Error	Invalid selection
5	Error	Too few data octets received
16	Error	Access restricted

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8.3.6.20.3 Procedure at responding device

This command allows the network manager to change the security level included in advertisements generated by the device. Security Level Supported is included in all advertisements and indicates the security protocols supported by the network manager. All network managers shall support at least the "Join Keyed" security type.

This command shall be rejected with a response code “Access Restricted” if the source address is any device other than the network manager.

8.3.7 Data coding rules

8.3.7.1 General

If the user data is always a simple (primitive) component, it is encoded as shown in Figure 48. The semantics of the user data are known implicitly from the position in the PDU, the length is fixed and implicitly known.

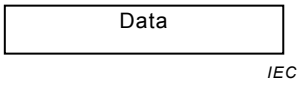

Figure 48 – Coding without identification

8.3.7.2 Coding for integer types

Integer values are signed quantities as shown in Figure 49 and Table 374. The MSB of this data type is transferred first followed by the next octets and the LSB is transferred last.

Notation:	**Integer8, Integer16, Integer24, Integer32**		
Range of Values:	Data Type	range of values	length
	Integer8	-128 ≤ i ≤ 127	1 octet
	Integer16	-32768 ≤ i ≤ 32767	2 octets
	Integer24	$-2^{23} \leq i \leq 2^{23} - 1$	3 octets
	Integer32	$-2^{31} \leq i \leq 2^{31} - 1$	4 octets
Coding:	In two's complement representation the MSB (Most Significant Bit) is the bit after the sign bit (SN) in the first octet. SN = 0: positive numbers and z SN = 1: negative numbers		

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Figure 49 – Coding of Integer type data

Table 374 – Coding of Integer16 type data

Octets	**Bits**							
	8	7	6	5	4	3	2	1
1	SN	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}
2	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}

8.3.7.3 Coding for unsigned Types

Unsigned Values are encoded as shown in Figure 50 and Table 375. The MSB of this data type is transferred first followed by the next octets and the LSB is transferred last.

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Notation:	Unsigned8, Unsigned16, Unsigned24, Unsigned32, Unsigned40		
Range of Values:	**Data Type**	**range of values**	**length**
	Unsigned8	$0 \le i \le 255$	1 octet
	Unsigned16	$0 \le i \le 65535$	2 octets
	Unsigned24	$0 \le i \le 2^{24} - 1$	3 octets
	Unsigned32	$0 \le i \le 2^{32} - 1$	4 octets
	Unsigned40	$0 \le i \le 2^{40} - 1$	5 octets

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Figure 50 – Coding of Unsigned type data

Table 375 – Coding of Unsigned16 type data

Octets	Bits							
	8	7	6	5	4	3	2	1
1	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^{9}	2^{8}
2	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}

8.3.7.4 Coding for floating point Type

Floating Point values are encoded as shown in Figure 51 and Figure 52. The sign and MSB of the exponent is transferred first followed by the balance of the exponent and the MSB to LSB of the fraction. If the value of an object of floating point data type is not known, then the value transferred is 0x7F, 0xA0, followed by all zeros (0x00); this value represents a 'Not-a-number'.

Notation:	Floating-Point (4 octet)
Range of Values:	See ISO/IEC/IEEE 60559, Short Real Number (32 bits)
Coding:	See ISO/IEC/IEEE 60559, Short Real Number (32 bits)

								LSB
bits	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
octets	**Exponent (E)**							
1	SN	2^{7}	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}
	(E)	**Fraction (F)**						
2	2^{0}	2^{-1}	2^{-2}	2^{-3}	2^{-4}	2^{-5}	2^{-6}	2^{-7}
	Fraction (F)							
3	2^{-8}	2^{-9}	2^{-10}	2^{-11}	2^{-12}	2^{-13}	2^{-14}	2^{-15}
	Fraction (F)							
4	2^{-16}	2^{-17}	2^{-18}	2^{-19}	2^{-20}	2^{-21}	2^{-22}	2^{-23}

SN: sign 0 = positive, 1 = negative

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Figure 51 – Coding of single precision floating point type data

Notation:	Floating-Point (8 octet)
Range of Values:	see ISO/IEC/IEEE 60559, Short Real Number (64 bits)
Coding:	see ISO/IEC/IEEE 60559, Short Real Number (64 bits)

								LSB
bits	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**

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octets								
	Exponent (E)							
1	SN	2^{10}	2^{9}	2^{8}	2^{7}	2^{6}	2^{5}	2^{4}
	Exponent (E)				**Fraction (F)**			
2	2^{3}	2^{2}	2^{1}	2^{0}	2^{-1}	2^{-2}	2^{-3}	2^{-4}
	Fraction (F)							
3	2^{-5}	2^{-6}	2^{-7}	2^{-8}	2^{-9}	2^{-10}	2^{-11}	2^{-12}
	Fraction (F)							
4	2^{-13}	2^{-14}	2^{-15}	2^{-16}	2^{-17}	2^{-18}	2^{-19}	2^{-20}
	Fraction (F)							
4	2^{-21}	2^{-22}	2^{-23}	2^{-24}	2^{-25}	2^{-26}	2^{-27}	2^{-28}
	Fraction (F)							
4	2^{-29}	2^{-30}	2^{-31}	2^{-32}	2^{-33}	2^{-34}	2^{-35}	2^{-36}
	Fraction (F)							
4	2^{-37}	2^{-38}	2^{-39}	2^{-40}	2^{-41}	2^{-42}	2^{-43}	2^{-44}
	Fraction (F)							
4	2^{-45}	2^{-46}	2^{-47}	2^{-48}	2^{-49}	2^{-50}	2^{-51}	2^{-52}

SN: sign 0 = positive, 1 = negative

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Figure 52 – Coding of double precision floating point type data

8.3.7.5 Coding for date type

The data type Date consists of a calendar date as shown in Table 376 and Figure 53. The first octet representing day of month is transferred first, followed by the month octet and the year octet is transferred last.

Notation: Date
Range of Values: 1 January 1900 to 31 December 2155
Coding: in 3 octets

Table 376 – Coding for Date type

Parameter	Range of values	Meaning of the parameters
d. of m.	1…31	day of month
months	1…12	months
years	0…255	years – 1900

Bits	8	7	6	5	4	3	2	1	
octets 1	RSV	RSV	RSV	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	1…31 d. of m.
2	RSV	RSV	RSV	RSV	2^{3}	2^{2}	2^{1}	2^{0}	1…12 months
3	RSV	2^{6}	2^{5}	2^{4}	2^{3}	2^{2}	2^{1}	2^{0}	0 … 255 years

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Figure 53 – Coding of Date type data

8.3.7.6 Coding for enumeration

The data type Enumeration is used to associate specific user definitions to numeric codes. For every object of Enumeration data type, there is a definition table that is shown in Annex F. This data type is transferred as either Unsigned8 for 1-octet long data, or Unsigned16 for 2-octet long data.

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8.3.7.7 Coding for bit field

The Bit Field type of data is used to transfer objects encoded as single-bit data. Table 377 and Table 378 show the numbering scheme of the bits of the data type Bit Field. Only multiples of eight are legal values of the length (in bits) of the Bit Field. For a 2-octet Bit Field the most significant octet is communicated first in a PDU. For every object of Bit Field data type, there is a definition table that is shown in Annex F.

Table 377 – Coding of 1-octet Bit Field type data

Octet	Bits							
	8	**7**	**6**	**5**	**4**	**3**	**2**	**1**
1	8	7	6	5	4	3	2	1

Table 378 – Coding of 2-octet Bit Field type data

Octet	Bits							
	8	**7**	**6**	**5**	**4**	**3**	**2**	**1**
1	16	15	14	13	12	11	10	9
2	8	7	6	5	4	3	2	1

8.3.7.8 Coding for time type

The data type Time is 32-bit unsigned integer and represents time in the increments of 1/32 of a millisecond. If this data type is used to represent time of day, then it indicates number of 1/32 of milliseconds since midnight. The MSB of this data type is transferred first followed by the next octets and the LSB is transferred last.

8.3.7.9 Coding for security key type

The data type security key is a string of sixteen octets. The MSB of this data type is transferred first followed by the next octets and the LSB is transferred last.

8.3.7.10 Coding for Unique ID type

The data type Unique ID is a string of five octets. The MSB of this data type is transferred first followed by the next octets and the LSB is transferred last.

8.3.7.11 Coding for engineering unit type

The data type Engineering unit is one octet long. The coding of this data type is same as that of Unsigned8.

8.3.7.12 Coding for packed ASCII string type

Packed ASCII is a 6-bit character code representing a subset of the ASCII character code set as shown in Table 379. It is produced by compressing four Packed ASCII characters into three octets. This type of string is always a multiple of 4 characters (3 octets) and is padded out to the end of the data item with SP characters. The length of the string is not transferred along with the string. The length is predetermined for each type of object, which is identified by object index. If the number of characters in the value of a string object is less than its predetermined length, then unused characters at the end of the string are set to SP (0x20). For example 4 SP characters at the end of a string would appear as the 3 octets: 0x82, 0x08, and 0x20. The first character of this string is transferred first, followed by the next character and the last character is transferred last.

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Table 379 – Packed ASCII character set

Bits 4 and 5	Bits 0 to 3															
	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	^	_
2	SP	!	"	#	$	%	&	'	(	)	*	+	,	-	.	/
3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?

NOTE Most significant hexadecimal digit is top to bottom; least significant is left to right. SP indicates a space character.

8.3.7.13 Coding for restricted ISO Latin-1 string type

ISO Latin-1 (ISO/IEC 8859-1) string consists of one character per octet. A restricted version that omits rows 0, 1, 8 and 9 in the Latin-1 table is used, as shown in Table 380.

The length of the string is not transferred along with the string. The length is predetermined for each type of object, which is identified by object index. If the number of characters in the value of a string object is less than its predetermined length, then unused characters at the end of the string are set to zeros (0x00). One zero (0x00) at the end of a string ISO Latin-1 data item may not be sufficient to meet this requirement. A valid restricted ISO Latin-1 character, other than zero, is permitted in the last octet of a restricted ISO Latin-1 data object. The first character of this string is transferred first, followed by the next character and the last character is transferred last.

Table 380 – Subset of ISO Latin-1 characters

Bits 4 to 7	Bits 0 to 3															
	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0																
1																
2	SP	!	"	#	$	%	&	'	(	)	*	+	,	-	.	/
3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	^	_
6	`	a	B	c	D	e	f	g	h	i	j	k	l	m	n	o
7	p	q	R	s	T	u	v	w	x	y	z	{	|	}	~	
8																
9																
A	NBSP	¢	£	¤	¥	¦	§	¨	©	ª	«	¬	SHY	®	¯	
B	°	±	²	³	´	µ	¶	·	¸	¹	º	»	¼	½	¾	¿
C	À	Á	Â	Ã	Ä	Å	Æ	Ç	È	É	Ê	Ë	Ì	Í	Î	Ï
D	Ð	Ñ	Ò	Ó	Ô	Õ	Ö	×	Ø	Ù	Ú	Û	Ü	Ý	Þ	ß
E	à	á	â	ã	Ä	å	æ	ç	è	é	Ê	ë	ì	í	î	ï
F	ð	ñ	ò	ó	Ô	õ	ö	÷	ø	ù	Ú	û	ü	ý	þ	Ÿ

NOTE Most significant hexadecimal digit is top to bottom; least significant is left to right. SP indicates a space character. NBSP indicates a non-breaking space character. SHY indicates a soft hyphen. Grayed out cells means that no character is assigned to this code.

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8.4 Common procedures

8.4.1 Delayed response

8.4.1.1 General operation

The delayed response mechanism (DRM) enables a slave to indicate to the requesting master that it received the request but is not able to immediately formulate the reply. This mechanism

provides an informative and flexible convention for slave devices needing additional time to perform operations such as self diagnostics, calibration, configuration or bandwidth requests. Unlike the response code “Busy”, the master knows that the slave has understood the command and is still communicating. The response APDU specification in 8.3.3, 8.3.4, 8.3.5 and 8.3.6 show which AL services allow the DRM responses. All network devices shall support DRM and comply with the following rules.

- If a request APDU is received that would normally initiate a DR and no buffers are available then the slave shall respond with a Busy.
- The device shall always respond to an Identity Command even if a DR is in progress. The field device may successfully respond to “Read” commands even if a DR is in progress.
- If a DR is in progress that will prevent a slave from responding to a request APDU, then the slave shall respond with a “DR_CONFLICT” code. For example DR_CONFLICT response is returned if a master tries to initiate a transducer trim while one is already in process.
- After DR processing is complete, the slave shall respond to READ commands even if the master has not sent the result of the DR.
- Bridging devices should support one DR buffer for each communication channel supported according to this standard.

Slave devices shall use the response codes listed in Table 381 to synchronize DR operation with master devices.

Table 381 – DRM related response codes

Mnemonic	Value	Description
Busy	32	Indicates the device is busy performing an indivisible operation. For commands supporting DRM, Busy indicates that no more DR buffers are available.
DR_INITIATE	33	Indicates the start of a DR. The slave device needs additional time to process the command
DR	34	Indicates that the slave device is still processing the command.
DR_DEAD	35	Used by multiplexers supporting Type 20 protocol to indicate that no response at all was received from the slave device.
DR_CONFLICT	36	Indicates that the command cannot be processed because it is in conflict with DR currently being processed.

All master class devices shall support DRM. When a master receives a DR_INITIATE response, the exact command (including the data) has to be reissued to retrieve the results. The master can issue this command after a delay.

8.4.1.2 Normal DR operation

A simple DR transaction is shown in Figure 54. The master sends a command that the slave cannot immediately complete. The slave initiates the DR and begins processing the command for later retrieval by the master. Sometime later the master issues the same exact command. The slave is not finished and issues a DR_RUNNING. Later the command completes and the master retrieves the result.

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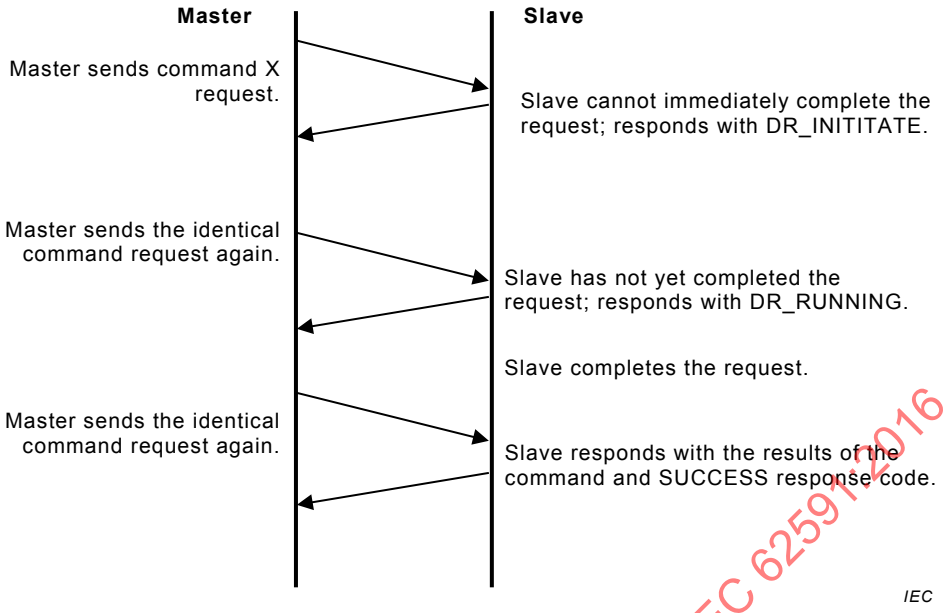

Figure 54 – Normal DR operation

8.4.1.3 Use of DR_CONFLICT response code

The example of DR_CONFLICT is shown in Figure 55. If a DR_CONFLICT is received, the master should delay it's retry to allow the responding slave to complete the pending DR. Masters should follow this procedure to minimize repetitive polling that, in turn, would delay the field device's completion of the DR.

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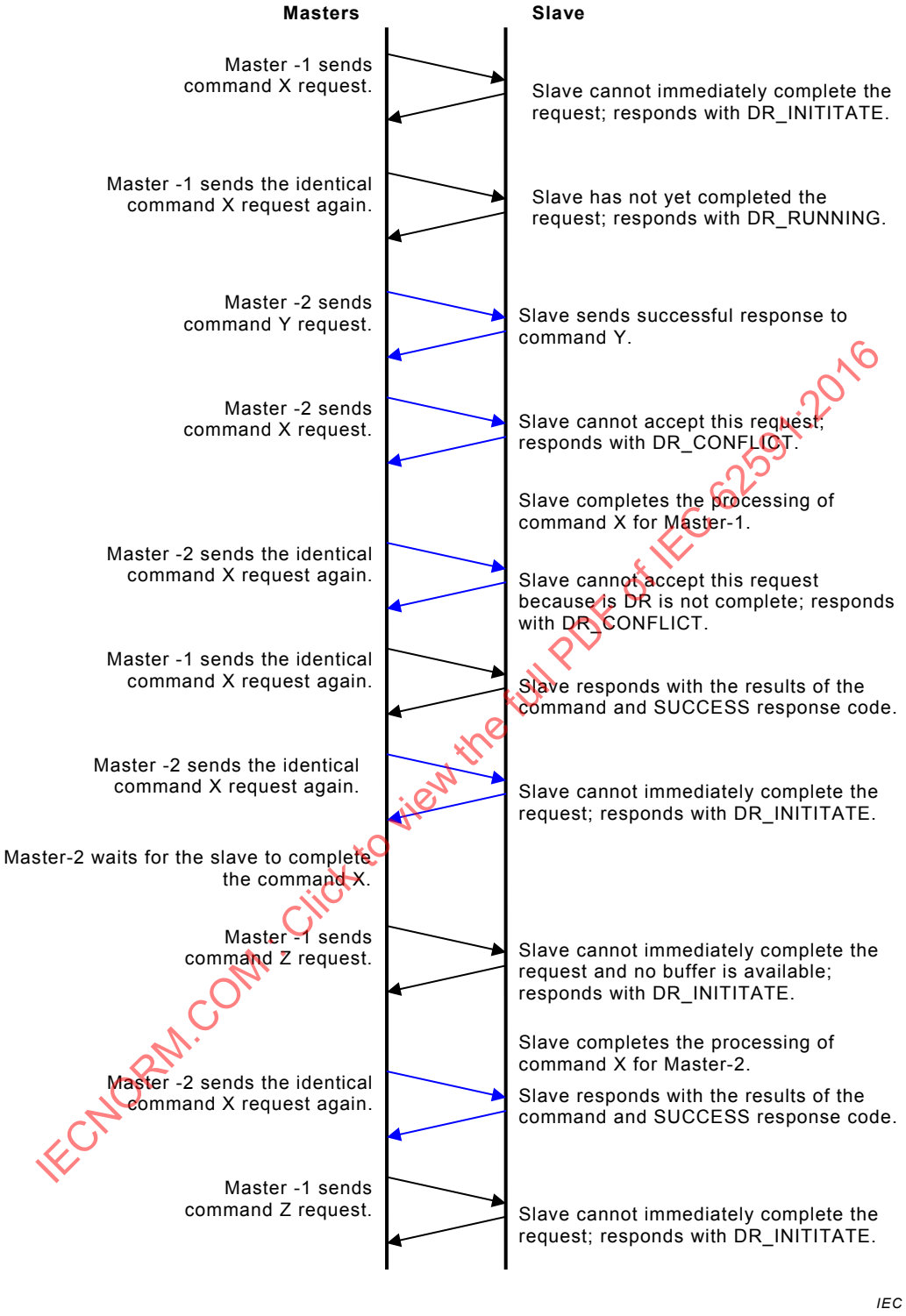

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Figure 55 – Command responses during DR processing

8.4.1.4 Multiple DR buffers

A slave device can have two DR buffers, one for each master. Some devices (for example multiplexers and I/O systems) may have many more buffers. Multiple DR buffers allow a DR from each master to be queued. However, the slave shall be careful to protect against inconsistencies. If implemented properly, out-of-order-completion of pending delayed responses is possible as shown in Figure 56.

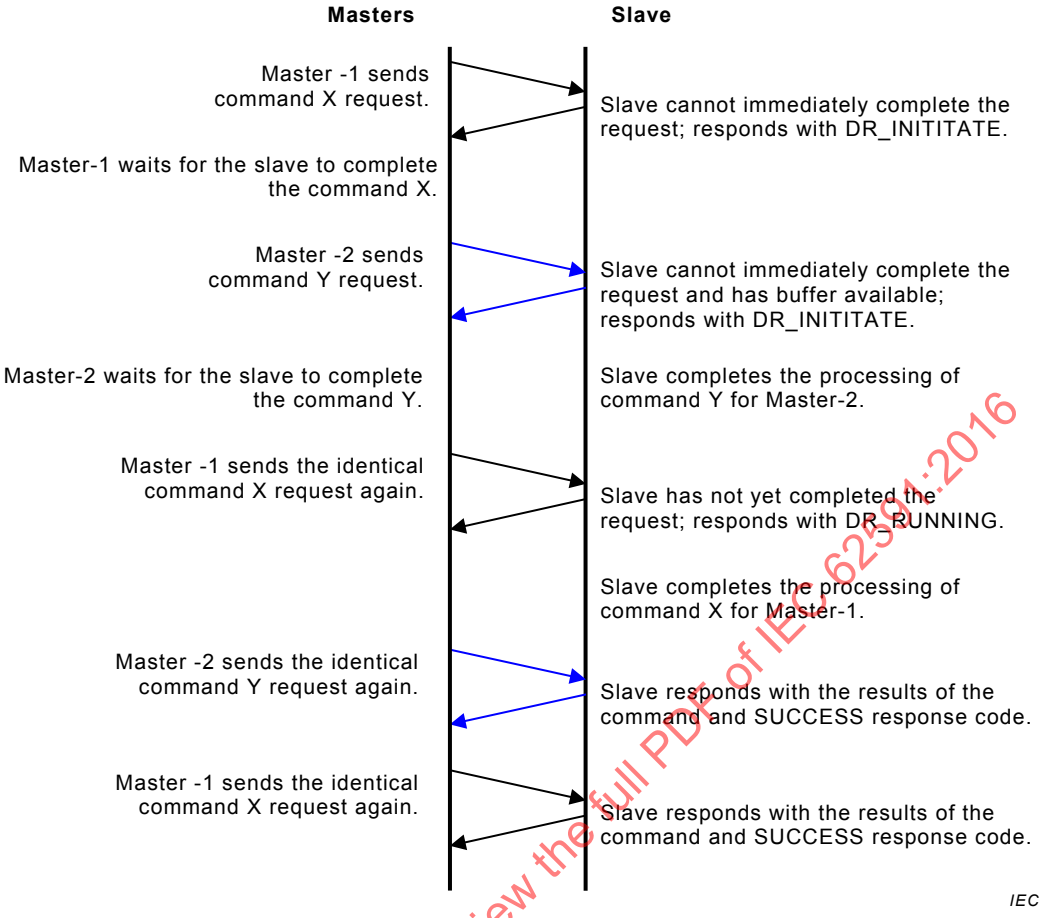

Figure 56 – Slaves with multiple DR buffers

8.4.1.5 Bridge device use of DRM

Bridge devices (for example multiplexers and I/O systems) function as slaves for the master that issues a request and as master for slaves that are addressed. Such devices are identified by setting the Protocol_Bridge_Device bit in the Flags byte of Identity Commands.

Bridge devices may introduce delays in relaying a command to and from the field device or sub-device. As a result, bridge devices are allowed to use the DRM for all command.

An additional response code (DR_DEAD) is used if the slave connected to the bridge device fails to reply at all. A master receiving DR_DEAD shall assume that a serious error has occurred. Since an intelligent bridge should automatically retry the command if the slave does not answer, the master should immediately notify the user that the slave device is not responding.

8.4.2 Response time

To minimize the network latency, the responding device shall meet the timing specified below.

- Prepare the response to a network management configuration specific (see 8.3.6) request, such that the response can be sent in the second slot following the slot in which the PDU was received (i.e., one intervening slot between the request and the response is allowed for command processing).
- Prepare the response to all other requests, such that the response can be sent in the sixth slot following the slot in which the PDU was received.

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- If the response code has to be ‘DR initiated’, then this response shall not be generated until after 75 % of the TL max_reply_time has elapsed.

8.5 FAL service protocol machine (FSPM)

8.5.1 General

FAL Service Protocol Machine is common for AL User services. It has one state called "ACTIVE" as shown in Figure 57.

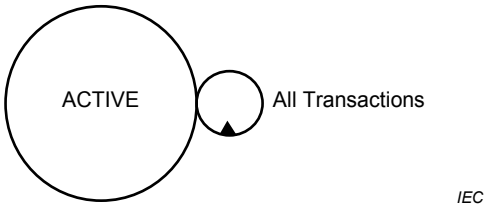

Figure 57 – State transition diagram of FSPM

8.5.2 FSPM state tables

Table 382 and Table 383 specify the FSPM protocol machine. All read and write services have identical state transition and identical actions. Therefore, this table does not list every service request and response separately.

Table 382 – FSPM state Table – client transactions

#	Current state	Event or condition => action	Next state

S1	ACTIVE	Identify.req
		=>
		Transaction.req {
		remote_address:= AREP_ID,
		transport_type:= TransportType (Identify.req),
		priority:= Priority (Identify.req),
		req_user_data:= FormReqApdu (Identify.req)
		}
			ACTIVE

S2	ACTIVE	Read(any).req
		=>
		Transaction.req {
		remote_address:= AREP_ID,
		transport_type:= TransportType(Variable index),
		priority:= Priority(Variable index),
		req_user_data:= FormReqApdu (Read.req)
		}
			ACTIVE

S3	ACTIVE	Write(any).req
		=>
		Transaction.req {
		remote_address:= AREP_ID,
		transport_type:= type(Variable index),
		priority:= priority(Variable index),
		req_user_data:= FormReqApdu (Write.req)
		}
			ACTIVE

S4	ACTIVE	Transaction.cnf
		&& status == "Error"
		&& RetrieveCommand (rsp_user_data) == 0 | 11 | 21
		=>
		Identify.cnf(-) {
		Status:= “Error”
		}
			ACTIVE

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#	Current state	Event or condition => action	Next state

S5	ACTIVE	Transaction.cnf
		&& CommandErr (rsp_user_data) == "True"
		&& RetrieveCommand (rsp_user_data) == 0 | 11 | 21
		=>
		Identify.cnf(-) {
		Resp_code:= ResponseCode (rsp_user_data),
		Dev_stat:= DeviceStat (rsp_user_data)
		}
			ACTIVE

S6	ACTIVE	Transaction.cnf
		&& status == "Error"
		&& RetrieveCommand (rsp_user_data) != 0 | 11 | 21
		=>
		Read.cnf(-) | Write.cnf(-) {
		Status:= “Error”
		}
			ACTIVE

S7	ACTIVE	Transaction.cnf
		&& CommandErr (rsp_user_data) == "True"
		&& RetrieveCommand (rsp_user_data) != 0 | 11 | 21
		=>
		Identify.cnf(-) | Write.cnf(-) {
		Resp_code:= ResponseCode (rsp_user_data),
		Dev_stat:= DeviceStat (rsp_user_data)
		}
			ACTIVE

S8	ACTIVE	Transaction.cnf
		&& CommandErr (rsp_user_data) == "False"
		&& RetrieveCommand (rsp_user_data) == 0 | 11 | 21
		=>
		Identify.cnf(+) {
		Resp_code:= ResponseCode (rsp_user_data),
		Dev_stat:= DeviceStat (rsp_user_data),
		data:= Value (rsp_user_data)
		}
			ACTIVE

S9	ACTIVE	Transaction.cnf
		&& CommandErr (rsp_user_data) == "False"
		&& RetrieveCommand (rsp_user_data) != 0 | 11 | 21
		=>
		Read (any).cnf(+) | Write (any).cnf(+) {
		Resp_code:= ResponseCode (rsp_user_data),
		Dev_stat:= DeviceStat (rsp_user_data),
		data:= Value (rsp_user_data)
		}
			ACTIVE

S10	ACTIVE	Receive.ind
		&& CommandErr (user_data) == "False"
		=>
		Information report.ind {
		AREP_ID:= remote_address,
		Variable index:= RetrieveCommand (rsp_user_data),
		Resp_code:= ResponseCode (rsp_user_data),
		Dev_stat:= DeviceStat (rsp_user_data),
		data:= Value (rsp_user_data)
		}	

NOTE Read (any) includes all AL Read services; Write (any) includes all AL Write services.			

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Table 383 – FSPM state Table – server transactions

#	Current state	Event or condition => action	Next state

R1	ACTIVE	Transaction.ind
		=>
		al_service.ind {
		AREP_ID:= remote_address,
		Variable index:= RetrieveCommand (req_user_data),
		data:= Value (req_user_data, transport_type)
		}
			ACTIVE

R2	ACTIVE	al_service.rsp
		=>
		
		Transaction.rsp {
		remote_address:= AREP_ID,
		rsp_user_data:= FormRspApdu (al_service.rsp)
		}
			ACTIVE

R3	ACTIVE	Information report(any).req
		=>
		
		Send.req {
		remote_address:= AREP_ID,
		transport_type:= type(Variable index),
		priority:= priority(Variable index),
		rsp_user_data:= FormApdu (Information report.req)
		}
			ACTIVE

NOTE The al_service includes all AL services.			

8.5.3 Functions used by FSPM

Table 384 to Table 392 describe the functions used by FSPM.

Table 384 – Function TransportType ()

Name	TransportType	Used in	FSPM
Input		Output	
Variable index		Transport type	
Function			
TransportType depends upon the command number (variable index). It has one of the following values: Request-unicast, Search-broadcast, Request-broadcast, Response-unicast, Response-broadcast, Block-transfer request, Block-transfer response, Publish-broadcast and Publish-unicast.			

Table 385 – Function PriorityType ()

Name	Priority	Used in	FSPM
Input		Output	
Variable index		Priority	
Function			
PriorityType depends upon the command number (variable index). It has one of the following values: Command, Process-data, Normal and Alarm.			

Table 386 – Function FormReqApdu ()

Name	FormReqApdu	Used in	FSPM
Input		Output	
User request		APDU	
Function			
Uses the parameters to form the request APDU as specified in 8.3.2.			

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Table 387 – Function FormRspApdu ()

Name	FormRspApdu	Used in	FSPM
Input		Output	
User response		APDU	
Function			
Uses the parameters to form the response APDU as specified in 8.3.2.			

Table 388 – Function RetrieveCommand ()

Name	RetrieveCommand	Used in	FSPM
Input		Output	
APDU		Variable index	
Function			
Retrieve the variable index (command number) from the APDU.			

Table 389 – Function CommandErr ()

Name	CommandErr	Used in	FSPM
Input		Output	
APDU		True || False	
Function			
Looks at the Response code field in the APDU. If its value is not zero (0) and if the Value field does not exist, then this function returns True; else it returns False.			

Table 390 – Function ResponseCode ()

Name	ResponseCode	Used in	FSPM
Input		Output	
APDU		Response code	
Function			
This function returns Response code field in the APDU. It can be either communication error or command response code.			

Table 391 – Function DeviceStat ()

Name	DeviceStat	Used in	FSPM
Input		Output	
APDU		Application process status	
Function			
This function returns “Application process status” field in the APDU.			

Table 392 – Function Value ()

Name	Value	Used in	FSPM
Input		Output	
APDU, transport_type		Data	
Function			
This function returns request or response data octets of the APDU. If transport_type is response, then there response code in addition to Value field in the APDU.			

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8.5.4 Parameters of FSPM/ARPM primitives

The parameters used with the primitives exchanged between the FSPM and the ARPM are described in Table 393.

Table 393 – Parameters used with primitives exchanged between FSPM and ARPM

Parameter name	Description
remote_address	This parameter is the network address of the destination device in Transaction.req, Transaction.rsp and Send.req; source device in Transaction.ind and Receive.ind.
transport_type	It indicates the type of transport pipe to use.
priority	It indicates the priority of the request.
req_user_data	This parameter conveys request APDU.
rsp_user_data	This parameter conveys response APDU.
status	This parameter conveys the status of response confirmation.

8.6 Application relationship protocol machines (ARPMs)

8.6.1 AREP mapping to transport layer

8.6.1.1 General

This section describes the mapping of the AL to the Fieldbus transport layer. It does not redefine the TLSAP attributes or TLME attributes that are defined in the transport layer specification; rather, it defines how they are used by each of the AR classes. A means to configure and monitor the values of these attributes is provided by network management.

The following class definitions describe the TSAP attributes and the TLME attributes required to support each of the AREP classes.

NOTE Undefined attributes use the same definitions as those previously defined.

8.6.1.2 TL mapping of client AREP class

8.6.1.2.1 Client AREP class formal model

The TL Mapping attributes and their permitted values and the TL services used with the Client AREP class are defined in this subclause.

```
CLASS: Client
PARENT CLASS: Top
ATTRIBUTES:
1.          (m) Key Attribute:    Remote_address
DLL SERVICES:
1.          (m) OpsService:       TL-DATA-EXCHANGE.req
2.          (m) OpsService:       TL-DATA-EXCHANGE.cnf
3.          (m) OpsService:       TL-DATA-TRANSFER.ind
```

8.6.1.2.2 Attributes

8.6.1.2.2.1 Remote_address

This attribute specifies the remote address to which request APDUs are sent, or from which confirm APDUs are received.

8.6.1.2.2.2 Void

NOTE To retain the overall structure of describing attributes in a separated subclause, this is an empty subclause to fulfill the ISO/IEC Directives Part 2 requirements not to have an isolated subclause.

8.6.1.2.3 TL services

8.6.1.2.3.1 TL-DATA-EXCHANGE.req

This service is used in Master device to transfer an APDU to the remote Slave TL user, which shall send a response.

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8.6.1.2.3.2 TL-DATA-EXCHANGE.cnf

The TL uses this service to transfer the response APDU from a remote Slave TL user in response to a prior request.

8.6.1.2.3.3 TL-DATA-TRANSFER.ind

This service is used in Master device to receive an APDU from the remote Slave TL user without a prior request.

8.6.1.3 TL mapping of server AREP class

8.6.1.3.1 Server AREP class formal model

The TL Mapping attributes and their permitted values and the TL services used with the Server AREP class are defined in this subclause.

```
CLASS: Server
PARENT CLASS: Top
ATTRIBUTES:
1.          (m)  Key Attribute:   Address
DLL SERVICES:
1.          (m)  OpsService:      TL-DATA-EXCHANGE.ind
2.          (m)  OpsService:      TL-DATA-EXCHANGE.rsp
3.          (m)  OpsService:      TL-DATA-TRANSFER.req
```

8.6.1.3.2 Attributes

8.6.1.3.2.1 Address

This attribute specifies the address that the Slave device uses to receive and send TPDU.

8.6.1.3.2.2 Void

NOTE To retain the overall structure of describing attributes in a separated subclause, this is an empty subclause to fulfill the ISO/IEC Directives Part 2 requirements not to have an isolated subclause.

8.6.1.3.3 TL services

8.6.1.3.3.1 TL-DATA-EXCHANGE.ind

The TL uses this service to transfer the indication APDU from a remote Master TL user, which shall send a response.

8.6.1.3.3.2 TL-DATA-EXCHANGE.rsp

This service is used in Slave device to transfer an APDU to the remote Master TL user, which is a response to prior indication.

8.6.1.3.3.3 TL-DATA- TRANSFER.req

This service is used in Master device to transfer an APDU to the remote Master TL user, which is not a response to an indication.

8.6.2 Application relationship protocol machines (ARPMs)

8.6.2.1 AR protocol machine (ARPM) for client AREP

8.6.2.1.1 Client ARPM states

The defined states and their descriptions of the Client ARPM are shown in Table 394 and Figure 58.

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Table 394 – Client ARPM states

State name	Description
IDLE	The AREP is not active.
WAIT for CONFIRM	The AREP has sent a request PDU to a Server and is waiting for a confirmation from the Server.

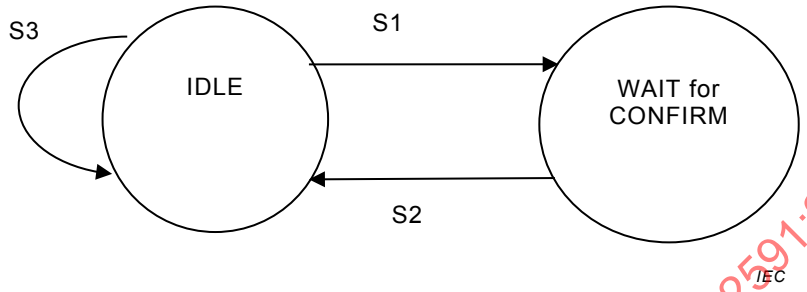

Figure 58 – State transition diagram of the client ARPM

8.6.2.1.2 Client ARPM state table

Table 395 specifies the Client ARPM state machine.

Table 395 – Client ARPM state table

#	Current state	Event or condition => action	Next state

S1	IDLE	Transaction.req
		=>
		DTC_req {
		called_address:= remote_address,
		transport_type:= transport_type,
		priority:= priority,
		req_user_data:= req_user_data
		}
			WAIT for CONFIRM

S2	WAIT for CONFIRM	DTC_cnf
		=>
		Transaction.cnf {
		rsp_user_data:= rsp_user_data,
		status:= status
		}
			IDLE

S3	IDLE	DTU_ind
		&& CommandErr (rsp_user_data) == "False"
		=>
		Receive.ind {
		remote_address:= calling_address,
		transport_type:= transport_type,
		rsp_user_data:= rsp_user_data
		}
			IDLE

NOTE The parameters transport_type, priority and status are present only for wireless Type 20 fieldbus.			

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8.6.2.2 AR protocol machine (ARPM) for server AREP

8.6.2.2.1 Server ARPM states

The defined states and their descriptions of the Server ARPM are shown in Table 396 and Figure 59.

Table 396 – Server ARPM states

State name	Description
IDLE	The AREP is not active.
WAIT for RESPONSE	The AREP has received a PDU from DLL, has sent the corresponding indication to the AL user and is waiting for a response from the AL user

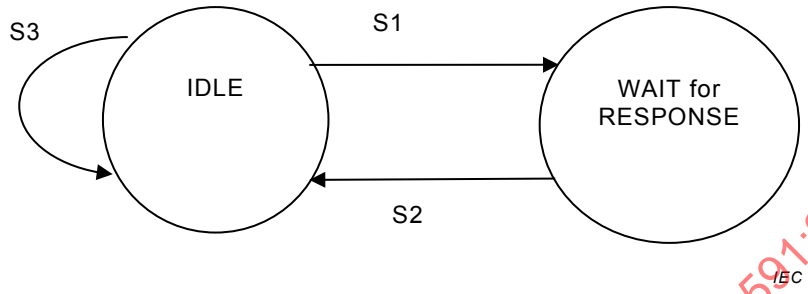

Figure 59 – State transition diagram of the server ARPM

8.6.2.2.2 Server ARPM state table

Table 397 specifies the Server ARPM state machine.

Table 397 – Server ARPM state table

#	Current state	Event or condition => action	Next state

S1	IDLE	DTC_ind
		=>
		Transaction.ind {
		remote_address:= calling_address,
		transport_type:= transport_type,
		req_user_data:= req_user_data
		}
			WAIT for RESPONSE

S2	WAIT for RESPONSE	Transaction.rsp
		=>
		DTC_rsp {
		called_address:= remote_address,
		rsp_user_data:= rsp_user_data
		}
			IDLE

S3	IDLE	Send.req
		=>
		DTU_req {
		called_address:= remote_address,
		transport_type:= transport_type,
		priority:= priority,
		rsp_user_data:= rsp_user_data
		}
			IDLE

NOTE The parameter transport_type is present only for wireless Type 20 fieldbus.			

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8.6.3 AREP state machine primitive definitions

The primitives exchanged between the TMPM and the ARPM are specified in Table 398 and Table 399.

Table 398 – Primitives issued from ARPM to TMPM

Primitive name	Source	Associated parameters	Functions
DTC_req	ARPM	called_address, transport_type, priority, req_user_data	This primitive is used to request the TMPM to transfer a confirmed request APDU to a Slave device
DTC_rsp	ARPM	called_address, rsp_user_data	This primitive is used to request the TMPM to transfer a response APDU to a Master device
DTU_req	ARPM	called_address, transport_type, priority, req_user_data	This primitive is used to request the TMPM to transfer a unconfirmed request APDU to a Master device

Table 399 – Primitives issued by TMPM to ARPM

Primitive name	Source	Associated parameters	Functions
DTC_ind	TMPM	calling_address, transport_type, priority, req_user_data	This primitive is used to pass an APDU received as a Transport layer service data unit to the Server ARPM
DTC_cnf	TMPM	rsp_user_data, status	This primitive is used to convey a response APDU received from the Slave device
DTU_ind	TMPM	calling_address, transport_type, priority, rsp_user_data	This primitive is used to pass an APDU received as a Transport layer service data unit to the Client ARPM

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8.6.4 AREP state machine functions

ARPM does not use any functions.

8.7 TL mapping protocol machine (TMPM)

8.7.1 TMPM states

The defined states and their descriptions of the TMPM are shown in Table 400 and Figure 60.

Table 400 – TMPM state descriptions

State name	Description
ACTIVE	The TMPM in the ACTIVE state is ready to transmit or receive primitives to or from the transport layer and the ARPM

Figure 60 – State transition diagram of TMPM

8.7.2 TMPM state machines

Table 401 and Table 402 specify the TMPM state machine.

Table 401 – TMPM state Table – Client transactions

#	Current state	Event or condition => action	Next state

S1	ACTIVE	DTC_req
		=>
		TL-DATA-EXCHANGE.req {
		destination_address:= called_address,
		transport_type:= transport_type,
		priority:= priority,
		tls_user_data:= req_user_data
		}
			ACTIVE

S2	ACTIVE	TL-DATA-EXCHANGE.cnf
		=>
		DTC_cnf {
		rsp_user_data:= tls_user_data,
		status:= status
		}
			ACTIVE

S2	ACTIVE	TL-DATA-TRANSFER.ind => DTU_ind calling_address:= source_address, transport_type:= transport_type, priority:= priority, rsp_user_data:= tls_user_data }	ACTIVE

Table 402 – TMPM state Table – Server transactions

#	Current state	Event or condition => action	Next state

S1	ACTIVE	DTC_rsp
		=>
		TL-DATA-EXCHANGE.rsp {
		tls_user_data:= rsp_user_data
		}
			ACTIVE

S2	ACTIVE	TL-DATA-EXCHANGE.ind
		=>
		DTC_ind {
		calling_address:= source_address,
		transport_type:= transport_type,
		priority:= priority,
		req_user_data:= tls_user_data
		}
			ACTIVE

S3	ACTIVE	DTU_req
		=>
		TL-DATA-TRANSFER.req {
		destination_address:= called_address,
		transport_type:= transport_type,
		priority:= priority,
		tls_user_data:= rsp_user_data
		}
			ACTIVE

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8.7.3 Primitives exchanged between transport layer and TMPM

The primitives exchanged between the data-link layer and the TMPM are specified in Table 403.

Table 403 – Primitives exchanged between network layer and TMPM

Primitive name	Source	Associated parameters
TL-DATA-EXCHANGE.req	TMPM	destination_address, transport_type, priority, tls_user_data
TL-DATA-EXCHANGE.ind	Transport layer	source_address, transport_type, priority, tls_user_data
TL-DATA-EXCHANGE.rsp	TMPM	tls_user_data
TL-Data-exchange.cnf	Transport layer	tls_user_data, status
TL-DATA-TRANSFER.req	TMPM	destination_address, transport_type, priority, tls_user_data
TL-DATA-TRANSFER.ind	Transport layer	source_address, transport_type, priority, tls_user_data

8.7.4 Functions used by TMPM

TMPM does not use any functions.

9 Communication Profile Family 9 (HART™)

9.1 General Overview

The principles and conventions for a Communication Profile Family (CPF) and a Communication Profile (CP) are specified in IEC 61784-1 and apply also to this standard except the conformance statement.

NOTE The concept of Communication Profiles and the association to Types is given in IEC 61158-1.

Communication Profile Family 9 defines a profile based on Type 20 IEC 61158 series, which corresponds to parts of a communication system commonly known as the HART™. There are two profiles:

- CP 9/1 also known as HART™ Universal Command set, and
- CP 9/2 also known as WirelessHART™.

All of the services and protocol elements of IEC 61158-5-20 and IEC 61158-6-20 application layer are referenced by IEC 61784-1 CP 9/1. The CP 9/2 is based on this standard and references to the services and protocol elements of IEC 61158-5-20 and IEC 61158-6-20 application layer.

Table 404 gives an overview of the specified profile sets.

Table 404 – CPF 9: overview of profile sets

Layer	Profile CP 9/1	Profile CP 9/2
Application	IEC 61158-5-20, IEC 61158-6-20	Clause 7 and 8
Data-link	—	Clause 5 and 6
Physical	—	Clause 4 with references to IEEE 802.15.4-2011

For CP 9/2 there are additional behaviors specified:

- Security in Annex A,
- Network Management in Annex C, and
- Gateway in Annex D.

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9.2 Profile 9/1

CP 9/1 is specified in IEC 61784-1.

9.3 Profile 9/2

9.3.1 Conformance statement

IEC 61784-2:2014, Clause 4 applies, but the project number shall be of this standard instead of IEC 61784-2 and the use of <Type> is mandatory.

A statement of compliance with a communication profile (CP) of this standard shall be stated as either

- Compliance to IEC 62591:2016 CP 9/2 <organization name><Identifier>, or
- Compliance to IEC 62591 (Ed.2.0) CP 9/2 <organization name><Identifier>.

where the <Identifier> is the name of the device types specified in 9.3.2 and a unique <organization name> specifies the corresponding values:

- Manufacturer ID (see IEC 61158-6-20:2014, Table 6),
- Expanded Device Type (see IEC 61158-6-20:2014, Table 6),
- Command Rev (see IEC 61158-6-20:2014, Table 6), and
- OUI (see 6.3.1.2.4).

These parameters shall be unique for the CP 9/2 devices that are within one network and in range of other networks.

A device may support more than one device type of 9.3.2.

The organization name could be for example a vendor or group or consortium name.

EXAMPLE The HART™ Communication Foundation would mark their compliant devices with:

IEC 62591:2016 CP 9/2 WirelessHART™ Field Device

or another organization would name their compliant devices with:

IEC 62591:2016 CP 9/2 MyOrganization_name Field Device

If WirelessHART™ is intended to be used as <organization name> then

- the parameters Manufacturer ID and Expanded Device Type shall be assigned by HCF;

  NOTE 1 See document HCF_SPEC-183 for already assigned codes.
- the Engineering unit codes shall be assigned by HCF;

  NOTE 2 See document HCF_SPEC-183 for already assigned codes.
- the parameter Command Rev shall be set to a valid code of HCF specification revision numbers (for example 7.2);
- an OUI, which has been obtained by HCF, shall be set to 0x001B1E; and
- a certificate from HCF shall be obtained based on a successful compliance test.

Another conformance statement can be done based on regional and national regulations. For example in Europe the additional conformance statement can be given based on the additional provisions and methods given in Annex M.

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9.3.2 Device types

9.3.2.1 General

Figure 61 shows various network components specified for CPF 9. The plant automation network can be based on a standard protocol or it can be a proprietary network. Its specification is out of the scope of this standard. The gateway is connected to the wireless network through its network access point(s). More than one network access points can be used to increase the throughput and improve the overall reliability of the wireless network.

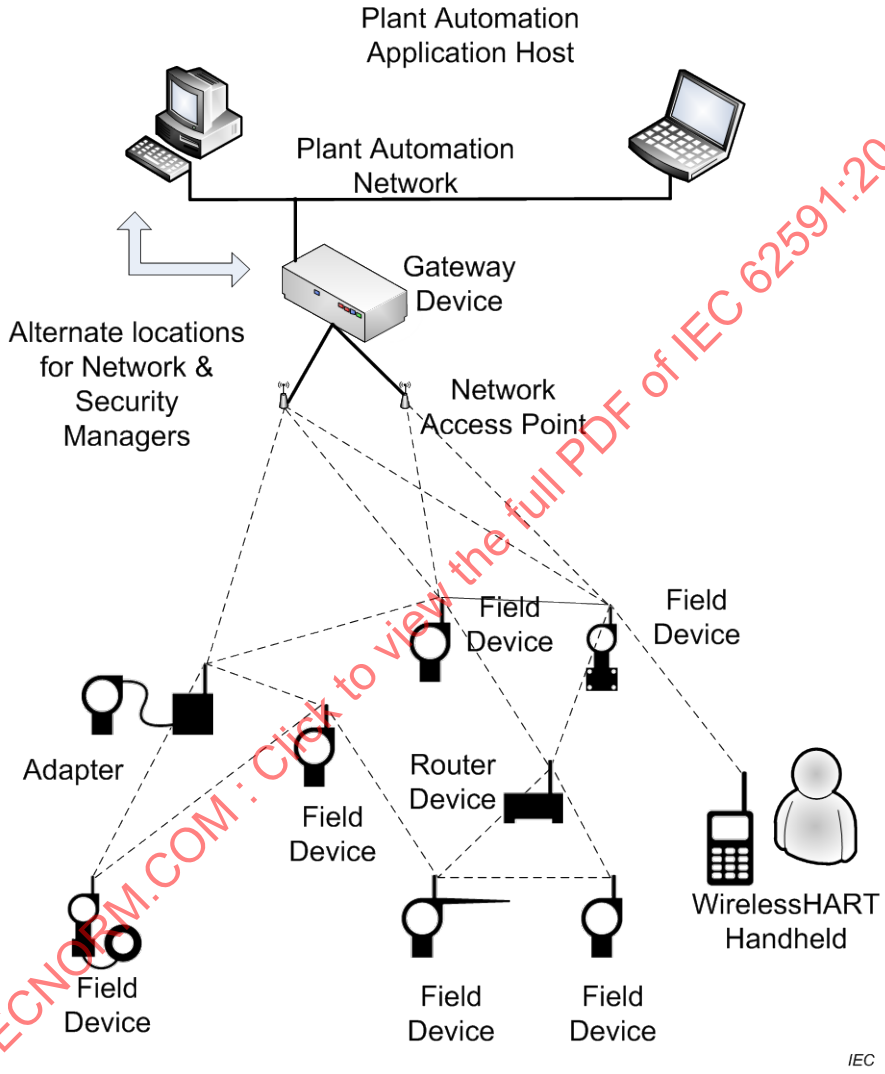

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Figure 61 – Wireless network components

Any device directly connected to the wireless network is one of the following types of network device:

- Field device,
- Adapter,
- Router,
- Gateway,
- Handheld device.

All wireless network devices transmit and receive PDUs and perform the basic functions necessary to support network formation and maintenance. All network devices are able to

source and sink packets and capable of routing packets received from other devices in the network. Each network device also has attributes holding information on update rates, sessions and device resources covering items such as the size of the superframe, etc. Each network device contains a list of Neighbor devices that it has identified during its listening operations.

All network devices have a 5 octet Unique ID assigned at the time of manufacturing the device. The EUI-64 address is a concatenation of the 24-bit OUI value assigned by the IEEE Registration Authority and a 40-bit extension identifier, which is the 5 octet Unique ID.

9.3.2.2 Field device

A Field device is directly connected to the field Process to measure it or to control it or it is connected to plant equipment. It is a producer and consumer of packets and is capable of routing packets received from other network devices compliant to this standard. The Field Device may be line, loop, battery powered or powered in some other fashion. Field device may also support traditional 4 mA to20 mA current loop signaling. The Field device shall have a maintenance port for example according to IEC 61784-1 CP 9/1 and may only have a wire connection to the process automation system.

9.3.2.3 Adapter

An Adapter device provides physical and logical connectivity to non-native communicating device(s) to the wireless network. It uses internal routing tables to coordinate traffic flow between the wireless network and its non-native communicating sub-device(s). An Adapter is not directly connected to the field process. It supports all commands required of the Field device (see 9.3.2.2) including the publishing of process data on behalf of the non-native connected field device. In response to Identify command, it sets Device Flag to 0x04 (Protocol bridge device).

Non-native communicating devices can be HART™ devices according to IEC 61784-1 CP 9/1 or 4 mA to 20 mA devices.

NOTE The gateway connects the Field devices to the host system or plant automation network. The Adapter makes the non-native device look like a Field device.

9.3.2.4 Router

A Router device forwards packets from one network device to another. It uses its graphs and connections to find the next hop neighbor to which the received packet has to be forwarded. In general standalone routers are not required since all network devices support routing. However, it may be beneficial (for example to extend the network, or to save the power of a Field devices in the network) to add additional devices to improve routing in the network. A router is not connected to the process and does not operate as a gateway. When a network access point does not source the network clock it shall synchronize to the network devices acting as its clock parents.

9.3.2.5 Gateway

Gateway device connects the wireless network according to this standard to a plant automation network, allowing data to flow between the two networks. It provides host applications access to the network devices. A gateway device can be used to convert from one protocol to another, as go-between two or more networks that use the same protocol, or to convert commands and data from one format to another. The wireless network also uses the gateway as the source for the synchronized clock used by the timeslots and superframes.

A gateway requires a Network Access Point, which is logically part of the gateway, to connect to the wireless network. The gateway can use more than one network access point to improve the effective throughput and reliability of the network. Network access points propagate the clock to the network. There is always at least one network access point providing the clock to the network.

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Annex D specifies the functions performed by the gateway.

9.3.2.6 Handheld device

A handheld device is used in the installation, control, monitoring, and maintenance of network devices. It is portable equipment and it is operated by the plant personnel. There are two approaches to connect handheld device to a network device.

- Wireless connected handheld device that communicates directly to the wireless network according to this standard. This handheld device joins the network as a wireless field device. When operating with a target network device that is connected to a wireless network, the handheld device operates in a special mode that allows it to communicate with one device at a time. A handheld device is not required to support routing.
- Plant automation network connected handheld device that connects to the plant automation network through some other networking technology. This device communicates with the network devices through the gateway device in the same way as the external plant automation host does. It appears as a host application to the network device.

9.3.2.7 Network manager

The network manager does not directly connect to the wireless network, but it is logically part of the gateway. It has its own Unique ID and thus it communicates with other network devices using the application layer protocol of this standard. The network manager is responsible for configuration of the network; scheduling communication between network devices; management of the routing tables and monitoring and reporting the health of the wireless network. It contains a complete list of network devices and ensures each has a network-unique short 16-bit Nickname.

As part of its system functions, the network manager collects performance and diagnostic information. This information is accessible during run-time, making it possible to view and analyze the behavior of the overall network. If problems are detected, the reconfiguration of the network is performed while the network is operating. This network grooming is performed continuously as the overall network operation and performance varies due to changes in network load and environmental conditions.

Annex C specifies the functions performed by the network manager.

9.3.2.8 Security manager

Join, network and session keys shall be provided to the network manager and join keys shall be provided to network devices. These keys are used for device authentication and encryption of data in the network. The security manager is responsible for the generation, storage, and management of keys. There is one Security manager associated with each wireless network. One security manager may service multiple wireless networks. The security manager function is required to manage these keys. The security manager may be a centralized function in some plant automation networks, servicing more than just one wireless network and in some cases other networks and applications.

The security manager communicates directly with the network manager for the distribution of the keys. The functional requirements and the operation of the security manager and its communication with the network manager are outside the scope of this standard.

9.3.3 Device worldwide applicability

9.3.3.1 General

This standard is designed to support operation within a fixed geographic area that operates under uniform regulations. As such it is intended to support operation in the 2,4 GHz band anywhere in the world. For example, Annex M discusses how systems and devices can be configured to meet EU regulatory constraints.

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Radio regulations often require devices to operate at constrained power levels at all times, including during over-the-air provisioning. Examples of EIRP and EIRP density limits in some country are:

- Japan: 10 mW/MHz;
- China: 10 dBm;
- EU: 10 dBm, 10 mW/MHz and 20 dBm;
- US: 36 dBm with at most 6 dBi antenna gain.

In some countries, such as France, emission levels on certain channels may need to be attenuated. In other countries, such as Korea, the number and range of channels needs to be constrained.

9.3.3.2 Operation within a fixed regulatory regime

In some country no operational method may override the RF emission limits established under regulation. A vendor can decide to select parameters so that the device can be brought to the market worldwide or just in some country with a specific set of parameters. Annex M lists some “in-some-country” clauses, which might be elevated to a normative text when this document is adopted by a regional or national standardization body.

9.3.4 Physical layer

9.3.4.1 General overview

Wireless devices (see 9.3.2) use Radio Frequencies (RF) to communicate between devices. The distance between two devices can be 100 meters or more depending upon the transmitter power, antenna type and lack of obstruction between two devices. Wireless devices can be powered either by mains power, battery, energy harvesting devices (for example solar, vibration, etc.), or a combination thereof.

The profile is used for devices implementing wireless mesh network communication as defined by this standard. The physical layer is responsible for the signaling method, signal strength, device sensitivity, and environment for sending bits across the network media. This wireless PhL is based on the 2.450 MHz direct sequence spread spectrum (DSSS) physical layer (PHY) according to IEEE 802.15.4-2011, Clause 10 and employing O-QPSK modulation. This profile specification includes the following:

- the PhL requirements many of which are adopted directly from IEEE 802.15.4-2011 including specific requirements on channels, transmit power, and receive sensitivity, and
- the PhL requirements to ensure interoperability among wireless devices.

The PhL of this standard deals with radio characteristics making a network connection. It associates with any part of the network structure that doesn't process information in any way. The physical layer is responsible for sending the bits across the network media. It does not define what a bit is or how it is used merely how it's sent. The PhL is responsible for transmitting and receiving the data.

Items defined by the PhL include RF transmitters, receivers, and transceivers. Any item that does not process information but is required for the sending and receiving of data is defined by this layer.

Table 405 specifies the PhL selection within Clause 4 for this profile. It includes the physical layer specification and service definition.

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Table 405 – CP 9/2: PhL selection

Clause	Header	Presence	Constraints
4	Physical layer specification and service definition	—	—
4.1	General	YES	—
4.2	Physical layer service definition	YES	Subclause 9.3.4.2 and 9.3.4.3 apply
4.3	Physical layer protocol specification	YES	Subclause 9.3.4.2 and 9.3.4.3 apply

9.3.4.2 Requirements based on IEEE STD 802.15.4-2011

Table 406 specifies the IEEE STD 802.15.4-2011 PhL selection for a communicating device and it's MAU.

Table 406 – CP 9/2: PhL protocol selection

Clause of IEEE 802. 15.4-2011	Header	Presence	Constraints
1-4	—	Partial	If applicable
5-7	—	NO	—
8	General PHY requirements	—	—
8.1	General requirements and definitions	—	—
8.1.1	Operating frequency range	Partial	Only 2 450 MHz band is included – see Table 407
8.1.2	Channel assignments	Partial	Only Channels 11-25 of channel page 0 are included – see Table 408
8.1.3	Minimum LIFS and SIFS periods	Partial	Only 2 450 MHz band is included
8.1.4	RF power measurement	YES	—
8.1.5	Transmit power	YES	See 9.3.4.3.5 for additional requirements
8.1.6	Out-of-band spurious emission	YES	—
8.1.7	Receiver sensitivity definitions	YES	—
8.2	General radio specifications	Partial	CCAEnabled
8.2.1 – 8.2.6	—	YES	—
8.2.7	Clear channel assessment (CCA)	YES	CCA Mode requested and CCA can be enabled/disabled by CCAEnabled
9	PHY services	—	See 4.2.2 for replacement of this clause
9.1	Overview		
9.2	PHY constants	YES	—
9.3	PHY PIB attributes	Partial	See 9.3.4.3.8
9.4	PHY PIB attribute values for phyMaxFrameDuration and phySHRDuration	YES	—
10	O-QPSK PHY	—	
10.1	PPDU format	YES	—
10.2	Modulation and spreading	Partial	Only 2 450 MHz band is included
10.3	O-QPSK PHY RF requirements	Partial	See 9.3.4.3.5 and 9.3.4.3.7 for further explanation and only 2 450 MHz band is included
11 – 15	—	NO	—
Annex A	Bibliography	Partial	If applicable
Annex B – Annex H	—	NO	—

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9.3.4.3 Other physical layer requirements

9.3.4.3.1 Frequency Allocations

The transceiver shall employ DSSS and operate in the license-free ISM band as shown in Table 407.

Table 407 – Transceiver Specifications

Frequency (MHz)	Communication rate (kchip/s)	Modulation	Bit rate (kb/s)	Symbol rate (ksymbol/s)	Symbols
2 400 – 2 483,5	2 000	O-QPSK	250	62,5	16-ary Orthogonal

9.3.4.3.2 Channel numbers and frequency assignments

The 2 450 MHz band supports channel assignments 11-26 as specified by IEEE STD 802.15.4-2011, 8.1.2.2. Since channel 26 is not compliant with the regulation of some world regions, it is not included in this profile.

The frequency assignment for the channels 11 – 25 is shown in Table 408.

Table 408 – Frequency assignments

Channel number	Frequency (MHz)		Channel number	Frequency (MHz)		Channel number	Frequency (MHz)
11	2 405		16	2 430		21	2 455
12	2 410		17	2 435		22	2 460
13	2 415		18	2 440		23	2 465
14	2 420		19	2 445		24	2 470
15	2 425		20	2 450		25	2 475

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9.3.4.3.3 Radio transceivers

A communicating device using this profile can be implemented with readily available 'off the shelf' or custom radio transceivers that are compliant to IEEE 802.15.4-2011 and meets the criteria listed below.

This standard is intended to conform to worldwide regulations in Europe, Canada, Japan, China, the United States and other locations. Annex M provides information of aspects in some country and describes possibilities how a device can comply with these regulations.

9.3.4.3.4 Unspecified or improved required radio performance

This profile includes following that is not specified in IEEE 802.15.4-2011.

- Time to switch between channels shall be 12-symbol periods max (0,192 ms).
- Recommended cold start radio turn-on time is 4 ms maximum. It includes frequency lock and settling time.

9.3.4.3.5 Transmit power

Transmit power shall be the Equivalent Isotropic Radiated Power (EIRP) of the device. All communicating device using this profile shall provide a nominal EIRP of +10 dBm (10 mW) ±3 dB.

In addition, manufacturers shall ensure that their device complies with localized transmit power regulations applicable to the device's installation.

In both cases the rated transmit power shall be representative of the manufacturer's production device with power source (batteries, solar, or otherwise) at 95 % to 100 % of rated capacity. All devices should be provided with an Omni-direction antenna. The rated transmit

power data including maximum output power and radiation patterns for all antennae supported by the product shall be available in the product manual or upon request.

9.3.4.3.6 Output power control

The device power level shall be programmable at discrete, monotonic levels from -10 dBm to +10 dBm EIRP (within ±4 dBm of error in actual power level). The application layer command is available to control the output power.

9.3.4.3.7 Receiver sensitivity

Device sensitivity is defined as the combined sensitivity of the receiver and the antenna as a system. All devices shall achieve a system (radio, circuit card, cabling, and connectors) device sensitivity of -85 dB or better.

9.3.4.3.8 PHY PIB attributes

This profile includes the attributes specified in the IEEE STD 802.15.4-2011, 9.3 and additional attributes that apply only to this profile. Some of these attributes are assigned a constant value for this profile as shown in Table 409.

Table 409 – PHY PIB attributes

Attribute	Comment
phyCurrentChannel	Set by PH-ENABLE request
phyChannelsSupported	Only channels 11 – 25 are supported
phyTransmitPower	The values from ‘-10 dBm to +10 dBm’ are supported
phyCCAMode	Table F.40 summarizes the modes
phyCurrentPage	Only value 0 is included
phyMaxFrameDuration	Only value ‘266’ is included
phySHRDuration	Only value ‘10’ is included
phySymbolsPerOctet	Only value ‘2’ is included
SleepState	It takes one of the two values – sleep, awake
RcvOvewrflowEnable	If true, then it enables the receive overflow error indication

9.3.5 Data-link layer

9.3.5.1 DLL service selection

Table 410 specifies the DLL service selection within Clause 5 for this profile. It includes the services provided by data-link, network and transport layers.

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Table 410 – CP 9/2: DLL service selection

Clause	Header	Presence	Constraints
5	Data-link layer service definition – Type 20 elements	—	—
5.1	General	YES	—
5.2	Data-link layer services	—	—
5.2.1	Facilities of the data-link layer services	YES	—
5.2.2	QoS for message service	YES	—
5.2.3	Sequence of primitives	YES	—
5.2.4	DL-TRANSMIT Service	YES	—
5.2.5	DL-RECEIVE service	Partial	This service is optional. It is normally used for network troubleshooting in "promiscuous operating mode".
5.2.6	DL-DISCONNECT service	YES	—
5.2.7	DL-PATH-FAILURE service	YES	—
5.2.8	DL-ADVERTISE service	YES	—
5.2.9	DL-NEIGHBOR service	YES	—
5.2.10	DLM-SET	YES	—
5.2.11	DLM-GET	YES	—
5.2.12	DLM-ACTION	YES	—
5.2.13	DLM-EVENT	YES	—
5.3	Network layer services	YES	—
5.4	Transport layer services	YES	—

9.3.5.2 DLL protocol selection

Table 411 specifies the DLL service selection within Clause 6 for this profile. It includes the protocol specifications of data-link, network and transport layers.

Table 411 – CP 9/2: DLL protocol selection

Clause	Header	Presence	Constraints
6	Data-link layer protocol specification – Type 20 elements		
6.1	Overview	YES	—
6.3	Logical link control	YES	—
6.4	Medium access control	YES	—
6.5	DL-management-information	YES	—
6.6	Network layer	YES	—
6.7	Transport layer	YES	—

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9.3.6 Application layer

9.3.6.1 AL service selection

9.3.6.1.1 AL service selection common to all device types

IEC 61158-5-20 applies. Table 412 shows the AL service selection within Clause 7 for this profile.

Table 412 – CP 9/2: AL service selection

Clause	Header	Presence	Constraints
7	Application layer service definition – Type 20 elements	—	—
7.1	Common concepts	YES	—
7.2	General	YES	—
7.3	Data Type ASE	YES	—
7.4	Communication model specification	—	—
7.4.1	Common parameters	YES	—
7.4.2	ASEs	—	—
7.4.2.1	Virtual field device ASE	YES	—
7.4.2.2	Variable ASE	YES	—
7.4.2.3	Action ASE	YES	—
7.4.2.4	Device application services	Partial	See Table 413
7.4.2.5	Layer management services	Partial	See Table 414
7.4.2.6	Gateway and network manager services	Partial	See Table 415
7.4.2.7	Network management configuration services	Partial	See Table 416
7.4.3	ARs	YES	—

9.3.6.1.2 Variable ASE service selection

This clause specifies the services that are required for various device types. The following convention is used:

X: the service is required;

O: the service optional;

Blank cell: the service is not required.

Table 413, Table 414, Table 415 and Table 416 specify the Variable ASE service selection within Clause 7 for this profile.

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Table 413 – CP 9/2: Device application service selection

Clause	Header	VAR ID [a]	Field device	Adapter	Gateway	Hand held	Network manager
7.4.2.4.1	Read primary variable	1	X	X			
7.4.2.4.2	Read loop current and percent of range	2	X	X			
7.4.2.4.3	Read dynamic variables and loop current	3	X	X			
7.4.2.4.4	Write loop configuration	6	X	X			
7.4.2.4.5	Read loop configuration	7	X	X			
7.4.2.4.6	Read dynamic variable families classifications	8	X	X			
7.4.2.4.7	Read device variables with status	9	X	X			
7.4.2.4.8	Read message	12	X	X			
7.4.2.4.9	Read tag, descriptor and date	13	X	X			
7.4.2.4.10	Read primary variable transducer information	14	X	X			
7.4.2.4.11	Read device information	15	X	X			
7.4.2.4.12	Read final assembly number	16	X	X			
7.4.2.4.13	Write message	17	X	X			
7.4.2.4.14	Write tag, descriptor and date	18	X	X			
7.4.2.4.15	Write final assembly number	19	X	X			
7.4.2.4.16	Read long tag	20	X	X			
7.4.2.4.17	Write long tag	22	X	X			
7.4.2.4.18	Reset configuration changed flag	38	X	X	X		
7.4.2.4.19	Perform self test	41	X	X	X		
7.4.2.4.20	Perform device reset	42	X	X	X		
7.4.2.4.21	Read additional device status	48	X	X	X		
7.4.2.4.22	Reset more status available	48	X	X	X		
7.4.2.4.23	Read device variable information	54	X	X			
7.4.2.4.24	Write device variable	79	X	X			
7.4.2.4.25	Read real-time clock	90	X	X			
7.4.2.4.26	Write publish data period	103	X	X	X		
7.4.2.4.27	Write publish data trigger	104	X	X	X		
7.4.2.4.28	Read publish data mode configuration	105	X	X	X		
7.4.2.4.29	Flush delayed responses	106	X	X	X		
7.4.2.4.30	Write publish data device variables	107	X	X	X		
7.4.2.4.31	Write publish data mode command number	108	X	X	X		
7.4.2.4.32	Write publish data mode control	109	X	X	X		
7.4.2.4.33	Read event notification summary	115	X	X	X		
7.4.2.4.34	Write event notification bit mask	116	X	X	X		
7.4.2.4.35	Write event notification timing	117	X	X	X		
7.4.2.4.36	Write event notification control	118	X	X	X		
7.4.2.4.37	Write event notification acknowledgement	119	X	X	X		

[a] VAR ID is Numeric Identifier in the service definition. It is also referred to as HART™ command number.

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Table 414 – CP 9/2: Layer management service selection

Clause	Header	VAR ID [a]	Field device	Adapter	Gateway	Handheld	Network manager
7.4.2.5.1	Write Join_key	768	X	X		X	
7.4.2.5.2	Read join status	769	X	X		X	
7.4.2.5.3	Write active_search_shed_time	770	X	X		X	X
7.4.2.5.4	Write join mode configuration	771	X	X		X	
7.4.2.5.5	Read join mode configuration	772	X	X		X	X
7.4.2.5.6	Write network_ID	773	X	X	X	X	X
7.4.2.5.7	Read network_ID	774	X	X	X	X	X
7.4.2.5.8	Write network_tag	775	X	X	X	X	
7.4.2.5.9	Read network_tag	776	X	X	X	X	
7.4.2.5.10	Read wireless device capabilities	777	X	X			O
7.4.2.5.11	Read battery life	778	X	X	X		O
7.4.2.5.12	Report device health	779	X	X			X
7.4.2.5.13	Read neighbor health list	780	X	X			X
7.4.2.5.14	Read device nickname	781	X	X	X		
7.4.2.5.15	Read session list	782	X	X	X		
7.4.2.5.16	Read superframe list	783	X	X			
7.4.2.5.17	Read link list	784	X	X			
7.4.2.5.18	Read graph list	785	X	X			
7.4.2.5.19	Read neighbor attribute flag	786	X	X			
7.4.2.5.20	Read neighbor signal level	787	X	X			X
7.4.2.5.21	Report path down alarm	788	X	X			X
7.4.2.5.22	Report source route failed alarm	789	X	X			X
7.4.2.5.23	Report graph route failed alarm	790	X	X			X
7.4.2.5.24	Report transport layer failed alarm	791	X	X			X
7.4.2.5.25	Write UTC time mapping	793	X	X	O		
7.4.2.5.26	Read UTC time mapping	794	X	X	X		X
7.4.2.5.27	Write timer interval	795	X	X			X
7.4.2.5.28	Read timer interval	796	X	X			X
7.4.2.5.29	Write radio power output	797	X	X			X
7.4.2.5.30	Read radio power output	798	X	X	X		X
7.4.2.5.31	Request timetable	799	X	X			X
7.4.2.5.32	Read timetable list	800	X	X			
7.4.2.5.33	Delete timetable connection	801	X	X			X
7.4.2.5.34	Read route list	802	X	X			
7.4.2.5.35	Read source route	803	O	O			
7.4.2.5.36	Read CCA mode	804	X	X	X		
7.4.2.5.37	Write CCA mode	805	X	X			X
7.4.2.5.38	Read handheld superframe	806	X	X	X		X
7.4.2.5.39	Write handheld superframe	807	X	X		X	
7.4.2.5.40	Read packet hop-to-live	808	X	X	X		X
7.4.2.5.41	Write packet hop-to-live	809	X	X			O
7.4.2.5.42	Read join_priority	810	X	X	X		
7.4.2.5.43	Write join_priority	811	X	X			X
7.4.2.5.44	Read receive Priority_threshold	812	X	X	X		
7.4.2.5.45	Write receive Priority_threshold	813	X	X			X
7.4.2.5.46	Read device list	814	O	O	X		
7.4.2.5.47	Add device list entry	815	O	O	X		
7.4.2.5.48	Delete device list entry	816	O	O	X		
7.4.2.5.49	Read channel blacklist	817	X	X	X		
7.4.2.5.50	Write channel blacklist	818			X		
7.4.2.5.51	Read back-off exponent	819	X	X			
7.4.2.5.52	Write back-off exponent	820	X	X			X
7.4.2.5.53	Write network access mode	821			X		
7.4.2.5.54	Read network access mode	822			X		
7.4.2.5.55	Request session	823				X	X

[a] VAR ID is Numeric Identifier in the service definition. It is also referred to as HART™ command number.

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Table 415 – CP 9/2: Gateway and network manager service selection

Clause	Header	VAR ID [a]	FD [b]	Adapter	Gateway	Hand held	Network manager
7.4.2.6.1	Read network device identity using Unique ID	832			X		
7.4.2.6.2	Read device's neighbor health	833			X		
7.4.2.6.3	Read network topology information	834			X		
7.4.2.6.4	Read publish data message list	835			X		
7.4.2.6.5	Flush cached responses for a device	836			X		
7.4.2.6.6	Read network device statistics	840			X		
7.4.2.6.7	Read network device identity using nickname	841			X		
7.4.2.6.8	Write network device's scheduling flags	842			X		
7.4.2.6.9	Read network device's scheduling flags	843			X		
7.4.2.6.10	Read network constraints	844			X		
7.4.2.6.11	Write network constraints	845			X		
7.4.2.6.12	Read network statistics	846			X		
7.4.2.6.13	Transfer network list to white list	847			X		
7.4.2.6.14	Generate key	848			X		
7.4.2.6.15	Read device join key	849			X		
7.4.2.6.16	Write device join key	850			X		
7.4.2.6.17	Change key now	851			X		
7.4.2.6.18	Read stale data setpoints	852			X		
7.4.2.6.19	Write stale data timer	853			X		
7.4.2.6.20	Write stale data count setpoint	854			X		
7.4.2.6.21	Read session extended	855			X		
7.4.2.6.22	Read device suspend settings	856			X		
7.4.2.6.23	Read security level advertised	857			X		
7.4.2.6.24	Reset availability statistics	858			X		
7.4.2.6.25	Read active advertising status	859			X		
7.4.2.6.26	Read join key mode	860			X		
7.4.2.6.27	Write join key mode	861			X		
7.4.2.6.28	Read timetable by id	862			X		

[a] VAR ID is Numeric Identifier in the service definition. It is also referred to as HART™ command number.

[b] FD = Field device.

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Table 416 – CP 9/2: Network management configuration service selection

Clause	Header	VAR ID [a]	FD [b]	Adap-ter	Gate-way	Hand held	Network manager
7.4.2.7.1	Disconnect device	960	X	X			X
7.4.2.7.2	Write network key	961	X	X			X
7.4.2.7.3	Write device nickname	962	X	X			X
7.4.2.7.4	Write session	963	X	X			X
7.4.2.7.5	Delete session	964	X	X			X
7.4.2.7.6	Write superframe	965	X	X			X
7.4.2.7.7	Delete superframe	966	X	X			X
7.4.2.7.8	Write link	967	X	X			X
7.4.2.7.9	Delete link	968	X	X			X
7.4.2.7.10	Write graph connection	969	X	X			X
7.4.2.7.11	Delete graph connection	970	X	X			X
7.4.2.7.12	Write neighbor attribute flag	971	X	X			X
7.4.2.7.13	Write network suspend	972	X	X			X
7.4.2.7.14	Write timetable	973	X	X			X
7.4.2.7.15	Write route	974	X	X			X
7.4.2.7.16	Delete route	975	X	X			X
7.4.2.7.17	Write source route	976	O	O			X
7.4.2.7.18	Delete source route	977	O	O			X
7.4.2.7.19	Write status counter mode	978	X	X			X
7.4.2.7.20	Write security level supported	979	X	X			X

[a] VAR ID is Numeric Identifier in the service definition. It is also referred to as HART™ command number.

[b] FD = Field device.

9.3.6.2 AL protocol selection

9.3.6.2.1 AL protocol selection common to all device types

IEC 61158-6-20 applies. Table 417 specifies the AL service selection within Clause 8 for this profile.

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Table 417 – CP 9/2: AL protocol selection

Clause	Header	Presence	Constraints
8	Application layer protocol specification – Type 20 elements	—	—
8.1	General	YES	—
8.2	Abstract syntax	YES	—
8.3	Transfer syntax	—	—
8.3.1	Common APDU fields	—	—
8.3.1.1	Command number field	YES	—
8.3.1.2	Octet count field	YES	—
8.3.1.3	Response code field	YES	—
8.3.1.4	Application process status	YES	See Table 418
8.3.1.5	Extended status	YES	—
8.3.1.6	Value field	YES	—
8.3.1.7	Formats of APDU structures	YES	—
8.3.2	Common APDU structure	YES	—
8.3.3	Device application service-specific APDU structures	Partial	See Table 419
8.3.4	Layer management service specific APDU structures	Partial	See Table 420
8.3.5	Gateway and network manager specific APDU structures	Partial	See Table 421
8.3.6	Network management configuration specific APDU structures	Partial	See Table 422
8.3.7	Data coding rules	YES	—
8.4	Common procedures	YES	—
8.5	FAL Service Protocol Machine (FSPM)	YES	—
8.6	Application Relationship Protocol Machines (ARPMs)	YES	—
8.7	TL mapping protocol machine (TMPM)	YES	—

Table 418 – Application process status values

Bit mask	Definition
0x80	Device Malfunction – the device detected a serious error or failure that compromises device operation
0x40	Configuration changed – an operation was performed that changed the device's configuration
0x20	Cold Start – a power failure or Device Reset has occurred
0x10	More status available – more status information is available via another Read Command
0x08	Loop Current Fixed – the Loop Current is being held at a fixed value and is not responding to process variations
0x04	Loop Current Saturated – the Loop Current has reached its upper (or lower) endpoint limit and cannot increase (or decrease) any further
0x02	Non-Primary Variable Out of Limits – a Device Variable not mapped to the Primary Variable is beyond its operating limits
0x01	Primary Variable Out of Limits – the Primary Variable is beyond its operating limit

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9.3.6.2.2 Variable ASE protocol selection

The service-specific APDU selection tables use following convention:

X: the APDU is required;

O: the APDU optional;

blank: the APDU is not required.

Table 419 – CP 9/2: Device application service-specific APDU selection

Clause	Header	CMD ID [a]	Field device	Adapter	Gateway	Hand held	Network manager
8.3.3.1	Identify FAL PDU	0, 11, 21	X	X			
8.3.3.2	Read primary variable FAL PDU	1	X	X			
8.3.3.3	Read loop current and percent of range FAL PDU	2	X	X			
8.3.3.4	Read dynamic variables and loop current FAL PDU	3	X	X			
8.3.3.5	Write loop configuration FAL PDU	6	X	X			
8.3.3.6	Read loop configuration FAL PDU	7	X	X			
8.3.3.7	Read dynamic variable families classifications FAL PDU	8	X	X			
8.3.3.8	Read device variables with status FAL PDU	9	X	X			
8.3.3.9	Read message FAL PDU	12	X	X			
8.3.3.10	Read tag, descriptor and date FAL PDU	13	X	X			
8.3.3.11	Read primary variable transducer information FAL PDU	14	X	X			
8.3.3.12	Read device information FAL PDU	15	X	X			
8.3.3.13	Read final assembly number FAL PDU	16	X	X			
8.3.3.14	Write message FAL PDU	17	X	X			
8.3.3.15	Write tag, descriptor and date FAL PDU	18	X	X			
8.3.3.16	Write final assembly number FAL PDU	19	X	X			
8.3.3.17	Read long tag FAL PDU	20	X	X			
8.3.3.18	Write long tag FAL PDU	22	X	X			
8.3.3.19	Reset configuration changed flags FAL PDU	38	X	X	X		
8.3.3.20	Perform self test FAL PDU	41	X	X	X		
8.3.3.21	Perform device reset FAL PDU	42	X	X	X		
8.3.3.22	Read additional device status FAL PDU	48	X	X	X		
8.3.3.23	Reset more status available FAL PDU						
8.3.3.24	Read device variable information FAL PDU	54	X	X			
8.3.3.25	Write device variable FAL PDU	79	X	X			
8.3.3.26	Read Sub-Device Identity Summary	84	X	X			
8.3.3.27	Read real-time clock FAL PDU	90	X	X			
8.3.3.28	Write publish data period FAL PDU	103	X	X	X		
8.3.3.29	Write publish data trigger FAL PDU	104	X	X	X		
8.3.3.30	Read publish data mode configuration FAL PDU	105	X	X	X		
8.3.3.31	Flush delayed responses FAL PDU	106	X	X	X		
8.3.3.32	Write publish data device variables FAL PDU	107	X	X	X		
8.3.3.33	Write publish data mode command number FAL PDU	108	X	X	X		
8.3.3.34	Write publish data mode control FAL PDU	109	X	X	X		
8.3.3.35	Read event notification summary FAL PDU	115	X	X	X		
8.3.3.36	Write event notification bit mask FAL PDU	116	X	X	X		
8.3.3.37	Write event notification timing FAL PDU	117	X	X	X		
8.3.3.38	Write event notification control FAL PDU	118	X	X	X		
8.3.3.39	Write event notification acknowledgement FAL PDU	119	X	X	X		

[a] CMD ID is the value of Command field in the APDU. It is also referred to as HART™ command number.

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Table 420 – CP 9/2: Layer management service-specific APDU selection

Clause	Header	CMD ID [a]	Field device	Adap-ter	Gate-way	Hand held	Network manager
8.3.4.1	Write Join_key FAL PDU	768	X	X		X	
8.3.4.2	Read join status FAL PDU	769	X	X		X	
8.3.4.3	Write active_search_shed_time FAL PDU	770	X	X		X	X
8.3.4.4	Write join mode configuration FAL PDU	771	X	X		X	
8.3.4.5	Read Join mode configuration FAL PDU	772	X	X		X	X
8.3.4.6	Write network_ID FAL PDU	773	X	X	X	X	X
8.3.4.7	Read network_ID FAL PDU	774	X	X	X	X	X
8.3.4.8	Write network_tag FAL PDU	775	X	X	X	X	
8.3.4.9	Read network_tag FAL PDU	776	X	X	X	X	
8.3.4.10	Read wireless device capabilities FAL PDU	777	X	X			O
8.3.4.11	Read battery life FAL PDU	778	X	X	X		O
8.3.4.12	Report device health FAL PDU	779	X	X			X
8.3.4.13	Read neighbor health list FAL PDU	780	X	X			X
8.3.4.14	Read device nickname FAL PDU	781	X	X	X		
8.3.4.15	Read session list FAL PDU	782	X	X	X		
8.3.4.16	Read superframe list FAL PDU	783	X	X			
8.3.4.17	Read link list FAL PDU	784	X	X			
8.3.4.18	Read graph list FAL PDU	785	X	X			
8.3.4.19	Read neighbor attribute flag FAL PDU	786	X	X			
8.3.4.20	Read neighbor signal level FAL PDU	787	X	X			X
8.3.4.21	Report path down alarm FAL PDU	788	X	X			X
8.3.4.22	Report source route failed alarm FAL PDU	789	X	X			X
8.3.4.23	Report graph route failed alarm FAL PDU	790	X	X			X
8.3.4.24	Report transport layer failed alarm FAL PDU	791	X	X			X
8.3.4.25	Write UTC time mapping FAL PDU	793	X	X	O		
8.3.4.26	Read UTC time mapping FAL PDU	794	X	X	X		X
8.3.4.27	Write timer interval FAL PDU	795	X	X			X
8.3.4.28	Read timer interval FAL PDU	796	X	X			X
8.3.4.29	Write radio power output FAL PDU	797	X	X			X
8.3.4.30	Read radio power output FAL PDU	798	X	X	X		X
8.3.4.31	Request timetable FAL PDU	799	X	X			X
8.3.4.32	Read timetable list FAL PDU	800	X	X			
8.3.4.33	Delete timetable FAL PDU	801	X	X			X
8.3.4.34	Read route list FAL PDU	802	X	X			
8.3.4.35	Read source route FAL PDU	803	X	X			
8.3.4.36	Read CCA mode FAL PDU	804	X	X	X		
8.3.4.37	Write CCA mode FAL PDU	805	X	X			X
8.3.4.38	Read handheld superframe FAL PDU	806	X	X	X		X
8.3.4.39	Write handheld superframe FAL PDU	807	X	X		X	
8.3.4.40	Read packet hop-to-live FAL PDU	808	X	X	X		X
8.3.4.41	Write packet hop-to-live FAL PDU	809	X	X			O
8.3.4.42	Read Join_priority FAL PDU	810	X	X	X		
8.3.4.43	Write Join_priority FAL PDU	811	X	X			X
8.3.4.44	Read receive Priority_threshold FAL PDU	812	X	X	X		
8.3.4.45	Write receive Priority_threshold FAL PDU	813	X	X			X
8.3.4.46	Read device list FAL PDU	814	O	O	X		
8.3.4.47	Add device list entry FAL PDU	815	O	O	X		
8.3.4.48	Delete device list entry FAL PDU	816	O	O	X		
8.3.4.49	Read channel blacklist FAL PDU	817	X	X	X		
8.3.4.50	Write channel blacklist FAL PDU	818			X		
8.3.4.51	Read back-off exponent FAL PDU	819	X	X			
8.3.4.52	Write back-off exponent FAL PDU	820	X	X			X
8.3.4.53	Write network access mode FAL PDU	821			X		
8.3.4.54	Read network access mode FAL PDU	822			X		
8.3.4.55	Request session FAL PDU	823				X	X

[a] CMD ID is the value of Command field in the APDU. It is also referred to as HART™ command number.

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Table 421 – CP 9/2: Gateway and network manager service-specific APDU selection

Clause	Header	CMD ID [a]	FD	Adap-ter	Gate-way	Hand held	Network manager
8.3.5.1	Read network device identity using unique ID FAL PDU	832			X		
8.3.5.2	Read device's neighbor health FAL PDU	833			X		
8.3.5.3	Read network topology information FAL PDU	834			X		
8.3.5.4	Read publish data message list FAL PDU	835			X		
8.3.5.5	Flush cached responses for a device FAL PDU	836			X		
8.3.5.6	Read network device statistics FAL PDU	840			X		
8.3.5.7	Read network device identity using nickname FAL PDU	841			X		
8.3.5.8	Write network device's scheduling flags FAL PDU	842			X		
8.3.5.9	Read network device's scheduling flags FAL PDU	843			X		
8.3.5.10	Read network constraints FAL PDU	844			X		
8.3.5.11	Write network constraints FAL PDU	845			X		
8.3.5.12	Read Network Statistics FAL PDU	846			X		
8.3.5.13	Transfer network list to white list FAL PDU	847			X		
8.3.5.14	Generate key FAL PDU	848			X		
8.3.5.15	Read device join key FAL PDU	849			X		
8.3.5.16	Write device join key FAL PDU	850			X		
8.3.5.17	Change key now FAL PDU	851			X		
8.3.5.18	Read stale data setpoints FAL PDU	852			X		
8.3.5.19	Write stale data timer FAL PDU	853			X		
8.3.5.20	Write stale data count setpoint FAL PDU	854			X		
8.3.5.21	Read session extended FAL PDU	855			X		
8.3.5.22	Read device suspend settings FAL PDU	856			X		
8.3.5.23	Read security level advertised FAL PDU	857			X		
8.3.5.24	Reset availability statistics FAL PDU	858			X		
8.3.5.25	Read active advertising status FAL PDU	859			X		
8.3.5.26	Read join key mode FAL PDU	860			X		
8.3.5.27	Write join key mode FAL PDU	861			X		
8.3.5.28	Read Timetable by ID FAL PDU	862			X		

[a] CMD ID is the value of Command field in the APDU. It is also referred to as HART™ command number.

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Table 422 – CP 9/2: Network management configuration service-specific APDU selection

Clause	Header	CMD ID [a]	FD	Adapter	Gate-way	Hand held	Network manager
8.3.6.1	Disconnect device	960	X	X			X
8.3.6.2	Write network key	961	X	X			X
8.3.6.3	Write device nickname	962	X	X			X
8.3.6.4	Write session	963	X	X			X
8.3.6.5	Delete session	964	X	X			X
8.3.6.6	Write superframe	965	X	X			X
8.3.6.7	Delete superframe	966	X	X			X
8.3.6.8	Write link	967	X	X			X
8.3.6.9	Delete link	968	X	X			X
8.3.6.10	Write graph connection	969	X	X			X
8.3.6.11	Delete graph connection	970	X	X			X
8.3.6.12	Write neighbor attribute flag	971	X	X			X
8.3.6.13	Write network suspend	972	X	X			X
8.3.6.14	Write timetable	973	X	X			X
8.3.6.15	Write route	974	X	X			X
8.3.6.16	Delete route	975	X	X			X
8.3.6.17	Write source route	976	X	X			X
8.3.6.18	Delete source route	977	X	X			X

[a] CMD ID is the value of Command field in the APDU. It is also referred to as HART™ command number.

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Annex A
(normative)

Security

A.1 General

Security function for a network according to this standard specifies the communications security functionality and related security aspects. Other security aspects such as physical device security are not in the scope of this standard. The specific messages that are protected by the security functionality are:

- single-hop MAC sublayer protocol data units,
- end-to-end transport layer protocol data units, and
- management of keys within AL protocol data units.

Security should be policy driven and multi-layered, not subject to the choice of the device installer or software author. It shall be structured so that casual acts of a single individual that put system security at risk either are not permitted, or are strictly controlled. Security related services should be selected by policy coupled with individual application choice.

The policy should be distributed with a shared-secret symmetric key, permitting focused policy application that can be changed by a network security manager sharing a shared-secret key with the target device. Where policy permits more than one selection for a security attribute, the application should determine the selection within the permitted range via its initial or current service request.

The hop-by-hop transmission security is provided by the LLC sublayer. It defends against attackers who are outside the system and do not share system secrets.

The end to end security is provided by the security sublayer at the top of the network layer. It defends against attackers who may be on the network path between the source and the destination.

A new device is connected to the network only after it has received a Join_key via its maintenance port.

Devices with credentials participate in secured communications with other such devices through the use of a shared-secret symmetric key (see 6.6.3.2) that authenticates their messages to each other.

When only two devices share a secret key, receipt of an authenticated message by one of the devices shall imply either that it was sent by the other device or that the receiving device's own software has been compromised. Thus, for a pair of devices, message authentication implies the additional condition of source authentication i.e. that the claimed message source was the actual message sender.

NOTE Protection against compromise of the cryptographic boundaries inside the hardware of devices is outside the scope of this standard. Other publications, including ISO/IEC 15408 and the US NIST FIPS 140 series, address those vulnerabilities; compliance decisions are left to those that evaluate what implementers have built.

The primary security elements of the provided services include authorization of communications relationships between or among communicating entities, (see 6.6.5.4 – Quarantined state and Request session service).

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In both cases, a symmetric data key that is shared among intended communicants is used. Attackers that do not share the key cannot modify the message without being detected and cannot recover the encrypted higher-layer payload information (other than its size).

In general, a security policy associated with each key determines the type and amount of keyed protection to be provided when that key is used. Operation is based on a shared sense of time based on clock synchronization. The LLC sublayer and transport layer security services authenticate to the receiver the time of PDU transmission and the approximate time of TPDU creation. The protocol elements are specified in the appropriate layers.

See 6.3.4 Error detection and security for MAC sublayer security protocol.

See 6.6.3 Security function for end to end security protocol.

See Clause A.2 for joining protocol.

See Clause A.3 for changing key operation.

See Clause A.4 for security management.

See Clause A.5 for maintenance port.

See Clause C.2 for the key distribution function performed by the network manager.

The following APDU are used for managing the security objects:

Write Join_key service (see 8.3.4.1, command 768), Read session list service (see 8.3.4.15, command 782), Request session service (see 8.3.4.55, command 823), Write network key service (see 8.3.6.2, command 961), Write session service (see 8.3.6.4, command 963) and Delete session service (see 8.3.6.5, command 964).

A.2 Joining

A.2.1 The join sequence

A.2.1.1 Overview

"Joining" refers to the process used by a device to obtain access to the network and to become integrated into it. An overview of the sequence is shown in Figure A.1. The steps required to join a new device into the operational network are listed below.

- The device shall be provisioned by a maintenance tool. It consists of writing the network_ID and the Join_key in the new device.

  NOTE The Join_key can be different for every device.

- The new device monitors the network and receives the Advertise DLPDUs transmitted by other devices. The Advertise DLPDU includes sufficient information for the new device to synchronize to the network clock and communicate on the correct link i.e. the correct slot number and channel. The new device locates the network with the matching network_ID and synchronizes to it.
- It then establishes a secure channel between it and the network manager using the Join_key to encipher the initial communications between the two. It sends its credentials to the network manager to demonstrate it is trustworthy.
- The network manager verifies the trustworthiness of the new device.
  - The device's Identity according to CMD ID #0 and Long_tag are presented to the network manager.

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  - The Join_key works like a password.
  - The network manager considers all of these three items when making a decision to allow the device into the network.
  - After the device is deemed trustworthy, the network manager provides the network manager session key and the network key to the joining device.
- The network manager should implement a whitelist to ensure only known, trusted field devices join the network. After security requirements for new devices have been met, the network manager proceeds to integrate the device into the network. This is accomplished by provisioning the device with normal superframes and links.
- The network manager may choose to leave the device quarantined. In this case the device can participate in the network but does not have a gateway session.
- After the quarantined device obtains a session with the gateway, it becomes operational. It then begins acquiring the bandwidth and communication resources required to publish process data and events as dictated by its configuration.

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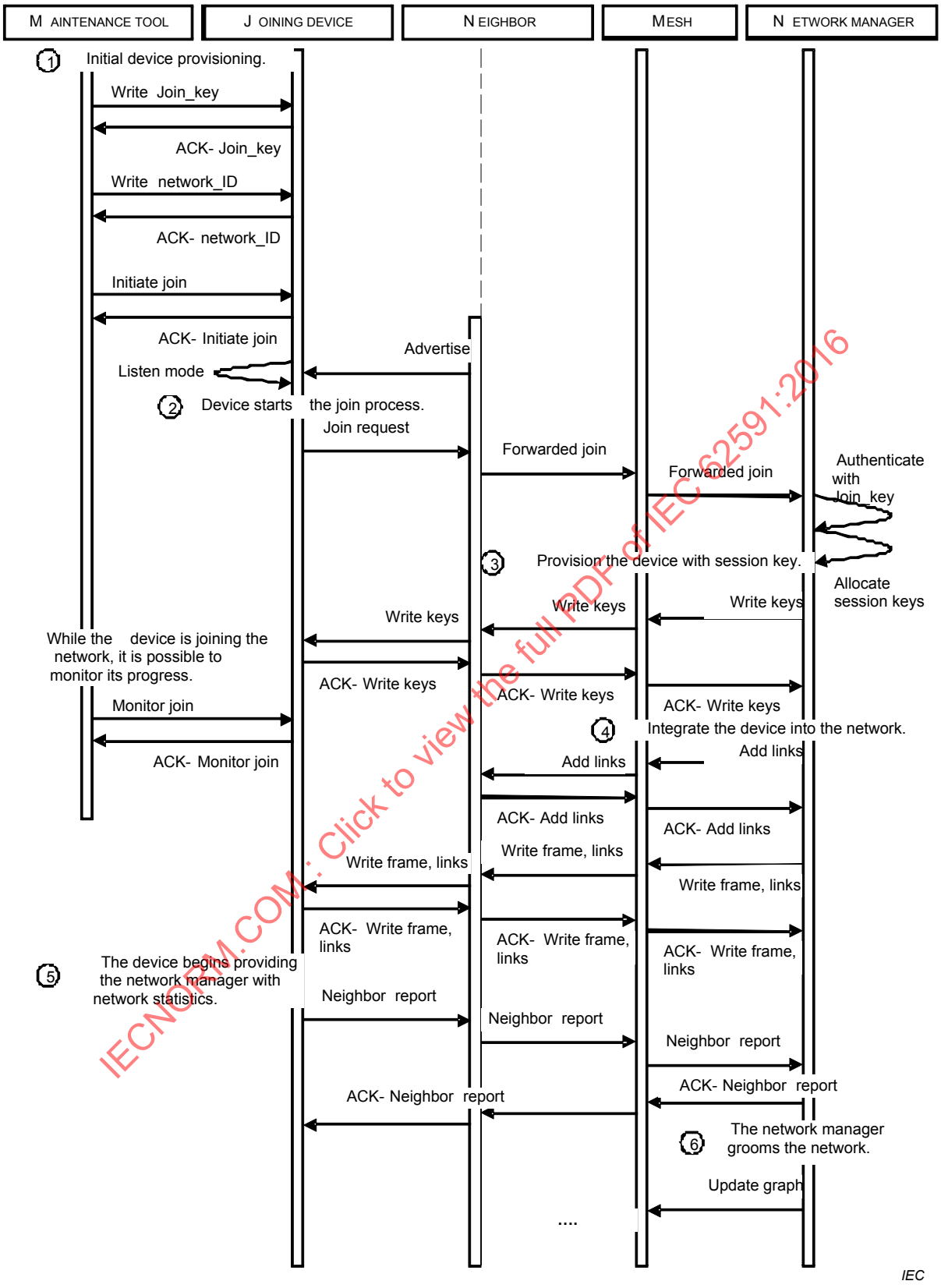

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Figure A.1 – Join sequence

A.2.1.2 Initial Device Provisioning

Prior to attempting to join the network the device requires two pieces of data – the Join_key and the network_ID. The network_ID identifies the network the device is to join and the Join_key is the network password that will allow the device to join the network. These two items should be written to the device via the device's maintenance port (see Clause A.5).

After initial provisioning is complete, the device can be immediately configured to join the network. Alternatively, the device can be mounted in the process and then the end user can use a device maintenance tool to place the device into join mode.

The maintenance tool may also be used to monitor the join process allowing the operator to intervene, if necessary.

A.2.1.3 Listening for Network Traffic

After the join has been initiated, the device's DLE is placed into search mode to synchronize to the network and receive Advertise DLPDU. In this mode, the device shall identify neighbors (advertising or not) and gather neighbor statistics for example average signal level. After identifying one or more advertising neighbors, the joining device shall select one of them as parent for its joining process. The neighbor with the lowest joining priority and adequate RSL shall be selected as parent neighbor. The NPDU Graph_ID shall be set to the same value contained in the advertise DLPDU received from the neighbor being joined through.

A.2.1.4 Presenting Credentials

After the device has synchronized to the network, it transmits a join request (see ② in Figure A.1) to the network manager. The join request and its encipherment contain the device's credentials for the network manager to inspect prior to allowing the device to join the network. The device's objective is to obtain a session key a network key, so that it can continue to communicate with the network manager. The network key is used for data-link layer device-to-device, one hop security and authentication. There are three key credentials.

- The device's identity (using command Identify FAL PDU, Command 0 response).
- Its Long_tag (using command Read long tag FAL PDU, Command 20 response).
- The list of Neighbors detected by the device (using command Read neighbor signal level FAL PDU, Command 787 response).
- The device's Join_key.

The first three are contained in the join request's payload. The Command 787 response should contain 2 neighbors: the neighbor being joined through and one other neighbor. The second neighbor shall be the advertising neighbor not being joined through with the highest RSL. The device shall listen on all receive links advertised by the two neighbors sent in Command 787. The Join_key is used as the Session_key for all communications until the device receives session and network keys from the network manager. Therefore, successful authentication by the network manager confirms the device has the correct Join_key.

The join request shall be transmitted at Normal priority.

Since the joining device does not know the network key, it shall use the well-known key for communicating the DLPDUs with the advertising neighbor, which is used as prospective parent. This prospective parent receives the DLPDU from the joining device and forwards it through the mesh using the network key.

After sending the join request, the joining device shall start a response timer to monitor the response. If this timer expires, then the device shall send another join request to the next available advertising neighbor. Join requests are sent until max_join_retries is exceeded. See Table 126.

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A.2.1.5 Getting the First Keys

When the network manager receives a join request it shall verify that the request was from a trusted device. A trusted device:

- has a trusted identity (i.e., the right device name),
- is using an appropriate Join_key, and
- properly combines the device name and Join_key with each other.

The join request has sufficient information to satisfy all of these criteria. Identity is established using the binary information in the command 0 or using the Long_tag in command 20.

NOTE There are a wide range of methodologies and security techniques to establish whether a joining device is to be trusted. Selection of the strategy employed by the network manager to verify that the join device is a trusted device is beyond the scope of this specification.

Several strategies that directly may be used by a Network Manager:

- If a device whitelist is supported then only devices on that whitelist shall be allowed to join the network.
- If a device blacklist is supported then devices on that blacklist shall NOT be allowed to join the network.

In addition, the network manager should always check the active device list to ensure a duplicate device (e.g., duplicate unique ID) is not trying to spoof its way into the network.

If the device's credentials meet the verification criteria, then the join request is considered as authentic. The network manager shall allocate session key, the device's nickname and write these two and the network key into the joining device (see ③ in Figure A.1). The response includes:

- Command 961 Write Network Key (truncated);
- Command 962 Write Device Nickname Address; and
- Command 963 Write Session (truncated).

The join response PDU is enciphered using the Join_key. The NPDU containing the keys shall be routed to the joining device via its prospective parent.

The device shall acknowledge the reception of join response. The acknowledgement PDU shall use the just received session and network keys. The join response reply PDU uses the new session and network keys and the newly created network manager unicast transport layer pipe.

When the join response reply is transmitted the device starts a response timer in the same fashion as used in the transport layer. When this timer lapses another join request is generated to the next available advertising neighbor.

A.2.1.6 Device Integration into the Network

Since, the device has session key and the network key, it is able to communicate with the network manager. At this point in the Join sequence, its communication requires the network manager to use proxy routing to reach the joining device. The network manager shall integrate the joining device more tightly into the network. This includes:

- providing the device with the identity of at least two time-source neighbors,
- specifying the Graph_ID (Write graph connection service, Command 969) used in the network manager route (Write route service, Command 974),
- updating the communication tables in the device's neighbors, and
- transferring the device's communication from join links to normal links.

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Examples of the associated communication activity are shown starting at ④ in Figure A.1. This communication activity will continue for some time and result in the network manager writing a series of graphs, routes, superframes and links to the joining device. After this, the device is integrated into the network and shall stop using the join links for communication.

The Network Manager shall maintain all join links related to a device while that device is in the process of joining.

A.2.1.7 Quarantine

If a device has joined the network, but it does not have any session with the gateway, the device shall be in "Quarantined" state. In this state, the device can only communicate with the network manager and shall not publish any process data. The device shall otherwise operate normally, conveying DLPDUs received from neighbors, generating neighbor reports and network statistics. The network manager can modify the network communication configuration as needed to groom the network.

Upon entering "Quarantined" state, the HealthReport timer shall be initialized to Health_report_time (see Table 58) and started. The device shall begin generating health reports (see ⑤ in Figure A.1). It generates health reports whenever the HealthReport timer expires. Health reports shall be transmitted at the "Command " priority level. Following every health report, the HealthReport timer shall be reset to Health_report_time. The network the network manager is responsible for allocating sufficient bandwidth for network management communication traffic. Management communication traffic does not have a Timetable and, consequently, is not constrained. The network manager shall write the route to be used for network management communication traffic.

After joining the network, the first health report shall be generated after identifying at least three neighbors or when the HealthReport timer expires, whichever occurs first. If multiple Advertise packets were captured, the first report shall be generated immediately after entering the Quarantine state.

Health reports consist of the response APDUs for Report device health FAL PDU, Command 779 (see 8.3.4.12), Read neighbor health list FAL PDU, Command 780 (see 8.3.4.13) and Read neighbor signal level FAL PDU, Command 787 (see 8.3.4.21). Using Command 780, statistics on all linked neighbors are returned. Command 787 reports on all detected neighbors that do not have links to the device. Depending on the network and number of devices, multiple packets are normally generated. Health reports are aggregated into as few TPDUs as possible.

Depending on the network manager's security strategy, it may immediately write the gateway session to the quarantined device or leave the device quarantined for a time. In any case, the device shall remain quarantined until it receives a session allowing communication with the gateway.

A.2.1.8 Becoming operational

When a new gateway session is written to the device it becomes operational. Once this session is operational, a gateway will normally begin filling the gateway's data cache for the device. This will cause a surge in request/response traffic to the device and it may be several hundred transactions. This communication uses the maintenance Timetable the gateway received from the network manager. The maintenance Timetable is owned and controlled by the gateway. In turn, the network manager shall write this Timetable to the device (using Command 973) to establish the route and communication bandwidth used for device responses.

Upon receiving a session to a new device, the gateway should request significant bandwidth (for example one request/response per second) to the device while it fills its cache then lower it to a normal rate (for example one request/response per 10 s).

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In addition, external host applications (for example instrument management packages, process automation controllers, etc.) may begin communicating with the device through the gateway. The gateway should increase and decrease the maintenance Timetable bandwidth guaranteeing responsive communications with the field device. This communications rate should be similar to that found in wired HART™ communication network.

After the device receives its gateway session, it shall obtain enough bandwidth and communication resources to meet its responsibilities to the process automation system as a whole. After receiving begins requested bandwidth for the process data (the publish Timetable) and alarms (the event Timetable), the device shall start publishing reports.

All maintenance traffic is request to the field device and response from the field device. The field device shall assume the gateway has allocated sufficient communication bandwidth. Therefore, responses to command requests generated by the gateway and the network manager shall be immediate and not associated with any Timetable in the device.

A.2.2 The network layer join process

A.2.2.1 General

The NLE state machine as shown in Figure A.2 enforces the high-level join procedure (including retries for security purposes) while the DLE state machine is focused on synchronizing the device to the communication slot times. The primary objective of the join process at the network layer is to receive admission to the network and obtain a superframe with links allowing the device to communicate reliably with the network manager.

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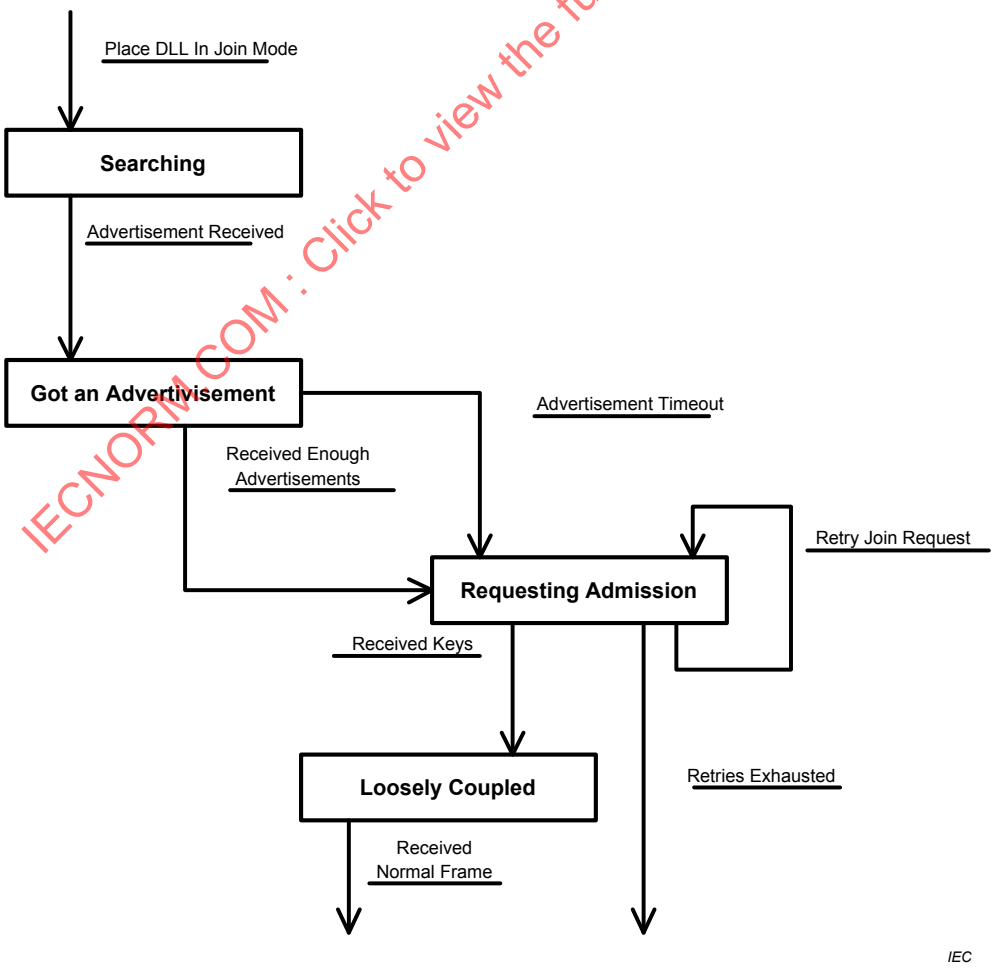

Figure A.2 – Network layer join procedure

A.2.2.2 Searching

While in the searching mode the NLE waits for reception of an Advertise packet. While in this mode the DLE is searching for the network, synchronizing to it and receiving DLPDUs.

After the Advertise indication primitive is received from the DLE, the NLE sequences to the "Got an Advertising Neighbor" state.

A.2.2.3 Got an advertising neighbor

Upon entering the "Got an Advertising Neighbor" the AdWaitTimer shall be initialized to Ad_wait_timeout (see Table 58) and started. The device shall continue to receive additional Advertise packets. If at least three different Advertise packets have been received or the AdWaitTimer expires, the device shall change to the "Requesting Admission" state.

A.2.2.4 Requesting Admission

Upon entry into the "Requesting Admission" state, the device shall send a join request to the network manager, initialize the JoinRspTimer to Join_rsp_time (see Table 58), and start the JoinRspTimer. If JoinRspTimer expires, the device shall:

- a join request to the network manager,
- start the JoinRspTimer, and
- decrement the JoinRetry counter.

If the network manager responds by writing the network key, the network manager session and the device's nickname, the device shall change to the "Loosely Coupled" state.

Else, if the JoinRetry counter becomes zero, the state machine shall exit with an error.

A.2.2.5 Loosely Coupled

After the device has a nickname and the network key, it is able to communicate with the network manager. However, the device's connection to the network is tenuous at best (it only can talk via the shared join links). The device shall stay in the "Loosely Coupled" state until it receives a superframe and links from the network manager. If the device gets such a superframe and links, then it shall exit the network layer join process successfully. Reliable communications between the network manager and the device is now ensured.

A.2.3 The data-link layer join process

A.2.3.1 General

The DLE is triggered to enter the network search mode by the NLE. The objective of this mode is to synchronize the device's slot timing to that of the network. The first step in synchronizing is to begin actively searching for the network. Figure A.3 shows the state diagram of the DL network search procedure.

The join process is a device-level process and requires close coordination between the network and data-link layers.

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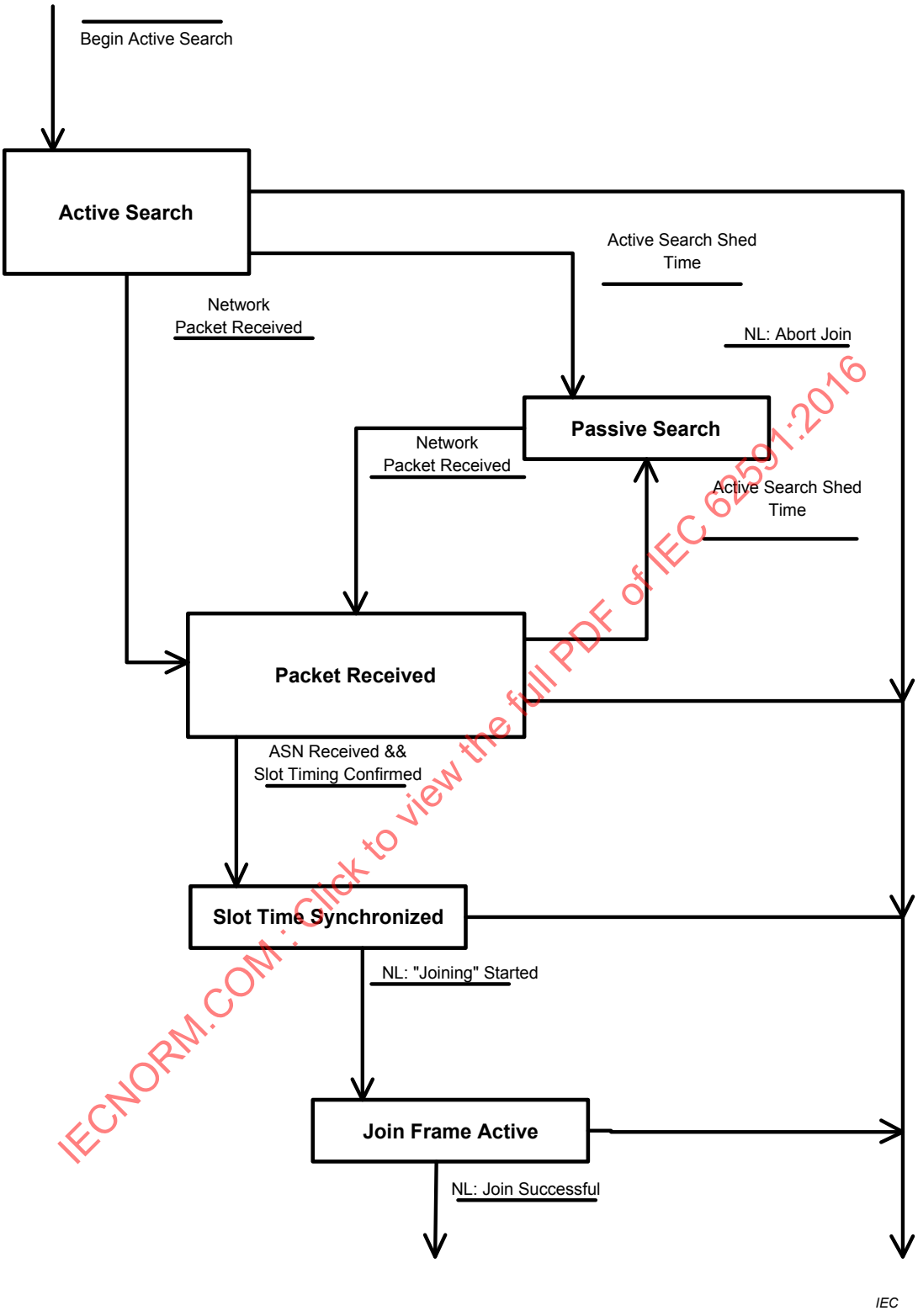

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Figure A.3 – Data-link layer join procedure

A.2.3.2 Active search

While in the "Active search" state, the device shall leave its transceiver in receive mode while continuously listening for packets. When the DLE enters this state, it shall set a timer to Active_search_shed_time to limit the network active search time. If this timer expires without identifying the network, the device shall transition to the "Passive search" state.

The device's transceiver shall remain on a channel for the interval indicated by the ChannelSearchTime value. When that time period lapses, the device shall switch to the next channel and resume listening. Channels are scanned sequentially until Active_search_shed_time lapses or a packet is received.

NOTE The default value of ChannelSearchTime is 400. An implementation can select a different value depending upon its need to conserve power.

When a packet is received and its Network_ID matches the network_ID set in the device, the device shall transition to the "Packet received" state.

A.2.3.3 Passive search

The "Passive search" state is a reduced cycle, power saving mode of operation entered when the network cannot be located. In this mode, the device continues to look for network packet, but at a slower rate. The device shall wake up and listen for the interval indicated by the PassiveWakeTime. If no packet is received, the device shall turn off its transceiver and returns to low-power mode. This cycle shall repeat as specified by the PassiveCycleTime.

NOTE The default value of PassiveWakeTime is 6,5 s; the default value of PassiveCycleTime is 600 s. An implementation can select a different value depending upon its need to conserve power.

If a packet is received, the device shall transitions to the "Packet received" state. The device can also be forced back into the "Active search" state by the reception of the "Force join mode" command.

A.2.3.4 Packet received

The objective of this state is to synchronize the device's slot timer to the network. The device shall receive DLPDUs. If the DLPDU is not an ACK, then the start time of that packet shall be recorded and the device's slot time is established. Subsequently, the start time of all additional non-ACK packets shall be compared to the device's slot timing and statistics shall be compiled measuring the device's synchronization to the network slot time. The device is considered synchronized when the slot timing statistics converge.

While in this state the device shall continue to receive DLPDUs and update its neighbor table. In addition, channels shall be changed as indicated by the ChannelSearchTime value. When an Advertise DLPDU is received, the tables in the device are updated including:

- the superframe and links are created or updated as needed,
- graphs are created or updated using the Graph_ID in the Advertisement DLPDU,
- graph edge is created to the neighbor generating the advertisement; and
- the slot time is synchronized, and
- each unique Graph_ID received via an Advertisement PDU should internally create a route to the network manager with IDs in the range 0xF0-0xF9.

This device shall transition to the "Slot time synchronized" state when

- the slot time is synchronized, and
- the Absolute Slot Time has been aligned to the network.

A.2.3.5 Slot time synchronized

In this state the DLE can reduce its listening to slot times. As DLPDUs are received, the device's timers shall be updated keeping it in sync with the network. The DLE shall wait for to receive another Advertise DLPDU. When an Advertise DLPDU is received, the DLE shall provide Advertise indication primitive to the NLE. The device shall configure the Join superframe(s) and links as indicated in the Advertise DLPDU it receives. These superframes

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remain disabled until join requests are generated. In addition, the graph indicated in the Advertise packet is initialized and the connection to the advertising device created.

In this state the DLE shall wait for the NLE to signal that it has started the join process by sending join request. When a join request is received from the NLE, the device shall enable the join superframe(s) and transitions to the "Join superframe active" state.

A.2.3.6 Join superframe active

The first join attempt shall be made via the neighbor demonstrating adequate RSL and indicating the lowest Join_priority. After the join request is transmitted, the device shall begin transmitting Keep-Alive DLPDUs, as needed, to maintain synchronization with Neighbors connected via join links. The device shall stay in this state until the NLE signals that the join was successful or the join is aborted.

Before the join request is generated, the join superframes received via the Advertise DLPDUs are enabled. Joined frames contain shared slots. Therefore, collisions with other joining devices are probable. To minimize collisions resulting from many devices trying to join simultaneously, the Backoff_exp shall be initialized to four prior to transmitting the first join request and the Back-Off Counter (Backoff_cntr) calculated. This results in the randomized slot being used for transmitting the join request.

A.3 Network key change operation

Changing the security keys used by the network is an important operation that shall be done periodically to ensure the overall integrity of the system. There are four classes of keys to consider: the Join Key; the Network Key; Broadcast Session Keys; and Unicast Session Keys. Two techniques can be used to change these keys. First, since the Network Key and the Broadcast Session Keys are normally common to all devices, these keys can be all changed in a single broadcast commands (e.g., Command 961 or Command 963). Figure A.4 illustrates a broadcast message changing the Network Key. The sequence begins with the network manager (the master in this example) generating an acknowledged Broadcast-request (see 8.3.6.2). The Transport entity sends it to all devices (see ① in Figure A.4).

Each device, in turn, sends the response to the command (see ② in Figure A.4). The device response is enciphered using the unicast device-Network Manager session. This ensures intervening devices cannot spoof the response, which contains the Key. However, to allow the Network manager to correlate the response the transport type is set to Response-broadcast.

The Network manager's Transport entity receives acknowledges from all devices (retrying as needed). At the stipulated Absolute Slot Number the Network Key in all devices is changed to the new value (see ③ in Figure A.4).

The Join and Unicast Session Keys, on the other hand should be different for every device (and, of course, different from each other). Therefore a Unicast Command 963 or Command 768 changes these keys. The Join Key should be changed immediately after the device exits the quarantine state and enters the operational state.

Key changes can also take effect immediately or at a specified ASN (i.e., a specified future time). Network Key changes should always be scheduled. An immediate change of the network key will disrupt network (in most cases).

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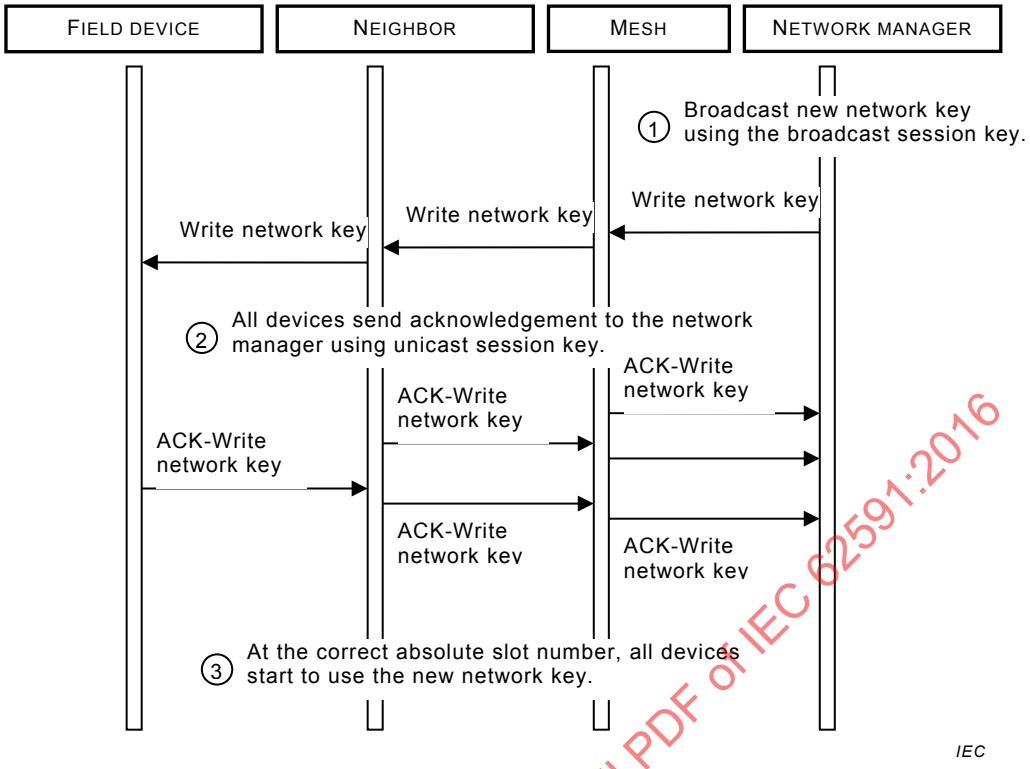

Figure A.4 – Network Key change operation

A.4 Security management

The security manager generates and manages the cryptographic material used by the network. It is responsible for the generation, storage, and management of keys. The security management is a function that is separate from the network management function. The security manager may be a centralized function in some plant automation networks, servicing more than one wireless network and in some cases other networks and applications. There is one security manager associated with each wireless network. One security manager may service multiple wireless networks.

The security manager works with the network manager to secure the wireless network from adversarial threats to its operation. A secure connection between the network manager and the security manager is required. This secure connection is beyond the scope of this specification.

A.5 Maintenance Port

All field devices shall provide a maintenance port that complies with the requirements of this standard. The maintenance port interface is used for provisioning (for example to load the Join_key and network_ID or to monitor the join process). The device shall allow reading of the device parameters and writing of parameters required for provisioning via the maintenance port. Any write request that can only be sent by the network manager shall not be available via the maintenance port; the device shall respond to such request with "Access Restricted". Any tools connected to the maintenance port shall not have access to the wireless network.

The maintenance port can be either a standard wired HART™ interface designed for connection to the process automation system according to IEC 61784-1 CP 9/1 or a dedicated maintenance port. If it is a dedicated maintenance port, the port shall comply with following requirements.

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- Through the maintenance port, the field device shall appear to be a wired HART™ multi-drop slave device. The field device shall be configured for polling address 1.
- The input impedance shall be 500 ohms simplifying the direct connection of legacy maintenance tools and applications supporting the wired HART™ communication protocol.
- The maintenance port shall not support publish data communication.
- The maintenance port shall not be permanently wired to the process automation system.
- The maintenance port shall be clearly marked as the maintenance port.

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Annex B
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Wireless procedures

B.1 Initializing a wireless network

Prior to forming the network, the network manager shall be provisioned with the network_ID. Using this ID and a supply of security keys network formation can be initiated. This begins with the network manager creating a secure and private connection with the gateway. As part of its initialization sequence, the network manager shall download following to each access point of the gateway:

- the network management superframe supporting base bandwidth required to monitor and service the network;
- the network graph supporting upstream traffic to the network manager;
- the Join superframe and join links allowing new devices to join the network; and
- dedicated and shared links (both transmit and receive) supporting management of devices, the transport of health reports, and communication of alarms (for example path down).

The access points shall be configured to be active in every slot. This will maximizes the network capacity available for advertising, network management and join packets. The network manager shall enable the first superframe, which starts the ASN zero (i.e. the network is born). The access point(s) shall begin transmitting Advertise DLPDU, so that other devices can join the network and the network begins to form.

There are three components of network formation: advertising, joining, and parameter negotiation. As part of advertising, network devices that are already part of the network send DLPDU announcing their presence to the network. Advertise DLPDU includes the network_ID, ASN, join frames and join links. Devices that are trying to join the network listen for these DLPDUs. The new device attempts to join the network as specified in Clause A.2.

When a device joins the network, this device and the gateway both request allocation of network capacity from the network manager. The device requests the network capacity to publish process data and the gateway requests network capacity to support request and response traffic to this new device. The network manager uses these Timetable requests to estimate and manage the available network capacity. If there is sufficient network capacity, the newly joined device shall be allocated superframes and links according to the requests. If network capacity becomes constrained, then the network manager may reduce the network capacity requested or refuse to allocate any network capacity to the requesting device.

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B.2 Neighbor Discovery

The Neighbor Discovery process is used by a device to learn the potential connectivity to devices in the network. The device maintains a list of discovered devices in its Neighbor table following the neighbors with links to the device. Network devices shall periodically report neighbor information in their health reports using Read neighbor health list service, Command 780 (see 8.3.4.13) and Read neighbor signal level service, Command 787 (see 8.3.4.20). The network manager shall use the information in the health report to adjust the overall network graph and in some cases, adjust the network schedule. This overall sequence is described in Figure B.1.

Neighbor Discovery is accomplished by three means:

– new neighbors joining via the device;

– communications between other devices in the network that are overheard; and
– the special discovery process.

In other words, devices shall continuously listen for communications from their neighbors and for communications from new neighbors. Continuous monitoring of neighbors and the discovery of new neighbors is critical to the maintenance of the mesh and the enhancement of communications reliability.

The discovery process consists of discovery links shared by all devices in the network. Devices shall listen on each discovery link and, occasionally, shall transmit on one of the discovery links. This discovery process directly promotes the discovery of new neighbors.

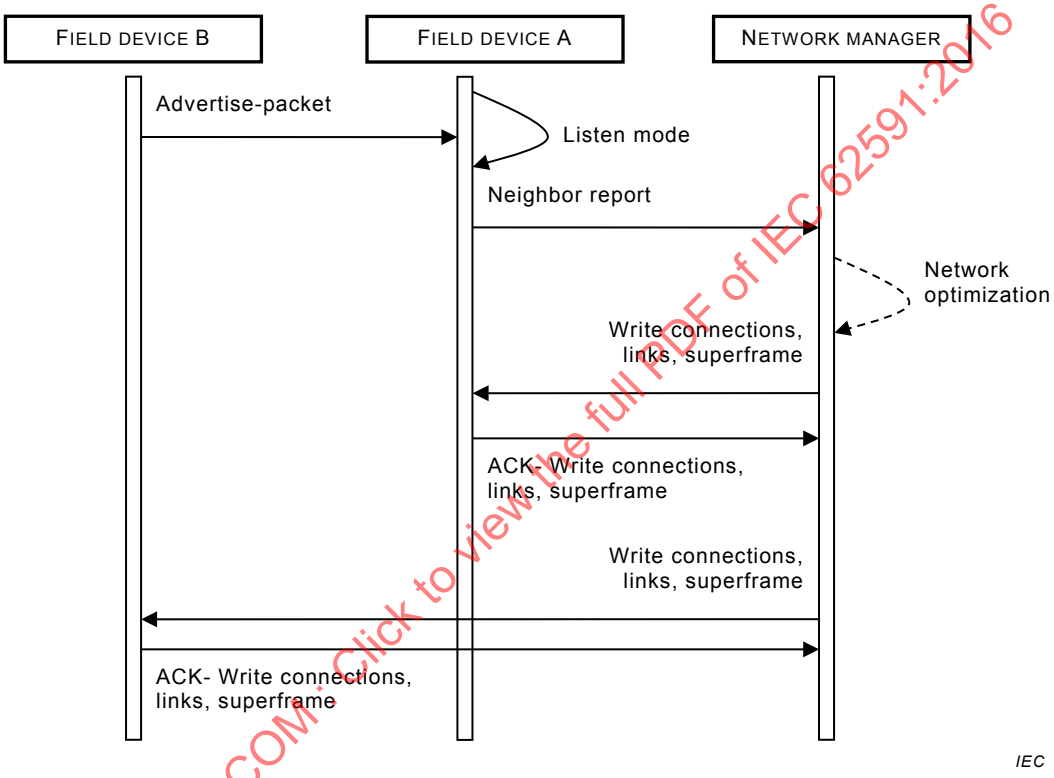

Figure B.1 – Neighbor Discovery

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B.3 Path failure

When a network device loses connectivity to a neighbor, it shall report the path failure to the network manager. Figure B.2 depicts three devices and shows that device A and device B have been successfully communicating (for example device A published via device B). However, interference or some blockage disrupts communication between device A and device B. The mesh allows device A to continue responding via an alternate route (for example via device C). Since communication was lost, device A and device B shall begin transmitting Keep-Alive DLPDUs to probe the connection. Furthermore, attempts to forward normal network packets across the suspect path will continue as well until the network manager deletes the links using the path. Communications continues to be broken and after the Path_fail_time interval expires, a path-down alarm using Report path down alarm service, Command 788 (see 8.3.4.21) shall be generated by both non-communicating devices.

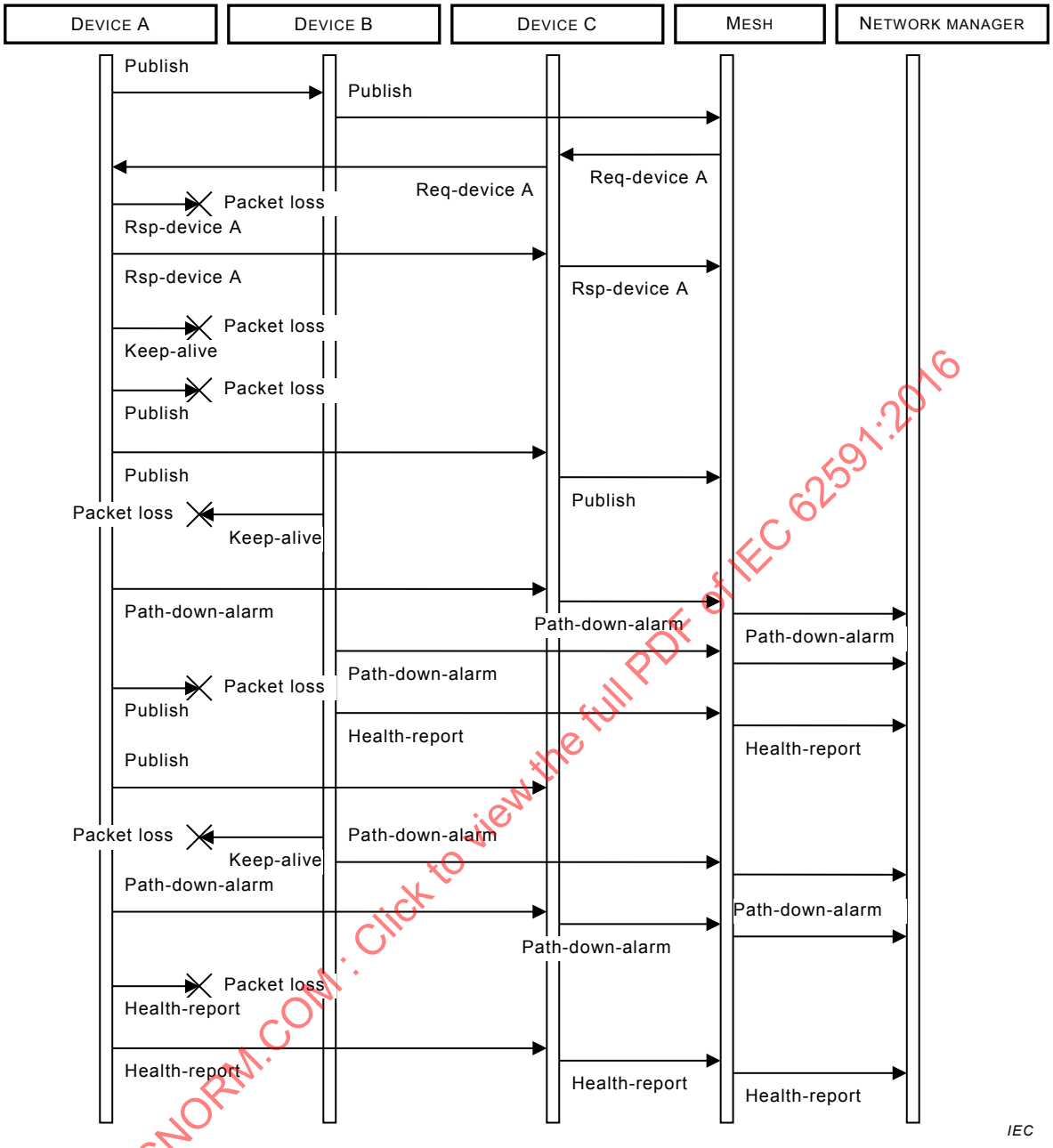

Figure B.2 – Path failure

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B.4 Device leaving the network

In the network operation there will be times when a device is either suspended or disconnected from the network. When this occurs, the device shall go through a complete re-join sequence. Prior to departing the network the device shall not accept any additional DLPDU, discard the DLPDUs waiting for transmission and shall send a disconnect DLPDU to all of its neighbors as shown in Figure B.3.

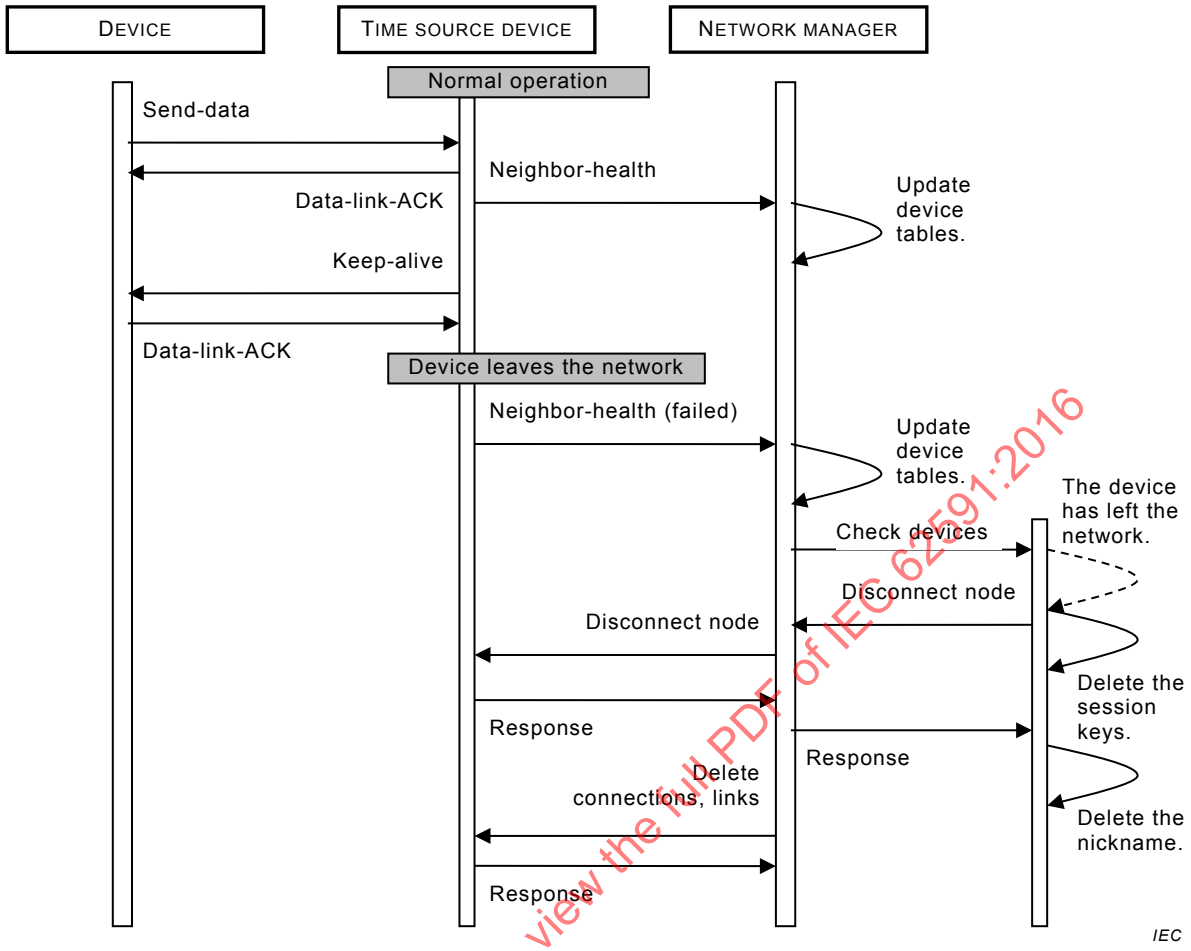

Figure B.3 – Device leaving the network

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Annex C
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Network management

C.1 Overview

The network manager is responsible for the overall management, scheduling, and optimization of the wireless network. As part of its tasks the network manager initializes and maintains network communication parameter values. The network manager provides mechanisms for devices to join and leave the network. It is also responsible for managing dedicated and shared network resources.

The network manager and the gateway shall be a single logical entity. The relationship of the network manager to the rest of the wireless network is illustrated in Figure C.1. The network manager may be co-located with the gateway in the same physical box or located in a completely separate physical box.

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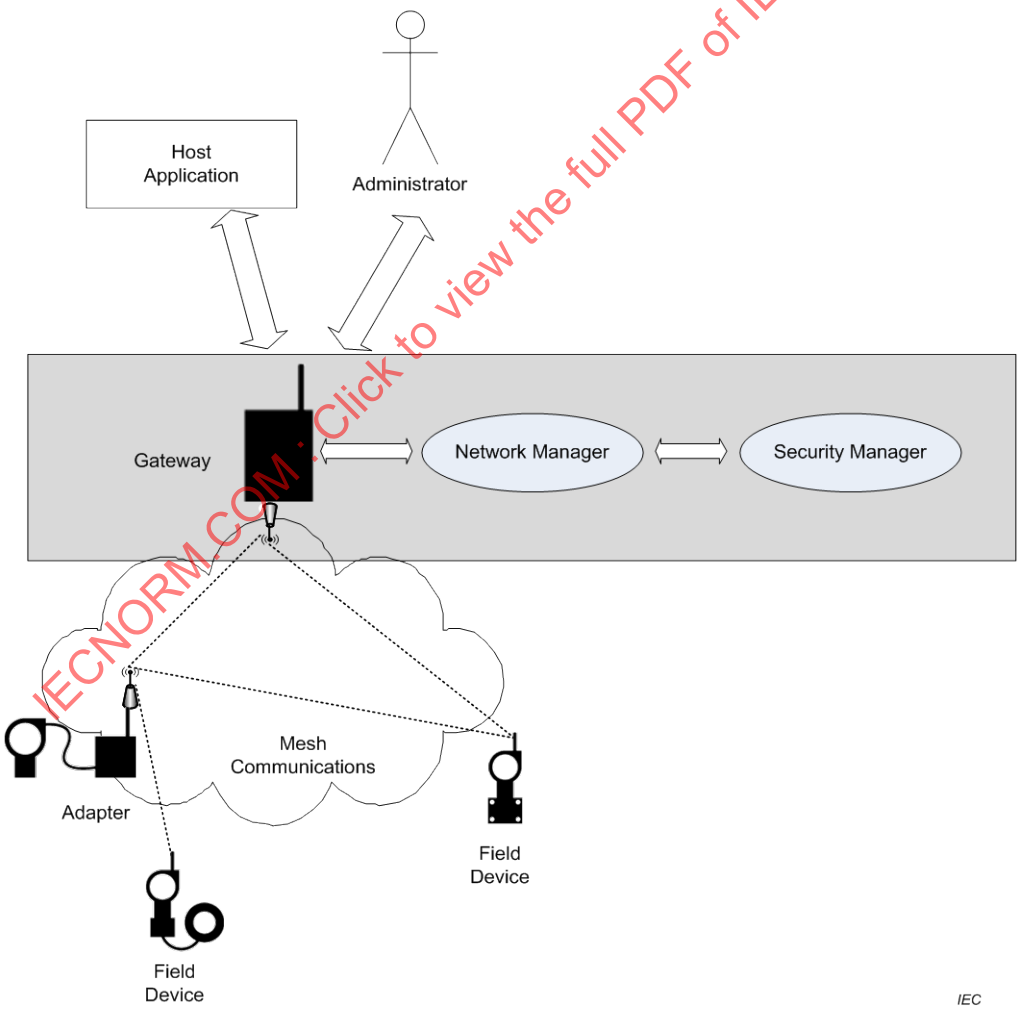

Figure C.1 – Network manager in wireless network

Although the network manager need not have a direct physical layer connection, it can communicate through the gateway that has the access point(s) to the network. The network manager shall have a fixed well known address (unique ID = 0xF980000001; nickname = 0xF980), which is used as destination for the APDUs from field device to the network

manager. It is possible to have redundant network managers connected to one network, but there shall be one and only one active network manager per instance of a wireless network.

NOTE One network manager can be used for more than one network. But, the devices in one network cannot communicate with the devices in the other network connected to the same network manager.

The Network Manager communicates with devices on the wireless network through the FAL. It also uses application layer PDU (see 8.3.6) to write and read the layer management objects in each device. The network manager is also responsible for collecting and maintaining diagnostics about the overall health of the network. These diagnostics are available to be reported to host-based applications. The diagnostics are also used to adapt the overall network to changing conditions.

For the network manager to perform its complete set of functions, it needs information about the devices, information about how the network is to be used, and feedback from the network on how well the network is performing. Configuration and setup information about devices is read from the devices. Communication resources are requested by devices, applications, and plant users. Feedback on how well the network is performing is provided by the devices through health reports and diagnostics.

The interface between a gateway and the network manager is outside the scope of this standard. The network manager and the gateway are responsible for establishing a secure connection with each other, and maintaining this connection to carry control and data traffic. Thus, it is not necessary for the gateway to go through the normal network device join process. After the gateway connects to the network manager, the network manager may configure the gateway to begin advertising to other devices.

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C.2 Network manager functions

The network manager shall perform the functions summarized in Table C.1.

Table C.1 – Network manager requirements

Network function	Requirement
Network formation and configuration	Provide logic for initializing itself and starting up the network
	Manage topology; adapt the network to changes as diagnostic information is reported from devices
	Manage distribution of the network key that is provided by the security manager to all network devices. Separate network manager and gateway keys shall be used for unicast and broadcast traffic that originates from each of them.
	Manage join process. The network manager shall validate the device that tries to join the network. After authenticating a network device, the network manager shall give the joining network device the network key and four session keys: 1– network manager unicast session keys, 2 – network manager broadcast session key, 3 – gateway unicast session key, and 4 – gateway broadcast session key. Device shall be configured with network_ID before it attempts to join the network, so that it can find the right network to join.
	Assign 16-bit nickname. The network manager shall assign and manage network unique 16-bit nickname (network addresses) to each network device. The network manager is responsible for ensuring that the Neighbor table inside each device is up-to-date.
	Establish a connection with the gateway. Whenever the gateway receives a message destined for the network manager gateway forwards it to the network manager. The network manager shall be connected to the network via the gateway.

Network function	Requirement
	Configure at least one of the network access points connected to the gateway to provide the network clock.
	Manage network configuration. Maintain a full map of the network configuration, including any information about the network that has been distributed to network devices.
	Respond to requests for network information. For example when a host application makes a network management information request for a device in the network, the network manager is responsible for providing the response.
Routing	Create and manage network route. The network route is a complete map of the network.
	Manage neighbor tables. The network manager shall collect network statistics and neighbor table information from each device through periodic health reports. This information shall be used to adapt the network to changes.
	Build route tables for graph routing. Graph routing is ideal for both scheduled upstream and downstream communications. Upstream communications include process measurements and alarms. Downstream communications include set point changes to actuators.
	Build source route lists for source routing.
	Allocate communication resources to the network devices, gateway and to itself so that it has the network capacity allocated to manage the network and the devices have sufficient network capacity to communicate.
Network Schedule	Create superframes. Multiple superframes are used to support communications at specific scan rates. Additional superframes shall be allocated to support device management and diagnostic applications which require large amounts of traffic for short periods of time.
	Assign links in Superframes.
	Create link tables. Each link includes exactly one slot associated with a superframe, its type (normal, advertising, discovery), its options (transmit, receive, shared), neighbor information, channel offset, and the device connected to this link.
	Activate and deactivate superframes in response to application demands.
Channel Management	Keep track of blacklisted channels. NOTE The assigning of a channel to the blacklist is a manual operation.
	Provide channel offset. The channel offset is used to calculate the channel number when channel hopping. The channel offset takes on a value of 0 to (number of channels less number of blacklisted channels).
Network Diagnostics and Adapting	Maintain overall wireless network diagnostic information. If a network device has not received a packet from one of its neighbors within the Keep_alive_time, the device sends a path-down notification to the network manager indicating that the path is no longer available.
	Maintain record of health information about each network device.
	Allocate communication resources as requested by network devices. Devices request network capacity so that it can support publish data operation, event notification, and block mode traffic. Gateways request network capacity to support its client demands. Network traffic is biased towards a particular path by increasing or decreasing the number of links through a particular device.
	Optimize routes and schedules in order to improve operation of the network while conserving power within devices.

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Annex D
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Gateway

D.1 Overview

Gateway device connects the wireless network to a plant automation network, allowing data to flow between the two networks. It provides host applications access to the network devices. A gateway device can be used to convert from one protocol to another, as go-between two or more networks that use the same protocol, or to convert commands and data from one format to another. The wireless network also uses the gateway as the source for the synchronized clock used by the timeslots and superframes.

The gateway provides a sink or source point for wireless network traffic. The gateway also provides a connection to the network manager. The gateway shall have fixed; well known address (unique ID = 0xF981000002; nickname = 0xF981). This also allows all devices joining the network to easily detect when they are promoted from quarantined to operational. There shall be one and only one gateway per network.

The gateway uses application layer services (see 8.3.5) to communicate with network devices. The gateway also works as a server responsible for collecting and maintaining cached data and command responses from all devices in the network. These cached responses correspond to publish data messages, event notifications and command responses. These cached responses are returned immediately to host application requests. This reduces network communication load improving power utilization and host application responsiveness.

D.2 Access point

The network access point provides the physical connection into the wireless network. The gateway can use more than one network access point to improve the effective throughput and reliability of the network.

NOTE 1 The physical location of the access point is selected based on the network topology and the signal strength. This is generally different than the location of the gateway, which is based on the location of the automation network. If there is more than one access point, then these are located at some distance to avoid RF interference.

The gateway resides at the root of all graphs allowing PDUs to be routed to the most convenient network access point. The access point shall work as a network layer router. It shall have its own unique ID and network address, which is different than the unique ID and network address of the gateway. The nickname for the network access point is assigned by the network manager. The network manager is also responsible for configuring the routes in the access point. When a gateway uses multiple network access points, the network manager provides redundant routing for each network device using at least of two of the gateway's network access points. The gateway shall use the routing table (configured by the network manager) to select one of several access points as the next hop for sending the NPDU. If a network access point fails, the network traffic will be impaired but communication will continue.

NOTE 2 The communication between the gateway and the access point is outside the scope of this standard.

Network access points shall propagate the clock to the network. There is always at least one network access point providing the clock to the network. If there are several network access points providing the clock, the gateway shall ensure that they stay synchronized with each other. This leads to one of three possible configurations:

- a single network access point (see Figure D.1);

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- multiple network access points, each providing the network clock (see Figure D.2); or
- multiple network access points with at least one not providing the network clock (see Figure D.3).

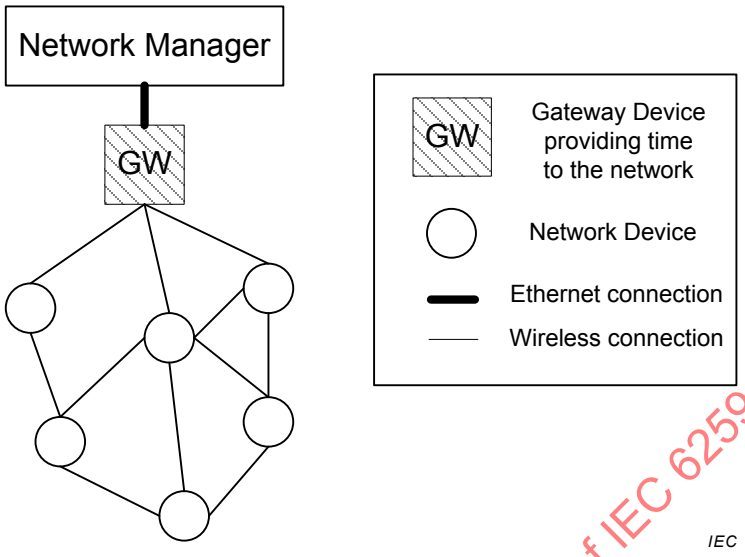

Figure D.1 – Single network access point with clock

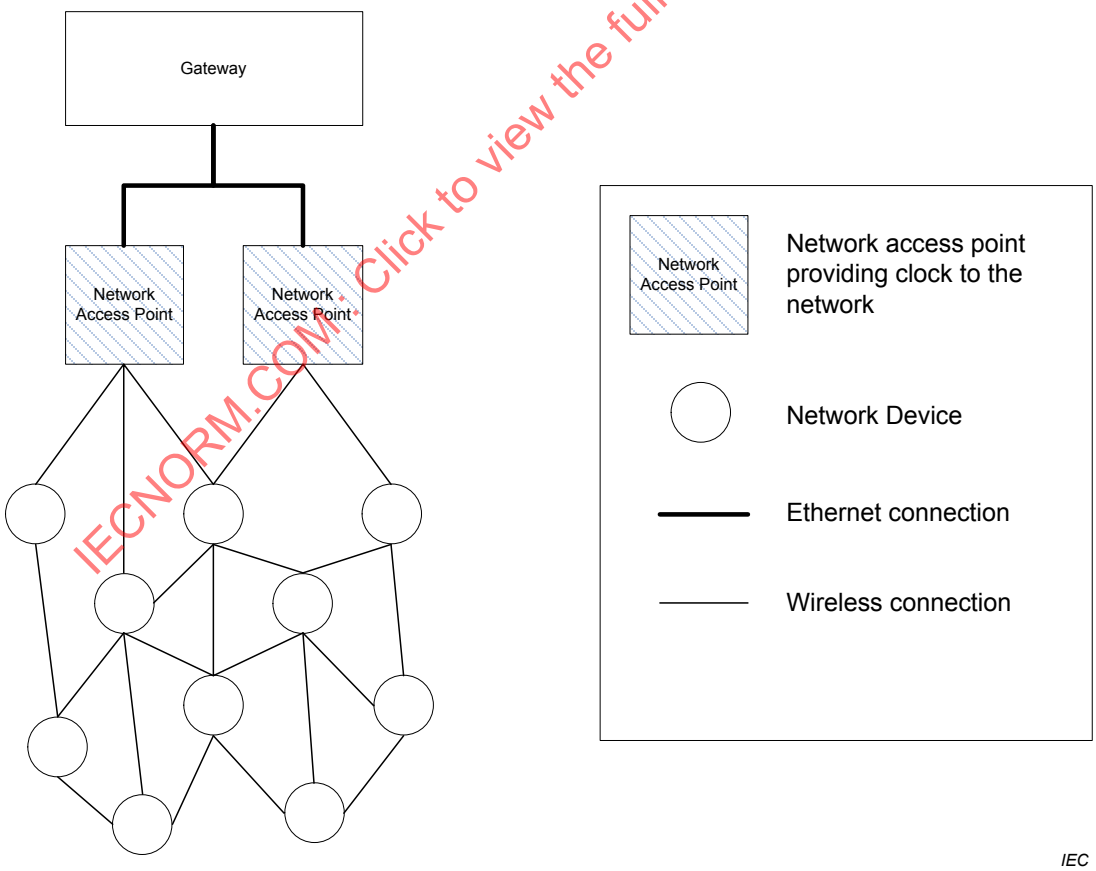

Figure D.2 – Multiple network access points with clocks

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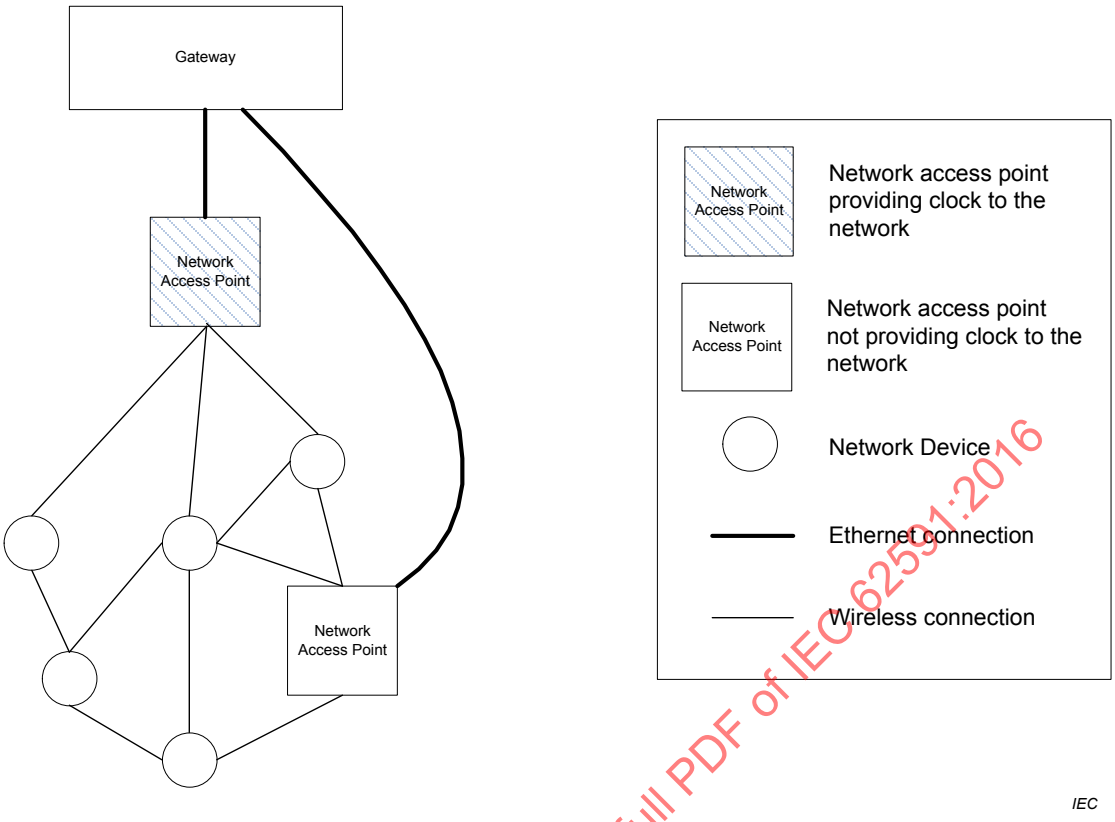

Figure D.3 – Network access point not providing clock

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D.3 Functions

D.3.1 General requirements

The gateway shall provide a single entry point into the wireless network. It has a unique ID and nickname. Therefore a host application can communicate with the gateway by using APDU of this standard.

- The gateway shall participate in the wireless network as a network device.

  NOTE 1 It communicates to all other network devices connected to the same wireless network through the network access point(s).

- It shall communicate directly with the network manager.
- It shall source time synchronization messages.
- It shall support one or more service access points for connecting to the automation network and plant backbone.

  NOTE 2 This standard does not specify the protocol between the host and the gateway. The network used on the host side may consist of a variety of technologies. Most PLC, DCS or SCADA vendors utilize a proprietary network. Asset management and device management functions tend to use open protocols, such as TCP/IP and one of several standard MAC/PHY layers such as IEEE 802.11 and IEEE 802.3. This interface may also be HSE specified by Fieldbus Foundation.

- The gateway shall check the destination address in a request message from the host. If the request is for one of the AL services defined in this standard then it shall service that request as specified below.
  - If the destination is the gateway itself, then it shall send the response message as required by the AL protocol specified in this standard.
  - Else, if the destination address in the request from the host application is for another network device, and if the response is cached and if it is current, the gateway shall

return the cached response. For example if a host issues identify request to a device in the network, the gateway shall check to see if it has a cached response to this request.

– Else, if the gateway does not have a cached response for that device, or if it is not current, it shall forward the command to the device, using APDU specified in this standard, receive the response APDU from the device and return the resulting response to the client.

- The gateway shall implement a data cache to optimize the overall performance of the wireless network and improve responsiveness to host applications. This cache shall be used to store the response to the requests that are used to read following:
  – publish data messages,
  – event notification,
  – cached command responses,
  – diagnostics, and
  – large data transfers.

  NOTE 3 The examples of large data transfers are a valve uploading its signature information and the results from a vibration analysis, data and file transfers down to a device.
- The gateway shall publish device variable data that it is caching, to other devices in the wireless network.
- The gateway shall maintain a complete list of all outstanding requests APDUs that have been sent to the network devices for which a response has not yet been received. If the response is not received within twenty-four hours, then that request shall be purged.
- The gateway shall send acknowledgement to the event notification APDU received from a network device.

D.3.2 Adding new network devices

Whenever the gateway adds a new network device in its route table, the gateway shall send the device an Identify FAL PDU, Command 0 (see 8.3.3.1) and Read long tag FAL PDU, Command 20 (see 8.3.3.17). The responses shall be cached for that device in the gateway.

D.3.3 Device configuration change status notifications

Whenever the gateway detects that the configuration of a network device has changed, it shall send the Identify FAL PDU, Command 0 (see 8.3.3.1) APDU to that device and read its Read long tag FAL PDU, Command 20 (see 8.3.3.17) APDU. The responses shall be cached for that device in the gateway. The configuration change counter shall be stored as part of the Identify response. If the device is a wireless adapter then the gateway shall repeat the "Join sequence for adapter sub-devices" connected to the wireless adapter.

D.3.4 Gateway change notification function

The gateway shall send change notification response to the host application, when change in a network device is detected by the gateway. These notifications provide an indication that a value or status has changed, but do not include the actual changed values. When the host application receives a change notification, it can send a request to the gateway to read the associated information. For example when a host application receives a change notification from the gateway for a publish data update from a device; the host application may issue a request to the gateway to return the cached response message.

D.3.5 Cached response messages

The gateway shall be able to cache the responses to the commands listed in Table D.1.

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Table D.1 – Cached Response Messages

	CMD ID[a]	Command Descriptor
Cached Response in gateway upon Read confirm	0	Identify
	11	Identify
	13	Read tag, descriptor and date
	20	Read long tag
	48	Read additional device status
	1	Read primary variable
	2	Read loop current and percent of range
	3	Read dynamic variables and loop current
	9	Read device variables with status
Event Notification	119	Write event notification acknowledgement response
Responses Cached in gateway upon Write confirm	18	Write tag, descriptor and date
	22	Write long tag
[a] CMD ID is the value of Command field in the APDU. It is also referred to as HART™ command number.		

D.3.6 Service access point

Service access point provides a connection to the automation network and plant backbone. It is an interface between the host systems or applications and the gateway. The required functions of this interface are specified below.

- It shall provide support for accessing all network devices that are connected to the network including the devices that are connected via an adapter.
- It shall provide access to cached response messages:
  - publish data responses,
  - event notification responses,
  - cached command responses.
- It shall provide access to diagnostics.
- It shall provide access to network manager data.
- It shall support block mode data transfers.
- It shall support functions to transfer the request received from the host (connected to the gateway), that have the network device (connected to the gateway) as the destination and response from the network device to the host.

D.3.7 Communication between gateway and network manager

NOTE This standard does not specify the architecture of the network manager, gateway and security manager.

The network manager and the gateway may be physically combined or may be separate. The network manager and the gateway shall establish and maintain a secure communication channel with each other. All communications between the network manager and the network devices pass through the gateway. Therefore, the gateway shall route PDUs to the specified destination – network device, host application or network manager.

The network manager creates an initial superframe, assigns links in it for the gateway's network access points, and configures the gateway. The ASN 0 is established when this initial Superframe is activated.

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Annex E
(normative)

Command response codes

E.1 Overview

E.1.1 General

Response code is a field in the response APDU from a slave device to the master device (see 8.3.1.3). This field indicates either the successful completion of the requested command, or completion of the requested command with a warning or an error in performing the requested command. When there is an error or warning, response code supplies as much detail as possible to simplify correction of any malfunction or misinterpretation of data. The purpose of the specification in this Annex E is to uniformly define all responses available to manufacturers for inclusion in their devices conforming to this standard. The response code field is encoded as a 7-bit enumeration and the range of its numeric value is 0 to 127.

E.1.2 Response code classifications

Response Codes are classified two ways. The first way is the severity of the exception encountered in the device's execution of the command. It can be either the successful completion of the requested command, or completion of the requested command with a warning or an error in performing the requested command, as shown in Table 78. If the severity is “Warning” then it indicates that the command was executed with some deviation. If the severity is “Error” then it indicates that the command was not executed.

The second way of classification is the number of definitions for one value of the response code – single-definition or multiple-definitions. Single-definition values have the same meaning independent of the command that uses them. Multiple-definition values have different definitions for different commands. These values have several meanings, which vary from one command to another command. However, all values have a single meaning for a given command at all times. All devices shall use only those values for response code values that are defined in this standard for all commands specified in application layer protocol and shall comply with the definitions specified for each command. All 128 possible response code values are assigned and classified. The classifications of all values are shown in Table E.1.

Table E.1 – Response code values

Value	Severity class	Number of definitions
0	Success	Single
1-7, 16-23, 32-64	Error	Single
9-13, 15, 28, 29, 65-95	Error	Multiple
24-27, 96-111	Warning	Single
8, 14, 30, 31, 112-127	Warning	Multiple

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E.1.3 Reserved values

Some of the single definition values are reserved for future use by this standard. A device shall not return reserved value as response code. The reserved values are:

1, 21 to 27, 29, 31, 37 to 59, 72 to 95, 96 to 111 and 112 to 127.

E.1.4 Unimplemented command

All devices shall send response to all commands addressed to it, even if the device does not implement the received command. If the device does not implement a command, then It shall send the response with the code value ‘64’, which is defined as “command not implemented”.

E.1.5 Busy

A device may return “Busy” response (response code value equal to ‘32’) in response to a master request. It indicates to the requesting application that the field device cannot begin its execution of the command due to other functions being performed. After receiving a “Busy” response from the slave, the host applications should continuously retry the request until the field device can execute the command. The device shall use “Busy” code only if it is listed in the command specification.

NOTE Response to a READ command does not return ‘Busy” code.

E.2 Response code definitions

E.2.1 General

This subclause provides the actual definition associated with each value of response code. For single definition codes all devices shall use the definition described in this subclause.

For multi-definition codes a variety of example definitions are included. The actual definition for a multi-definition response code is described in the application layer protocol for each command.

E.2.2 Value ‘0’

Success – no errors or warnings were found in verifying the parameters for this command and it was executed successfully.

E.2.3 Value ‘1’ – single-definition error

This value of the response code is reserved.

E.2.4 Value ‘2’ – single-definition error

Invalid selection – the code or index was not allowed in this command or for this field device.

E.2.5 Value ‘3’ – single-definition error

Received parameter value larger than allowed – the value of a parameter was too large and the command could not be executed in the field device.

E.2.6 Value ‘4’ – single-definition error

Received parameter value smaller than allowed – the value of a parameter was too small and the command could not be executed in the field device.

E.2.7 Value ‘5’ – single-definition error

Too few data octets received – the number of octets contained in the received PDU was less than required to execute the command.

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E.2.8 Value ‘6’ – single-definition error

Device-specific command error –an error has occurred for which a command-specific response code value has not been defined. This code is indicative of a device problem. If the device returns this code then it shall set the "Device malfunction" and "More status available" bits in the “Application process status” octet. The device shall provide the identification of the specific error source as a response to Read additional device status service, Command 48.

E.2.9 Value ‘7’ – single-definition error

In write protect mode – the device is write protected and cannot accept this write command.

E.2.10 Value ‘8’ – multi-definition warning

The exact meaning of this response code depends on the command. The command was executed, but a deviation from the request was necessary to complete the command successfully. The values actually used are returned in the response data octets. A few examples are shown below.

Update failure – the real-time data returned from the field device has not changed since the last time it was read.

Update in progress – the command cannot be executed, because the device is pending the completion of a command that requires a relatively long time to. The Client should retry the request after a delay.

Update times adjusted – the update period in the command was invalid. The device has corrected the period as returned in the response.

Update period increased – there is insufficient bandwidth to fulfill the publish rate requirement. The “Publish message” is enabled at a reduced rate.

Set to the nearest possible value – the data sent to the device has been rounded or truncated due to limitations within the device. The command has been accepted.

All but running delayed responses flushed – a delayed response is being performed by the device that cannot be interrupted or cancelled by Command 106 “Flush delayed responses”.

E.2.11 Value ‘9’ – multi-definition error

The exact meaning of this response code depends on the command. A few examples are shown below.

Lower range value too high – the “Lower range value” in the request was above the “Upper transducer limit” or some other physical device limitation is exceeded.

Applied process too high – the process applied to the field device was too high.

Invalid publish message – the “Publish message number” is not supported by the device.

Configuration change counter mismatch – the “Configuration change counter” value did not match the current value in the device. The “Configuration changed” bit remains set.

Insufficient bandwidth – there is not enough bandwidth available to enable the designated publish message.

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E.2.12 Value ‘10’ – multi-definition error

The exact meaning of this response code depends on the command. A few examples are shown below.

Lower range value too low – the “Lower range value” in the request was below the “Lower transducer limit” or some other physical device limitation is exceeded.

Applied process too low – the process applied to the field device was too low.

Invalid local panel lock – the code received in the request is not supported or the code is invalid.

E.2.13 Value ‘11’ – multi-definition error

The exact meaning of this response code depends on the command. A few examples are shown below.

Upper range value too high – the “Upper range value” in the request was above the “Upper transducer limit” or some other physical device limitation is exceeded.

Invalid device variable code – the “Device variable” specified in the request is valid, but it is not supported for the received command or the operation specified by the command.

Invalid device variable classification – the “Device variable classification code” included in the received write command is not valid for the “Device variable” specified in the received command.

Cannot lock panel – the device is in a mode that does not allow the local panel to be locked for example the operator is currently using the local panel.

E.2.14 Value ‘12’ – multi-definition error

The exact meaning of this response code depends on the command. A few examples are shown below.

Upper range value too low – the “Upper range value” in the request was below the “Lower transducer limit” or some other physical device limitation is exceeded.

Invalid units code – the “units code” specified in the request is not supported for the received command or the “Device variable” or “Dynamic variable” specified in the received command.

Invalid slot number – the requested slot code to capture the “Dynamic variable” or “Device variable” is not valid for the received command.

E.2.15 Value ‘13’ – multi-definition error

The exact meaning of this response code depends on the command. A few examples are shown below.

Invalid transfer function code – the requested transfer function is not supported for this “Dynamic variable”.

Upper and lower range values out of limits – the “Upper and Lower range values” in the received request are outside the transducer limits or some other physical device limitation has been exceeded.

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Computation error – an arithmetic error was encountered while the device was attempting to apply the new values in the received request.

Command number not supported – the requested command number to be captured is not supported in the device.

E.2.16 Value '14' – multi-definition warning

The exact meaning of this response code depends on the command. The command was executed, but a deviation from the request was necessary to complete the command successfully. The values actually used are returned in the response data octets. A few examples are shown below.

Span too small – the span as determined from the "Upper and Lower range values", was below the minimum span supported by the device.

Dynamic variables returned for device variables – the device does not expose any "Device variables". Therefore, "Dynamic variable" values were returned for codes 0-3 in Command 9.

Update rate uncertain – the device has not yet joined the network and therefore, it does not know if there will be sufficient capacity to meet the required notification parameters.

New lower range value pushed upper range value over transducer limit – the device used the "Lower range value" received in the requested and modified the "Upper range value" accordingly. The "Upper range value" is saturated and the span is not maintained.

E.2.17 Value '15' – multi-definition error

The exact meaning of this response code depends on the command. An example is shown below.

Invalid analog channel code number – the analog channel does not exist in the device.

E.2.18 Value '16' – single-definition error

Access restricted – the command is not allowed for the device in its current operating mode. For example the device is locked for Command 71.

E.2.19 Value '17' – single-definition error

Invalid device variable index – the "Device variable" in the received request does not exist in the device.

E.2.20 Value '18' – single-definition error

Invalid units code – the "Units code" in the received request is not supported for the received command or the "Device variable" or "Dynamic variable" specified in the received command.

E.2.21 Value '19' – single-definition error

Device variable index not allowed – the "Device variable" in the received request is not supported for the received command.

E.2.22 Value '20' – single-definition error

Invalid extended command number – the extended command number of the received command is less than 512.

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E.2.23 Values ‘21’to ‘23’ – single-definition error

These values of the response code are reserved.

E.2.24 Values ‘24’to ‘27’ – single-definition warning

These values of the response code are reserved.

E.2.25 Value ‘28’ – multi-definition error

The exact meaning of this response code depends on the command. An example is shown below.

Invalid ‘range units code’ – the “Units code” in the received request is not supported by the device for this “Dynamic variable” specified in the received command.

E.2.26 Value ‘29’ – multi-definition error

This value of the response code is reserved.

E.2.27 Value ‘30’ – multi-definition warning

The exact meaning of this response code depends on the command. The command was executed, but a deviation from the request was necessary to complete the command successfully. The values actually used are returned in the response data octets. An example is shown below.

Command response truncated – the device was not able to return as many “Device variable” values as requested. This is usually caused by limited command buffer length.

E.2.28 Value ‘31’ – multi-definition warning

This value of the response code is reserved.

E.2.29 Value ‘32’ – single-definition error

Busy – this code can be caused by one of two conditions:

a) the device is busy performing a function that cannot be interrupted by this command; or

b) the execution of the requested command requires the delayed response mechanism and all delayed response buffers are used.

In either case the requesting application should retry this request several times until the field device can execute the command.

NOTE The recommended value of retries of the command that causes “Busy” response is 30 or more.

E.2.30 Value ‘33’ – single-definition error

Delayed response initiated – the command could not be serviced within the response time specified by the data link layer protocol and therefore the delayed response was initiated. The requesting application should retry the exact same request after a time delay (for example after delaying several seconds). When communicating via a multiplexer this delay could be as little as half a second.

E.2.31 Value ‘34’ – single-definition error

Delayed response running – the execution of the delayed response is not yet finished. The command execution process is still running in the responding device.

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E.2.32 Value '35' – single-definition error

Delayed response dead – this response indicates that the responding device did not reply to the request. This response is valid for intelligent bridging devices only.

E.2.33 Value '36' – single-definition error

Delayed response conflict – the requested command would cause a conflict with a delayed response currently executing in the responding device.

E.2.34 Values '37' to '59' – single-definition error

These values of the response code are reserved.

E.2.35 Value '60' – single-definition error

This code is used in the ACK DLPDU. Use of this code indicates that the DLPDU was received correctly by the peer device but was not accepted by the peer device. The received DLPDU is not stored or forwarded by the device generating the ACK DLPDU.

Payload too long – the command payload is too long to fit in the DLPDU.

E.2.36 Value '61' – single-definition error

This code is used in the ACK DLPDU. Use of this code indicates that the DLPDU was received correctly by the peer device but was not accepted by the peer device. The received DLPDU is not stored or forwarded by the device generating the ACK DLPDU.

No buffers available – the responding device had no buffers available to accept the DLPDU.

E.2.37 Value '62' – single-definition error

This code is used in the ACK DLPDU. Use of this code indicates that the DLPDU was received correctly by the peer device but was not accepted by the peer device. The received DLPDU is not stored or forwarded by the device generating the ACK DLPDU.

No alarm/event buffers available – the responding device did not have any alarm or event buffer available to receive the DLPDU.

E.2.38 Value '63' – single-definition error

This code is used in the ACK DLPDU. Use of this code indicates that the DLPDU was received correctly by the peer device but was not accepted by the peer device. The received DLPDU is not stored or forwarded by the device generating the ACK DLPDU.

Priority too low – the priority of the received DLPDU was too low for the responding device to accept it.

E.2.39 Value '64' – single-definition error

The requested command is not implemented. The device shall not return this value for a command, if the device is required to implement the received command based on the profile class of the device.

E.2.40 Value '65' – multi-definition error

The exact meaning of this response code depends on the command. The descriptions are shown below.

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Declined,

Operator overridden,

Force join declined,

Invalid network_ID,

Invalid Timer_type,

Invalid hop-to-live,

Invalid Join_priority,

Unknown nickname,

Invalid nickname,

Service request denied,

Link not found,

No more entries available,

Entry not found,

Illegal frequency channel bits,

Unknown unique ID,

Key change failed,

Session with given peer device does not exist,

Invalid suspend time.

E.2.41 Value '66' – multi-definition error

The exact meaning of this response code depends on the command. The descriptions are shown below.

Invalid number of slots,

Session_type invalid,

Invalid execution time,

Unknown notification flag,

Device list conflict,

Invalid neighbor attribute,

Invalid Timetable ID,

Invalid Graph_ID,

Invalid resume time,

Link already exists,

Invalid reason code,

Unknown Timetable flag,

Invalid timer interval.

E.2.42 Value '67' – multi-definition error

The exact meaning of this response code depends on the command. The descriptions are shown below.

Invalid Graph_ID,

Unknown Superframe_ID,

Invalid superframe mode,

Reason code rejected, Timetable not deleted,

Unknown application domain.

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E.2.43 Value ‘68’ – multi-definition error

The exact meaning of this response code depends on the command. The descriptions are shown below.

Unknown nickname,

Invalid execution time,

Invalid slot number.

E.2.44 Value ‘69’ – multi-definition error

The exact meaning of this response code depends on the command. One description is shown below:

Unknown link options.

E.2.45 Value ‘70’ – multi-definition error

The exact meaning of this response code depends on the command. One description is shown below:

Invalid Channel_Offset.

E.2.46 Value ‘71’ – multi-definition error

The exact meaning of this response code depends on the command. One description is shown below:

Invalid Link_type.

E.2.47 Values ‘72’ to ‘95’ – multi-definition error

These values of the response code are reserved.

E.2.48 Values ‘96’ to ‘111’ – single-definition warning

These values of the response code are reserved.

E.2.49 Values ‘112’ to ‘127’ – multi-definition warning

These values of the response code are reserved.

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Annex F
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Common tables

F.1 Overview

F.1.1 General

The protocol of this standard uses lookup tables to associate specific definitions to numeric codes or to define the interpretation of an individual bit that is set to '1'. If the protocol references a table, the numeric values have specific definitions that allow all hosts to consistently utilize that data. This annex contains lookup tables (for example, engineering units, Device variable classification code etc.) used for Enumeration or Bit Field data types.

If one of the tables in this Annex F is referenced by the protocol specification, then the table or a subset of that table shall be used exactly as specified in this annex and undefined (i.e., unlisted) values shall not be used.

F.1.2 Enumeration

Data items that take on a single meaning from a list or table are encoded as enumerations and communicated as an unsigned integer of 1-octet or 2-octet length. Not all codes are allocated sequentially. Any intervening undefined codes are reserved for future use by this standard. Reserved values shall not be returned or transferred by any device. The code values 250 to 255 for all enumeration data types have the identical definition as shown in Table F.1.

Table F.1 – Reserved values

Code	Meaning	Description
250	Not used	implies that the responding device does not use this table
251	None	implies that the responding device does not use this table or does not use any other code defined in the table
252	Unknown	implies that the responding device uses this table, but has not yet been configured
253	Special	implies that the responding device uses this table, but does not use standard definition
254	Expansion	implies an expansion of a definition
255	Reserved	implies reserved by this standard for future use
The code 253 Special may be used in some instances for example when the flow units are being set by the user to something unusual like acre-feet/hour.		

F.1.3 Bit Field

Communication of information encoded as single-bit data (such as status and diagnostic information) is communicated using Bit Field as shown in 8.3.7.7. Individual bits are packed together, and reserved bits are added as necessary to transfer one octet. The lookup tables in this annex define the meaning of each bit in the Bit Field. Each bit shall be either true (set to a 1) or false (set to a 0). Any undefined bits are reserved for future use by this standard and shall be encoded as '0'.

The Bit Field data type is one of the following sizes:

4-bit,

1-octet, or

2-octets.

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The 4-bit Bit Field uses the following format for the bits:

0x01 for bit 1 (least significant bit),
0x02 for bit 2,
0x04 for bit 3, and
0x08 for bit 4 (most significant bit).

The 1-octet and the first eight bits of 2-octet Bit Fields use the following format:

0x01 for bit 1 (least significant bit),
0x02 for bit 2,
0x04 for bit 3,
0x08 for bit 4,
0x10 for bit 5,
0x20 for bit 6,
0x40 for bit 7, and
0x80 for bit 8 (most significant bit of the first octet).

The 2-octet Bit Field uses the following format for the next eight bits:

0x0100 for bit 9 (least significant bit of the most significant octet),
0x0200 for bit 10,
0x0400 for bit 11,
0x0800 for bit 12,
0x1000 for bit 13,
0x2000 for bit 14,
0x4000 for bit 15, and
0x8000 for bit 16 (most significant bit of the most significant octet).

F.2 Table definitions

F.2.1 Publish mode control codes

The 1-octet enumeration values for publish mode control are shown in Table F.2.

Table F.2 – Publish mode control codes

Code	Publish mode
0	Off
1	Enable Publish on token-passing data-link layer only
2	Enable Publish on TDMA data-link layer only
3	Enable Publish on TDMA and token-passing data-link layers

F.2.2 Write device variable codes

These codes as shown in Table F.3 indicate whether the “Device variable” value is a fixed value or if its value is derived from the normal operation.

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Table F.3 – Write device variable codes

Code	Description
0	Normal
1	Fixed value

F.2.3 Device variable family codes

These codes indicate which family the “Device variable” belongs to as shown in Table F.4. If a device does not support the “Device family” commands for a “Device variable”, then the device shall respond with 250 ("Not used").

Table F.4 – Device variable family codes

Code	Device variable family
0-3	Reserved
4	Temperature
5	Pressure
6	Valve or Actuator
7	Simple PID control
8	pH
9	Conductivity
10	Totalizer
11	Level
12	Vortex Flow
13	Mag Flow
14	Coriolis Flow
250	Not used

F.2.4 Device variable classification codes

These 1-octet enumeration codes indicate the function performed by the “Device variable” as shown in Table F.5. This identifies the type of process connection supported by the “Device variable” and the “Engineering unit code” table to be used.

Table F.5 – Device variable classification codes

Code	Device variable classification
0	Device variable not classified
1-63	Reserved
64	Temperature
65	Pressure
66	Volumetric flow
67	Velocity
68	Volume
69	Length
70	Time
71	Mass
72	Mass flow

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Code	Device variable classification
73	Mass per volume
74	Viscosity
75	Angular velocity
76	Area
77	Energy (work)
78	Force
79	Power
80	Frequency
81	Analytical
82	Capacitance
83	Emf
84	Current
85	Resistance
86	Angle
87	Conductance
88	Volume per volume
89	Volume per mass
90	Concentration
91	Reserved
92	Reserved
93	Reserved
94	Reserved
95	Reserved
96	Acceleration
97	Turbidity
98	Temperature Difference
99	Volumetric Gas Flow (per Second)
100	Volumetric Gas Flow (per Minute)
101	Volumetric Gas Flow (per Hour)
102	Volumetric Gas Flow (per Day)
103	Volumetric Liquid Flow (per Second)
104	Volumetric Liquid Flow (per Minute)
105	Volumetric Liquid Flow (per Hour)
106	Volumetric Liquid Flow (per Day)
107	Thermal Expansion

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F.2.5 Analog channel saturated codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.6.

Table F.6 – Analog channel saturated codes

Code	Channel number
0x01	Analog channel 1
0x02	Analog channel 2
0x04	Analog channel 3
0x08	Analog channel 4

F.2.6 Analog channel fixed codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.7.

Table F.7 – Analog channel fixed codes

Code	Analog channel number
0x01	Analog channel 1
0x02	Analog channel 2
0x04	Analog channel 3
0x08	Analog channel 4

F.2.7 Standardized status 0 codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.8.

Table F.8 – Standardized status 0 codes

Code	Name	Description
0x01	Simulation active	The device is in simulation mode and the level output is not representative of the process.
0x02	Non-volatile memory defect	The Non-volatile memory check is invalid or maybe corrupt, or the battery of a battery-backed memory is defective.
0x04	Volatile memory defect	The RAM memory check is invalid or maybe corrupt.
0x08	Watchdog reset executed	A watchdog reset has been performed.
0x10	Voltage conditions out of range	A voltage condition is outside its allowable range.
0x20	Environmental conditions out of range	An internal or environmental condition is beyond acceptable limits.
0x40	Electronic defect	A hardware problem not related to the sensor has been detected.
0x80	Reserved	

F.2.8 Standardized status 1 codes

Table F.9 is reserved for future use. Each bit of this 1-octet code is used as a Bit Field.

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Table F.9 – Standardized status 1 codes

Code	Name	Description
0x01	Status simulation active	Status Simulation Mode has been enabled and the Device Status and the status bits being returned in the Command 48 response are fixed and may not represent the current state of the device.
0x02	Discrete variable simulation active	The device is in simulation mode and one or more of its Discrete Variables are not representative of the process.
0x04	Event notification overflow	This bit shall be set when the event queue for one or more Event Specification (see Clause G.2) overflows resulting in an event not be recorded. This bit shall be reset when all pending events have been acknowledged.

F.2.9 Standardized status 2 codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.10.

Table F.10 – Standardized status 2 codes

Code	Name	Description
0x01	Sub-device list changed	The I/O system has lost communication with one of its sub-devices or discovered a new sub-device. This bit is reset by re-reading the sub-device list using command 84.
0x02	Duplicate master detected	The Adapter has discovered another master with the same address connected to its token-passing interface.
0x04	Sub-device mismatch	One or more of the sub-devices connected to the I/O system do not match the stored/pre-configured value.
0x08	Sub-device with duplicate IDs found	Sub-Devices with Duplicate Unique IDs or Long Tags found connected to the I/O System.
0x10	Stale data notice	This bit is set when the Stale Data Alarm for any Sub-device is set.

F.2.10 Standardized status 3 codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.11.

Table F.11 – Standardized status 3 codes

Code	Name	Description
0x01	Capacity denied	The device was unable to acquire the communication bandwidth required to support the publish messaging specified. This shall also be set if the network manager reduces the bandwidth allocated to the device.
0x02	Duplicate master detected	The Adapter has discovered another master with the same address connected to its token-passing interface.
0x04	Bandwidth allocation pending	The device has requested the bandwidth from the network manager and is awaiting network manager response.
0x08	Block transfer pending	The device has a data set (for example a waveform) awaiting transfer to the host application or the gateway.
0x10	Radio failure	The radio or radio module has failed and the device needs to be serviced or replaced. The "Device Malfunction" bit in the Device Status byte shall be set when this bit is set.

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F.2.11 Publish trigger mode codes

It indicates the trigger condition for publishing a message as shown in Table F.12.

Table F.12 – Publish trigger mode codes

Code	Name	Description
0	Continuous	The publish message is published continuously at (worst case) the minimum update period.
1	Window	The publish message is triggered when the source value deviates more than the specified trigger value.
2	Rising	The publish message is triggered when source value rises above the specified trigger value.
3	Falling	The publish message is triggered when the source value falls below the specified trigger value.
4	On-change	The publish message is triggered when any value in the message changes.

F.2.12 Event notification control codes

Each bit of this 4-bit code is used as a Bit Field as shown in Table F.13. It occupies the least significant four bits of one octet.

Table F.13 – Event notification control codes

Code	Description
0x00	Off
0x01	Enable event notification on token-passing data link layer
0x02	Enable event notification on TDMA data-link layer
0x03	Enable event notification on TDMA and token-passing data link layers

F.2.13 Event status codes

Each bit of this 4-bit code is used as a Bit Field as shown in Table F.14. It occupies the most significant four bits of one octet.

Table F.14 – Event status codes

Code	Definition
0x01	Configuration changed event pending
0x02	“Application process status” event pending
0x04	More status available event pending

F.2.14 Timetable request codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.15.

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Table F.15 – TimeTable request codes

Code	Definition
0x01	Source
0x02	Sink
0x04	Intermittent

F.2.15 Timetable application domain codes

It is 1-octet enumeration data as shown in Table F.16.

Table F.16 – TimeTable application domain codes

Code	Definition
0	Publish
1	Event
2	Maintenance
3	Block transfer

F.2.16 Synchronous action control codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.17.

Table F.17 – Synchronous action control codes

Code	Name	Description
0x01	Command	When set to '1', the indicated command will be executed at the time indicated. When reset to '0', a "Device variable" is to be sampled.
0x10	One-shot	When set to '1', the synchronous action shall be performed one time only. When reset to '0', the sampling will trigger at the indicated time and repeat continuously thereafter.
0x80	Action enabled	When set to '1', the action is enabled. When action is "One-shot" then the enabled bit is reset after the action occurs.

F.2.17 Real-time clock flags codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.18.

Table F.18 – Real-time clock flags codes

Code	Name	Description
0x01	Non-volatile clock	When set to '1', the device contains a battery-backed clock. In this case, the clock does not need to be reset if there is a power failure.
0x02	Clock un-initialized	The real-time clock has never been set with the date and time. For example the clock is volatile and power was removed from and restored to the device.

F.2.18 Wireless timer codes

It is 1-octet enumeration data as shown in Table F.19.

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Table F.19 – Wireless timer codes

Code	Timer_type
0	Discovery
1	Advertisement
2	Keep-alive
3	Path failure
4	Health report
5	Broadcast reply
6	Maximum PDU age
7	Maximum reply time (transport retry interval)

F.2.19 Device power source codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.20.

Table F.20 – Device power source codes

Code	Name	Description
0x01	Line power	Device is powered via a hardwired connection to a plant power source.
0x02	Battery power	Device operates solely off its (internal) battery.
0x04	Rechargeable battery power or power scavenging	The device has a short-term supply of energy (shall be at least one hour) that is continuously being replenished. The device's power is being replenished by harvesting and converting energy from the environment surrounding the device (for example solar, vibration, heat).
0x08 – 0x80	Reserved	

F.2.20 Link_type codes

It is 1-octet enumeration data as shown in Table F.21.

Table F.21 – Link_type codes

Code	Link_type
0	Normal
1	Discovery
2	Broadcast
3	Join

F.2.21 Link option flags codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.22.

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Table F.22 – Link option flags codes

Code	Definition
0x01	Transmit
0x02	Receive
0x04	Shared

F.2.22 Superframe mode flags codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.23.

Table F.23 – Superframe mode flags codes

Code	Name	Description
0x01	Active	This flag is '0' (inactive) on reset.
0x80	Handheld superframe	This bit shall only be set for one superframe in the device.

F.2.23 Session_type codes

It is 1-octet enumeration data as shown in Table F.24.

Table F.24 – Session_type codes

Code	Session_type
0	Unicast
1	Broadcast
2	Join

F.2.24 Timetable deletion reason codes

It is 1-octet enumeration data as shown in Table F.25.

Table F.25 – TimeTable deletion reason codes

Code	Reason
0	Requested by peer
1	Timetable cannot be established
2	Network failure

F.2.25 Disconnect cause codes

It is 1-octet enumeration data as shown in Table F.26.

Table F.26 – Disconnect cause codes

Code	Cause
0	User-initiated
1	Communication failure

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F.2.26 Wireless operation codes

It is 1-octet enumeration data as shown in Table F.27.

Table F.27 – Wireless operation codes

Code	Operation
0	Idle
1	Active search
2	Negotiating
3	Quarantined
4	Operational
5	Suspended
6	Deep sleep or Ultra-low power or Passive search

F.2.27 Join process status codes

Each bit of this 2-octet code is used as a Bit Field as shown in Table F.28.

Table F.28 – Join process status codes

Code	Name	Description
0x0001	Network packets heard	
0x0002	ASN acquired	
0x0004	Synchronized to slot time	
0x0008	Advertisement heard	
0x0010	Join requested	It is set to ‘1’ on transmission of first join request.
0x0020	Join retrying	It is set to ‘1’ after the first join request retry (i.e., when number of join requests is more than 2). It is reset to ‘0’ when device is authenticated or when “Active search” is started.
0x0040	Join failed	It is set to ‘1’ on transition from “Active search” mode to “Deep sleep” mode. It is reset to ‘0’ on transition from “Deep sleep” mode to “Active search”.
0x0080	Authenticated	It is set to ‘1’ when network key, network manager session are established.
0x0100	Network joined	It is set to ‘1’ when normal superframe and links are obtained.
0x0200	Negotiating network attributes	It is set to ‘1’ when gateway session is obtained. Initial bandwidth requirements may not have been negotiated with network manager.
0x0400	Normal operation commencing	

F.2.28 Security type codes

It is 1-octet enumeration data as shown in Table F.29.

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Table F.29 – Security type codes

Code	Security type
0	Session keyed
1	Join keyed
2	Reserved

F.2.29 Device list codes

It is 1-octet enumeration data as shown in Table F.30.

Table F.30 – Device list codes

Code	Device list	Description
0	Active devices	Active Device List (Mandatory-Gateway). The devices currently joined and available to Host Applications (i.e., they are not Quarantined). Active Device List is volatile.
1	White-listed devices	Whitelisted Devices (optional). Devices that are allowed to join the Network. This is similar to an Access Control List (ACL). Whitelist is non-volatile.
2	Blacklisted devices	Blacklisted Devices (optional). Devices that are not allowed to join the Network. Blacklist is non-volatile.
3	Network list	Network List (Mandatory-Gateway). The devices that are (or should be) part the Network (including Access Points). Includes the Active list plus devices that have joined Network but have currently dropped off the Network. Network list shall track quarantined devices that have not been approved (i.e., quarantined devices that have not been approved and, consequently, never been in the Active list). Network List is non-volatile
4	Quarantine list	Quarantine List (Mandatory-Gateway). These are devices that have successfully joined the network but are not approved for use managing the plant/process (i.e., quarantined devices cannot be accessed by Gateways, Host Applications or wirelessly by Handhelds). Quarantined devices shall not be included in the Active List but shall be included in the Network List. Quarantine List is volatile
5	Rejected device list	Rejected Device List (Optional-Gateway). This is the list of devices that have attempted to join the network but have had their join request discarded (i.e. access to the network was denied). Rejected Device List is volatile
6	Access point list	Access Point List (Mandatory-Gateway). The list of Access Points connected to the Gateway. Access Points shall be included in the Network List and shall not be included in the Active List. Access Point List is volatile

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F.2.30 Network access mode codes

It is 1-octet enumeration data as shown in Table F.31.

Table F.31 – Network access mode codes

Code	Network access mode
0	Open – accept all devices
1	Use white-list devices for access
2	Use blacklist devices for access
3	Use white-list and blacklist devices for access
4	Lockdown – disable join links
5	Quarantine – all authenticated devices are allowed to join. Devices on the network list are made active (i.e., provisioned with the Gateway session and added to the Active List). All other devices are quarantined (i.e., added to the Quarantine List). After network operator approval Quarantined devices are made active.

F.2.31 Device profile codes

It is 1-octet enumeration data as shown in Table F.32.

Table F.32 – Device profile codes

Code	Device profile
1	HART™ process automation device
2	HART™ discrete device
3	Hybrid – process automation and discrete device
4	I/O system
129	Wireless process automation device
130	Wireless discrete device
131	Wireless hybrid – process automation and discrete device
132	Wireless gateway
141	Wireless process adapter
142	Wireless discrete adapter
144	Wireless-enabled handheld or portable maintenance tool

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F.2.32 Device power status codes

It is 1-octet enumeration data as shown in Table F.33.

Table F.33 – Device power status codes

Code	Power status
0	Nominal
1	Low
2	Critically low
3	Recharging – low
4	Recharging – high

F.2.33 Neighbor flags codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.34.

Table F.34 – Neighbor flags codes

Code	Neighbor type
0x01	Time source
0x80	No links to this neighbor

F.2.34 Notification mask codes

Each bit of this 2-octet code is used as a Bit Field as shown in Table F.35.

Table F.35 – Notification mask codes

Code	Name	Description
0x0001	Publish mode	
0x0002	Event notification	
0x0004	Application process status	
0x0008	Device configuration	
0x0010	Network topology	Target device shall be gateway or network manager
0x0020	Network schedule	Target device shall be gateway or network manager
0x0040	Device list changed	IO system shall be a gateway

F.2.35 Join mode codes

It is 1-octet enumeration data as shown in Table F.36.

Table F.36 – Join mode codes

Code	Join mode description
0	Don't attempt to join.
1	Join now and return to join mode 2 after joining.
2	Attempt to join immediately on power up or reset.

F.2.36 Device scheduling flags codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.37.

Table F.37 – Device scheduling flags codes

Code	Device type
0x01	Transient device
0x02	Non-routing device
0x04	Handheld device

F.2.37 Network optimization flags codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.38.

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Table F.38 – Network optimization flags codes

Code	Optimization
0x01	Low latency
0x02	Use line powered devices as backbone

F.2.38 Wireless capabilities codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.39.

Table F.39 – Wireless capabilities codes

Code	Description
0x01	Reserved
0x04	Reserved
0x08	Saturating counters (reset= Rollover Counters). When this bit is set (not recommended) the status counter in, for example, Command 779 is reset after each Health Report. If this bit is reset the counters are never reset and rollover when the maximum value (e.g., 0xFFFF) is surpassed.

F.2.39 CCA mode codes

It is 1-octet enumeration data as shown in Table F.40.

Table F.40 – CCA mode codes

Code	Description
0	CCA Disabled
1	CCA Enabled. Mode 1: Energy Detect
2	CCA Enabled. Mode 2: Carrier Sense
3	CCA Enabled. Mode 3: Carrier Sense + Energy Detect

F.2.40 Wireless device connection status

It is 1-octet enumeration data as shown in Table F.41.

Table F.41 – Wireless device connection status

Code	Description
1	Device Operational. Device is currently connected to the network.
2	Device Disconnected: Device is not connected to the network
3	Device Attempting to Join. Join request has been received from the device but join sequence has not been completed
4	Device Quarantined. Device has successfully joined the network but is currently not publishing data. Device cannot be accessed via the gateway

F.2.41 Wireless device health status

It is 1-octet enumeration data as shown in Table F.42.

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Table F.42 – Wireless device health status

Code	Description
0x10	Stale data alarm is set

F.2.42 Change key flag codes

Each bit of this 1-octet code is used as a Bit Field as shown in Table F.43.

Table F.43 – Change key flags codes

Code	Description
0x01	Network key
0x02	Join key
0x04	Session keys

F.2.43 Join key mode code

It is 1-octet enumeration data as shown in Table F.44.

Table F.44 – Join key mode code

Code	Description
0	Normal, Default mode, each device has a different join key
1	Common join key; all devices use the same join key
2	Well-known key; all devices use the Well-known key 0x7777 772E 6861 7274 636F 6D6D 2E6F 7267 as their join key

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Annex G
(informative)

Application of publish data mode and event commands

G.1 Publish data mode operation

G.1.1 Overview

The Type 20 application layer protocol supports the publishing of cyclical process data. In publish data mode, a device is instructed to publish the response to a command continuously without any further Master action. This mode requires that the Master setup various parameters and then enable publishing. A device can be configured to publish several data sets (messages). If a device implements this mode, then it supports at least three publish data messages. The publish data mode commands are:

- Write publish data period, Command 103 (see 8.3.3.28) to write publishing period;
- Write publish data trigger, Command 104 (see 8.3.3.29) to write publishing trigger;
- Read publish data mode configuration, Command 105 (see 8.3.3.30) to read publish data mode Configuration;
- Write publish data device variables, Command 107 (see 8.3.3.32) to write Device variables to be published;
- Write publish data mode command number, Command 108 (see 8.3.3.33) to write Command number for publishing;
- Write publish data mode control, Command 109 (see 8.3.3.34) to enable or disable publishing.

G.1.2 Configuring a device for publish data mode operation

The Master should use the following procedure to place a field device into publish data mode.

a) Configure the command response by using Command 108 ‘to write Command number’ to for publishing. Commands 1, 2, 3, 9 and 48 are available for publishing and Command 33 is available, if it is implemented in the field device.

b) Assign Device variables to the response data slots for Commands 9 and 33 by using Command 107 ‘to write Device variables to be published’. Command 9 supports up to eight slots and Command 33 supports up to four slots.

c) Configure the update period and the maximum update period for publishing the data by using Command 103 ‘to write publishing period’. The master can use Command 54 to determine the update rates for the desired Device variables. The data-link requirements may result in publishing more frequently than the configured update period.

d) Configure the Trigger mode and level for publishing by using Command 104 ‘to write publishing trigger’. Publishing may be configured to occur continuously or based on the value of the device variable. Publishing will always occur at least as often as the maximum update period – see Figure 45, Figure 46 and Figure 47.

e) Issue Command 109 ‘to enable or disable publishing’. The field device follows the procedure specified in 8.3.3.34.3 and shown in Figure G.1. The network manager also sends request to other network devices to setup or delete superframe and link for publishing.

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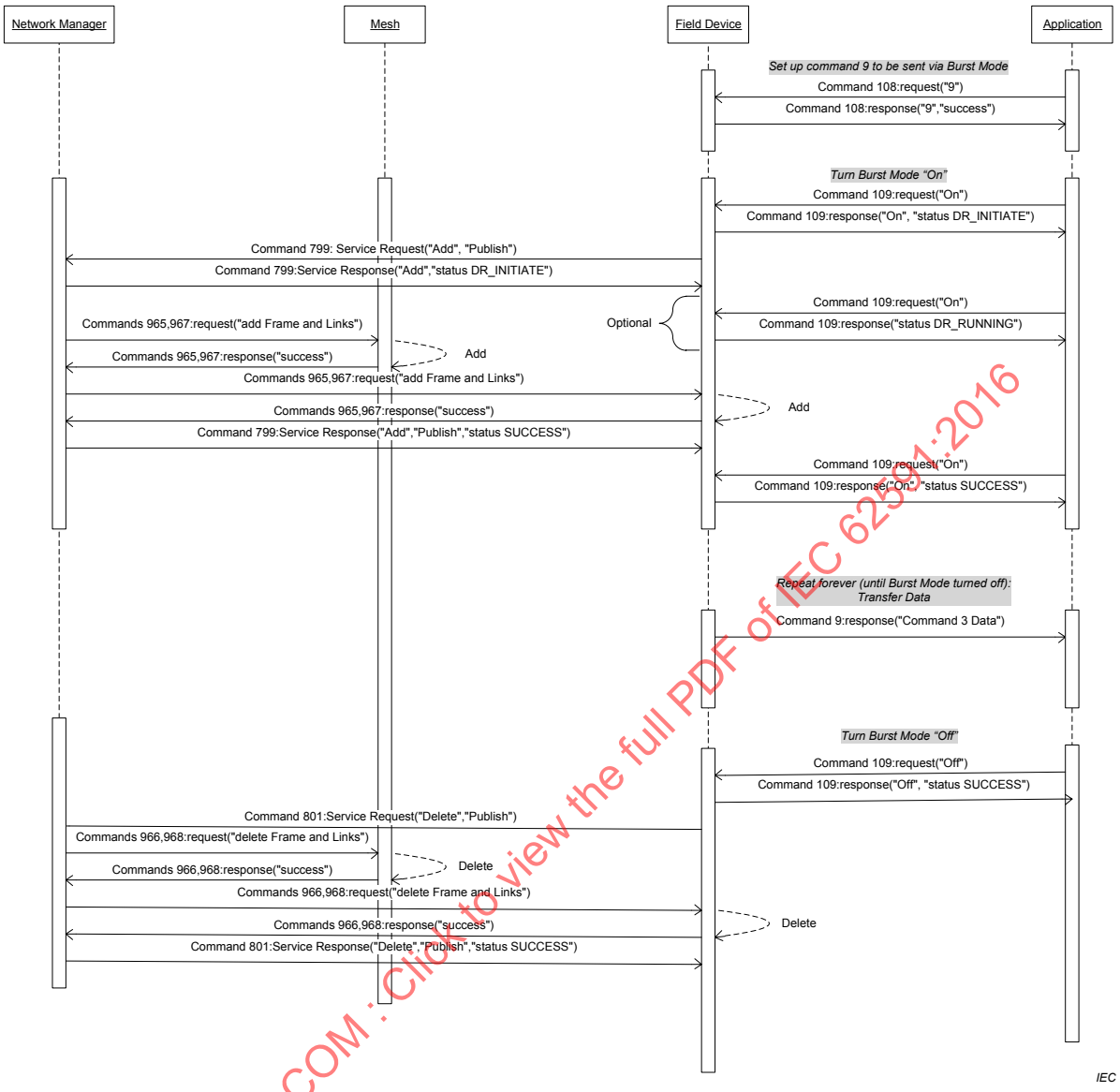

Figure G.1 – Enabling or disabling publishing sequence

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G.1.3 Response for publish data mode operation

While the publishing is enabled, the field device (slave) transmits the responses to the command number set by Command 108 based on the data-link requirements and the attributes configured using the other publish data mode commands.

Once the device is in publish data mode, Command 108 can be used to change the publish data command response. A device may take one publish cycle before the response changes to the new command number. Other publish data mode commands may also be used to adjust publish data mode operation on-the-fly.

The wireless field device aggregates multiple pending messages into one transaction, whenever possible (see 8.3.2.5). If the publish data messages does not fit into a single transaction, then these can be sent in separate transactions.

G.1.4 Publish data mode update periods

The update period is constrained by the protocol (see 8.3.3.28.3). For the Physical layer specified by IEEE 802.15.4-2011, the minimum period is 0,1 s. The Update period parameter

of Command 103 determines the communication rate. The acquisition period for a Device variable can be different; it can be read using Command 54.

G.2 Event notification operation

G.2.1 Overview

Event notification requires, and is built upon, publish data mode operation. If a device supports publish data mode, then it also supports all of event notification commands. The Type 20 application layer protocol offers two distinct methods to display events – the "Application process status" and the response to Command 48.

Event notification publishes changes in the device's status, independently from data publishing supported in other publish data mode commands. For events the status included in the "Application process status" octet, "Extended status" octet and command 48 can be used. It is possible to specify a subset of all these status bits that will trigger event notification. Event notification has a lower priority than other types of data transfer, but it requires a time stamp in order to indicate the first time when a notification occurred. Event notification is usually not required for monitoring or control; its use is rather infrequent. Event Notifications are aggregated with publish data messages, whenever possible.

The Event Notification commands are:

- Read event notification summary, Command 115, (see 8.3.3.35) to read the configuration of the Event notification;
- Write event notification bit mask, Command 116, (see 8.3.3.36) to select the bits that can trigger an Event notification;
- Write event notification timing, Command 117, (see 8.3.3.37) to control the timing of Event notifications;
- Write event notification control, Command 118, (see 8.3.3.38) is to enable or disable Event notification;
- Write event notification acknowledgement, Command 119, (see 8.3.3.39) to acknowledge the Event notification.

The device retains Event notification settings through a device reset, self-test or the power being removed and reapplied. While event transitions do not need to be retained through power cycles, the device should buffer five transitions buffered; required minimum is three.

G.2.2 Configuring a device event notification operation

The Master should use the following procedure to configure Event notifications.

- Configure the status bits that will trigger Event notification by using Command 116 'to write Event notification bit mask'.
- Configure how long the event has to be active before an event is recognized by configuring De-bounce interval associate with that event. Configure how often the device has to send the event notification before it receives the acknowledgement. Both of these timings are set by using Command 117 'to write Event notification timing'.
- Enable the event notification by using Command 118 'to enable Event notification control'. This command also selects the interface to send the event notification.

G.2.3 Handling of Event Notification in a Device

Any change in the status bits for which bit mask is '1' is considered as an event. The first occurrence of the event is captured and time stamped. If the event persists for duration equal to Event de-bounce interval, then the Event notification is generated and the Command 119 response transmitted. Command 119 is transmitted repeatedly at the rate indicated by the

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Event notification retry time until a Command 119 from a Master request acknowledges the event.

If there was no event generated during a Maximum update time, the device publishes the Command 119 response one time to the gateway. The latest values for “Application process status”, the Configuration change counter and the Command 48 response octets are always included in the Command 119.

Command 116 is used to identify the bits that may trigger the Event notification. Command 119 only returns only those status octets, for which the Event mask was established using Command 116 (i.e., Command 116 may be truncated). The octets returned in Command 119 include the current “Application process status” and Command 48 data regardless of which bits are masked. The time stamp remains the same until an acknowledgement is received. If an acknowledgement is received, the time stamp is set to the time when the acknowledgement was received.

Event Notification and Time Stamps are not required to be maintained through power cycles or a device reset.

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Annex H
(informative)

Network redundancy

The network redundancy is achieved by having more than one route from one device to another device, to the gateway and to the network manager. Redundancy is achieved in IEC 62591 through routing (primarily graph routing). The Network Manager is responsible for ensuring that all devices have more than one neighbour. Multiple access points may be utilized to ensure the required level of reliability. Duplicate PDU's, as described in 6.6.3.3.2.4, are detected through the nonce counter history. Graph routing is described in 6.6.1.3.2.

The network redundancy to the gateway is achieved by having more than one network access point as shown in Figure H.1 and as specified in Clause D.2. This figure also shows the relationship of the network manager to the wireless network. The network manager is responsible for establishing network routing.

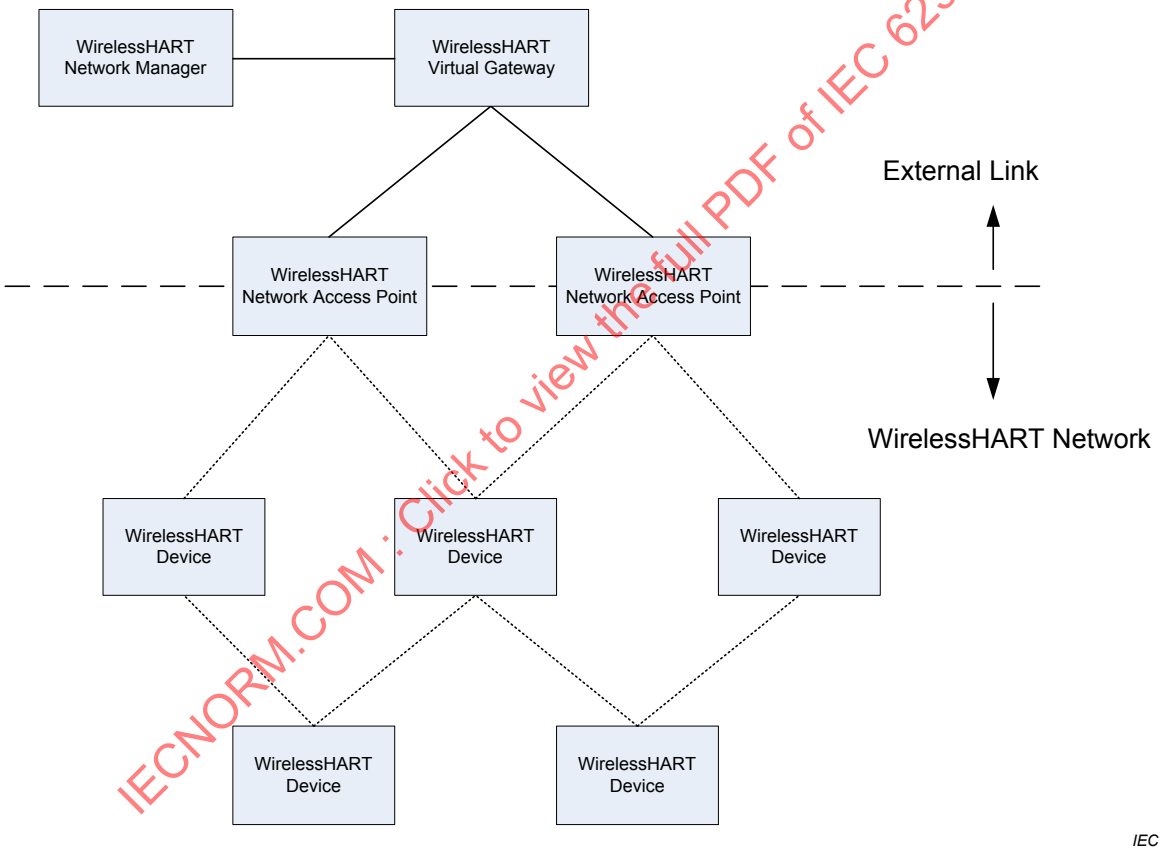

Figure H.1 – Network routing

If one of the access points fails, the communication between a network device and the gateway is routed via the other operational access point.

The redundancy of the gateway is outside the scope of this standard.

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Annex I
(informative)

Network manager implementation

I.1 Overview

The network manager is responsible for the overall management, scheduling, and optimization of the wireless network. The functions to be performed by a network manager in wireless network are:

- network formation and configuration,
- route setup and distribution of routes to the network devices,
- generation of network schedule and transfer to the network devices,
- channel management, and
- network diagnostics and adapting.

This annex describes the operation of these functions and guidelines on how these functions can be implemented.

I.2 Network manager model

I.2.1 General

The network manager data model is shown in Figure I.1. The data components are:

- the network schedule,
- the collection of network devices,
- the collection of neighbor tables,
- the collection of connection tables, and
- the collection of routes.

The network manager also maintains an association with the security manager.

When a new device joins the network, the network manager is responsible for managing the join process. As part of this join process, the network manager uses its model of the network along with algorithms that it has to optimize the network. After the schedule has been generated, the network and schedule information is transferred through the network in reverse order, i.e., from the gateways to each field device.

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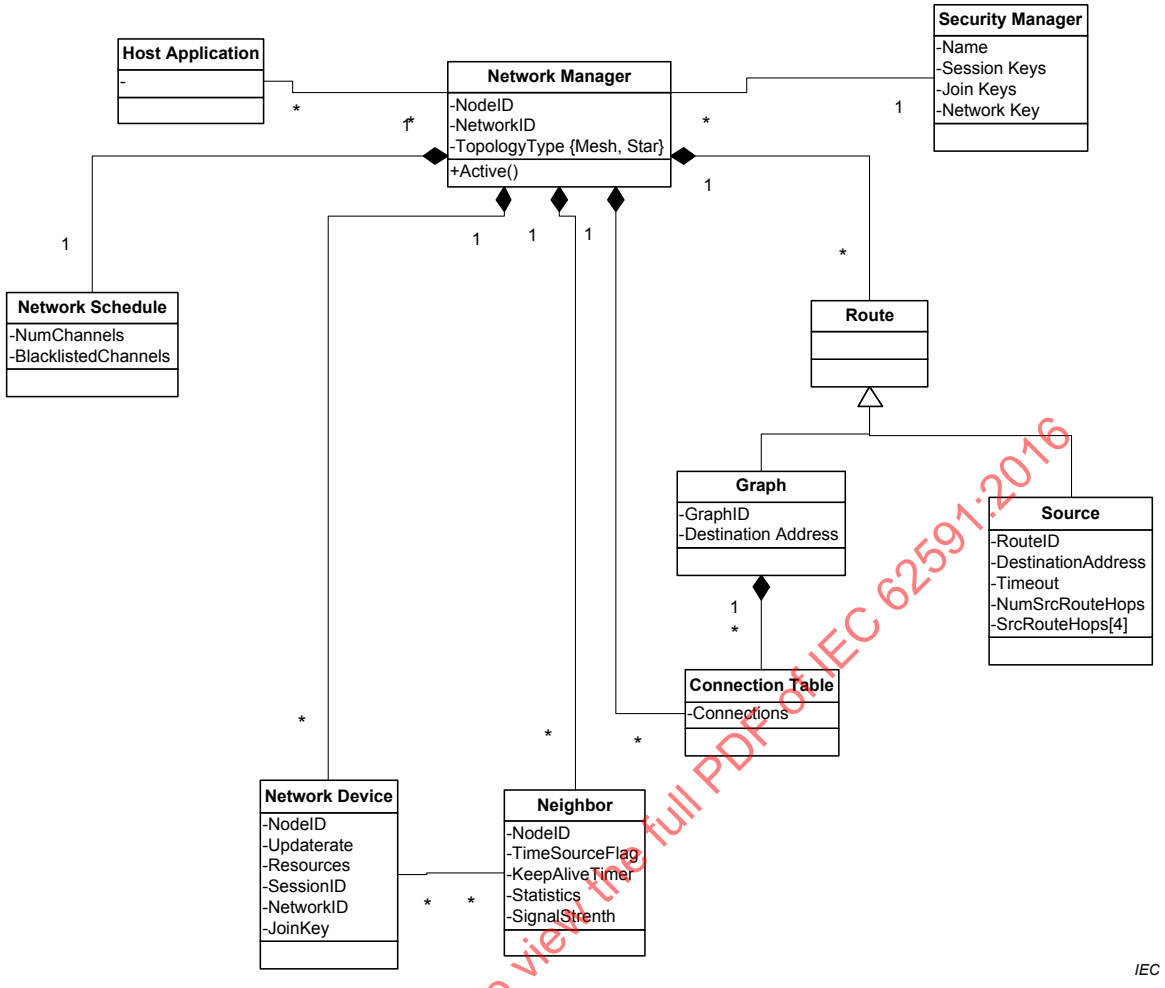

Figure I.1 – General model for network manager

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The network manager generates and maintains all of the route information for the network. It uses the list of network devices, their reported neighbors and device capacities to generate a complete graph leading from each network device to the network manager. There may also be special purpose routes that are used to send commands and other settings from the gateway to network devices. There are broadcast routes that are used to send broadcast messages from the network manager through the gateway to all of the network devices.

Each graph should use a maximum of 4 neighbors as a potential next hop destination.

Special purpose routes are also created. These routes provide paths from the gateway to devices and from devices to gateway. These are referred to as downstream and upstream paths. For example upstream paths are used for transfer of periodic process data from the devices to gateway and downstream paths are used for transferring control information from the gateway to the actuators.

The overall routing information is assembled by the network manager using device, neighbor and diagnostic information reported by the network devices. After determining the routing information and communication requirements for all of the devices, the scheduling of network resources can be performed. The network manager contains one overall network schedule.

The network manager is responsible for adapting the network to changing conditions and for scheduling communication resources. As devices join and leave the network, the network manager updates its internal model of the network and uses this information to generate the schedule and routes. Network performance and diagnostic information is also used by the

network manager to adapt the overall network to changes in topology and communication requirements. After the overall schedule has been generated, the schedule is transferred through a series of commands from the network manager to the network devices.

I.2.2 Initializing the network manager

The network manager is responsible for the network_ID, which is required for each specific wireless network. One possible way to initialize the network_ID is through a gateway that is hosting the network manager. It is done by connecting this gateway to a handheld or a host. The following parameters have to be configured to initialize the network manager:

network_ID, network manager nickname, network manager address, gateway nickname, gateway address and gateway Join_key.

NOTE The network manager and the gateway addresses and nicknames are fixed. These are specified by this standard.

I.2.3 Types of network devices

Network device behavior depends upon its type. Device types and their data models are shown in Figure I.2.

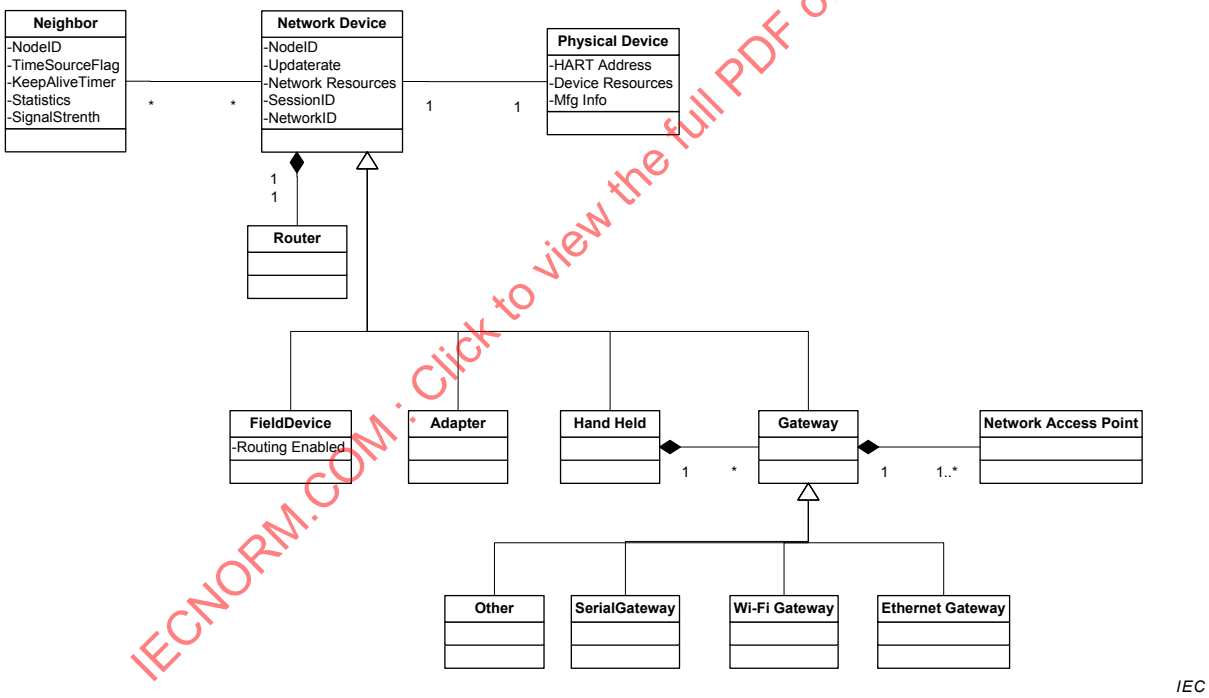

Figure I.2 – Device type data model

The root of the device data model is the network device. All network devices are globally identified by its 40-bit unique ID. The network manager contains a complete list of network devices connected to the network. It assigns a network unique 16-bit 'nickname' to each network device. All network devices also have attributes containing information on update rates, sessions and device resources, including items such as the size of the superframe table, etc. All network devices contain a list of neighbor devices that it has identified during its listening operations. Other attributes of a device depend upon the device type.

The most common type of network device is a field device. Field devices can be further differentiated by the type of measurement or control operation. All field devices contain routing capabilities.

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Handheld type of network device is used to configure devices, run diagnostics, perform calibrations, and manage network information inside other devices. If a handheld is used in a maintenance lab, it can connect directly to a field device via the maintenance port.

Gateway type of network device is used to connect the wireless network to a host application such as a process automation system or asset management system. The gateway connects to the network via the network access points.

I.2.4 Network routing

Network devices use routing to communicate with each other. There are two methods of routing packets in a wireless network—graph routing and source routing. These are illustrated in Figure I.3.

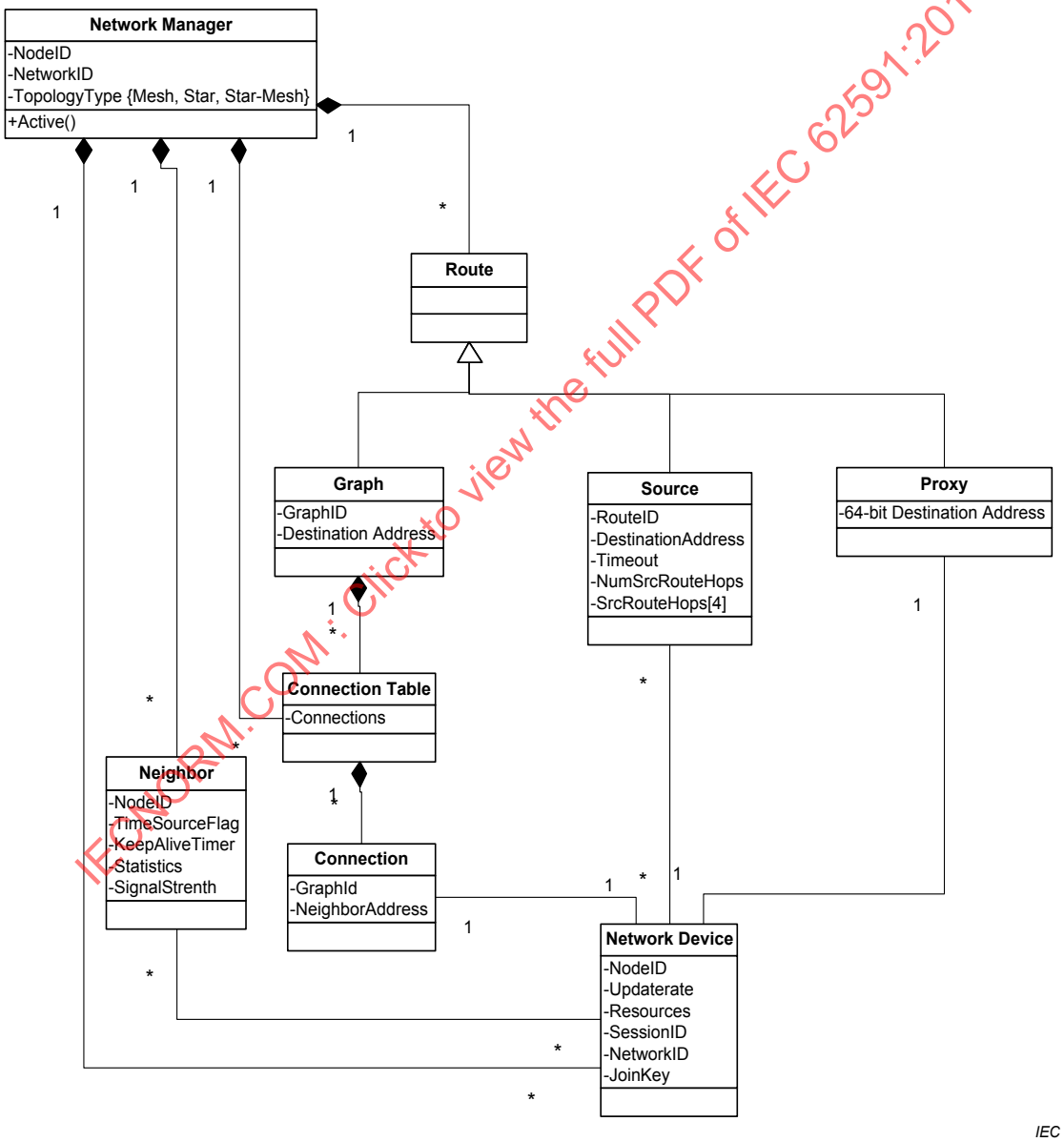

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Figure I.3 – Network routing

The network manager contains a complete list of routes, connections and network devices. When a device is initially added to the network, the network manager stores all neighbor entries including signal strength information as reported from that network device. The network manager uses this information to build a complete network graph. The network graph

is an optimized route map. During the optimization of the network graph, a large number of possible (but suboptimal) links are removed. The network graph is put together optimizing several attributes including reliability, hop count, reporting rates, power usage, and overall traffic flow. A key part of the topology is the list of connections that connect devices together.

One of the functions of the network manager is to configure graph and connection information in each network device. The network manager maintains a complete list of the graphs and connection information with which each network device has been configured. As the overall network adapts to changing information, the network manager is responsible for updating the overall topology, which includes adding and deleting information in each network device.

Using this knowledge, the network manager generates graph routes. It also generates source routes for the gateway. Source routes can be derived from graph routes assembled by the network manager. The graph route is like a tree. Single path from the root to the leaf is a source route. The network manager utilizes graph routes to generate schedules. This includes measurement information that is transferred from network devices to the gateway and control information that is transferred from the gateway to final control field device such as regulating valves, on-off valve, pump, fan, damper, as well as motors.

Every graph in a network is associated with a unique Graph_ID. To send a packet on a graph, the source network device includes a Graph_ID in the packet's network header. The packet travels along the paths corresponding to this Graph_ID until it reaches its destination, or is discarded. In order to be able to route packets along a graph, a device shall be configured with a connection table. The connection table contains entries that include the Graph_ID and neighbor address. Redundant paths may be setup by having more than one neighbor associated with the same Graph_ID. For routing a received packet, the device performs a lookup in the connection table by Graph_ID and sends that packet to any of the listed neighbors. After the neighbor acknowledges receipt of the packet (data-link level acknowledgement), the routing device may release it and remove the packet from the transmit buffer. If an acknowledgement is not received, the device attempts to retransmit the packet at its next available opportunity.

I.2.5 Network schedule

I.2.5.1 General

The network manager is responsible for allocating communication resources. The communication resources are divided up into slots and channel offsets and arranged in superframes. Communication resources are allocated based upon information from the communication requirements. The overall model for a network schedule is summarized in Figure I.4.

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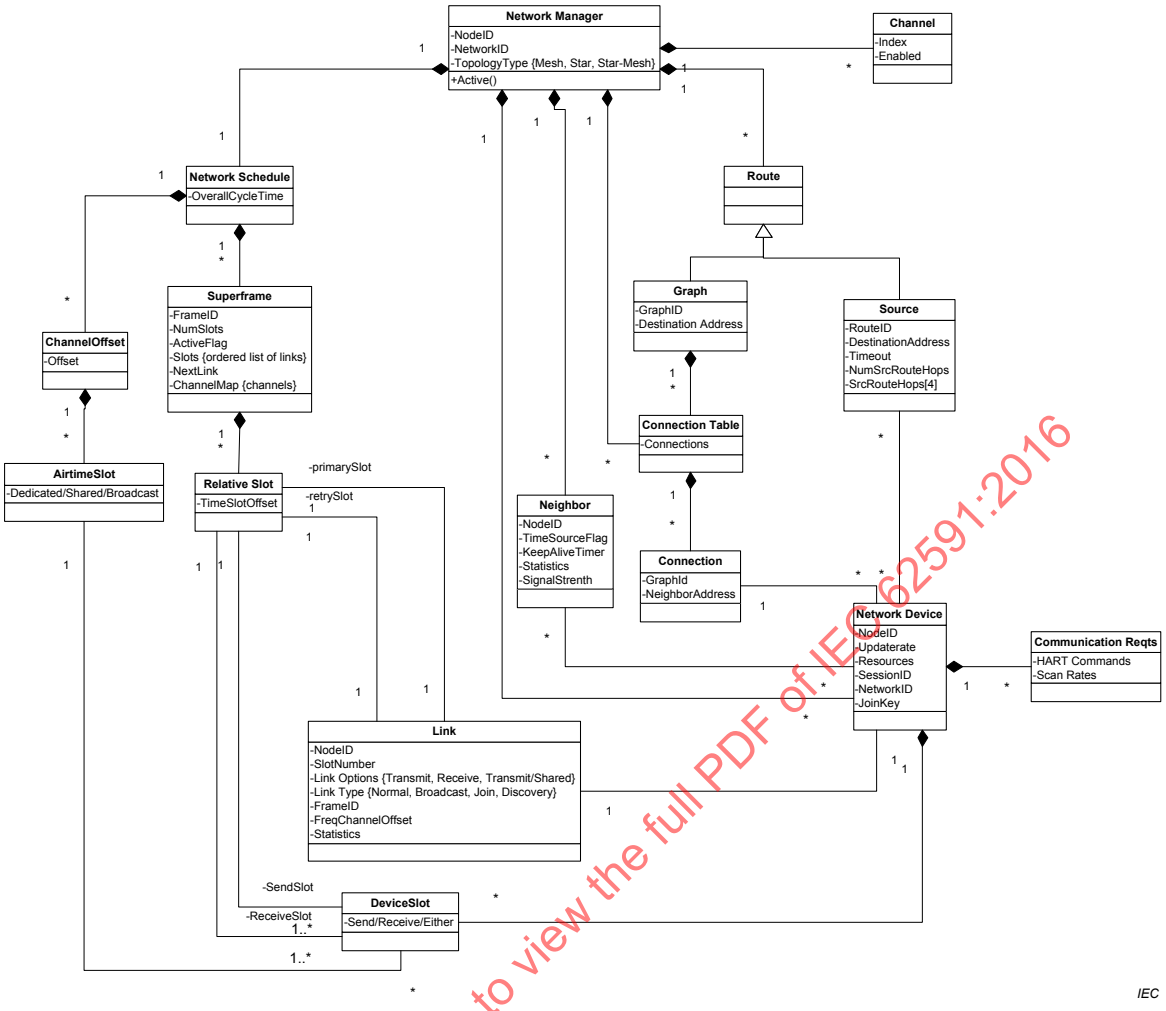

Figure I.4 – Network schedule

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Each wireless network contains exactly one overall schedule that is created and managed by the network manager for that network. The schedule is organized into superframes. Each superframe is further subdivided into slots that repeat at the superframe cycle rate. The slots in a superframe are called relative slots; these slots are relative to the start of the superframe. Relative slot is not the same as absolute slot number which indicates the actual time that is being used for transmission of a specific packet.

Link objects are associated with specific network device ID; for each link there are slot allocations in one or more devices. If it is a dedicated slot then there is a send slot in one device and a receive slot in another device. If it is a shared slot then there is a receive slot in one device and one or more transmit slots in several devices. If it is a broadcast slot then there is one transmit slot in one device and receive slots in several devices. The link object also contains the Superframe_ID, relative slot number, link options (transmit, receive, shared), and Link_type (normal, broadcast, advertising, discovery).

The channel offset is used to calculate the specific radio frequency channel that is used for a particular slot based on a pseudorandom sequence.

The network manager combines the communication requirements with the superframe information to create a set of links for each device. The specific links loaded into each device are used by that device to determine when the device's radio needs to wake up, and after it wakes up whether it should transmit, receive, or either transmit and receive. The link does not determine what is communicated; a link is an opportunity to communicate. The device determines what it will communicate in each slot.

I.2.5.2 Superframe

A superframe is a collection of links assigned to time slots repeating in time. The number of slots in a given superframe (superframe size) determines how often each slot repeats, thus setting a communication schedule for devices that use the slots. A superframe is a product of both channels and time slots. When a superframe is created, it is associated with a Graph_ID. The network manager uses this association to allocate slots and configure links. In runtime the device determines how a link will be used.

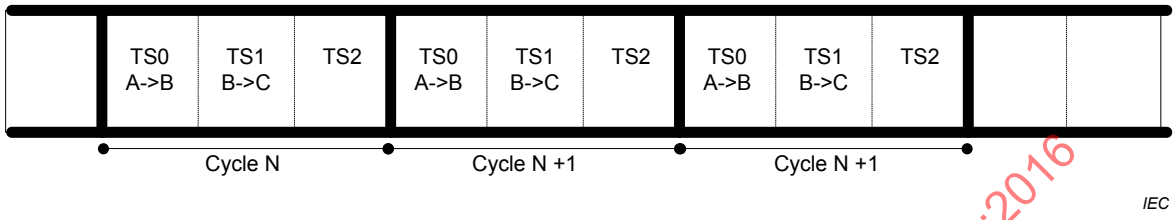

Figure I.5 – Example of a three-slot superframe

Every new superframe instance in time is called a superframe cycle. Figure I.5 shows how devices may communicate in a simple three slot superframe. Devices A and B communicate during slot 0; devices B and C communicate during slot 1; and slot 2 is not being used. Every three slots, the link schedule repeats.

The size of superframes should follow a harmonic chain, i.e. all periods should divide into each other. Examples of harmonic chains are 1, 2, 4, 8, 16, … and 3, 6, 12, 24 and as well as any other period that conforms to the expression ab^n.

I.2.5.3 Multiple superframes in the network

A wireless network may contain several concurrent superframes of different sizes. Multiple superframes may be used to define a different communication schedule for various groups of devices or to run the entire network at different duty cycles. Additional superframes may also be allocated for different communication rates, publish data requirements, event notifications, and application layer commands issued by host applications.

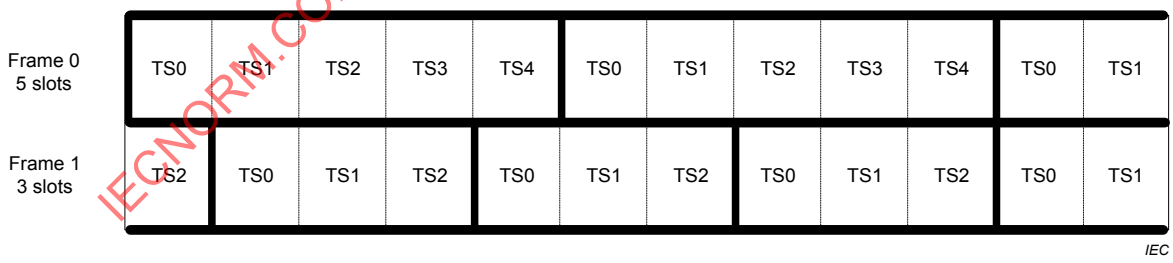

Figure I.6 – Multiple superframes in a network

A network device may participate in one or more superframes simultaneously, but not all devices need to participate in all superframes. By configuring a network device to participate in multiple overlapping superframes of different sizes, it is possible to establish different communication schedules and connectivity matrices that all work at the same time.

Key applications, such as asset management systems and device specific applications, often require considerable throughput for relatively short durations of time (measured in minutes) – used to call up configuration and diagnostic screens and respond to user requests. To support this temporary increase in demand for communication time slots, additional superframes may be used.

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Superframes can be added, removed, activated and deactivated while the network is running. All superframes have identical start time. Cycle 0, slot 0 of every Superframe occurs at the beginning of epoch. The epoch for a specific network is the time when the network manager starts the network. Because of this, time slots in different superframes are always aligned, even though beginnings and ends of superframes may not be aligned, as shown in Figure I.6. Because all superframes begin at the same time, it is always possible to identify start time of a specific superframe cycle and time slot.

A network device with links in multiple superframes may encounter a link arbitration situation. This may happen when two or more superframes with assigned links coincide in the same absolute time slot. In these cases, the device shall operate on the link that has the numerically lowest superframe ID. The rules for link arbitration are defined by this standard.

I.2.5.4 Time Slots

A time slot is a unit of fixed time duration commonly shared by all network devices in a network. The duration of a time slot is sufficient to send or receive one packet and an accompanying acknowledgement, including guard-band times for network-wide synchronization. The model also refers to a time slot as 'relative time slot'. This is because time slots in a superframe are always relative to the start of that superframe.

Dedicated links are shared by a pair of devices that communicate during an allocated time slot. Shared links can have more than one transmitter and only one receiver. For shared links, a defined back-off and retry mechanism handles collisions that may occur. Broadcast and multicast links have one transmitter and many receivers, but there is no data-link acknowledgement.

Time slots repeat in time at the rate corresponding to the size of its superframe. Time slots are assigned to devices through links. If a time slot is assigned to a device, the device can perform one of the following actions within the time slot, depending on the type of link:

- attempt to transmit a packet,
- wait to receive a packet, or
- remain idle.

A network device that has a transmit link or a transmit/receive link may send a packet during the associated time slot, if the destination of the packet matches the neighbor(s) on the other end of the link. A network device that has a receive link, or a transmit/receive link with no packet to send, listens for an incoming packet during the associated time slot. Time slots can also be shared by multiple devices. All devices that participate in either a dedicated or a shared link are awake and listening.

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I.2.5.5 Links

When the network manager creates connections between devices, link assignments is available to support those connections. In many cases it will be necessary for the network manager to create new link assignments. In these cases the network manager will transfer the link assignments to each of the devices that require it. A link assignment specifies how the network device uses a time slot. Each link includes exactly one time slot, a channel offset, its type (transmit, receive or shared), neighbor device on the other end of the link and transmit/receive attributes.

Links may be transmit-only, receive-only, or transmit/receive. A network device that has a transmit link or a transmit/receive link may transmit a packet during the associated time slot, if the destination of the packet matches the neighbor(s) on the other end of the link. A network device that has a receive link, or a transmit/receive link with no packet to transmit, listens for an incoming packet during the associated time slot.

Transmit links may be shared by multiple devices, which is indicated to the network device by the shared flag in the link configuration. For a shared link, the device uses a collision-avoidance scheme with a Backoff to handle collision situations. Using shared links may be desirable when throughput requirements of devices are low, and/or traffic is irregular or traffic has bursts. In some situations, using shared links may decrease latency because the network device does not need to wait for dedicated links, but only if the probability of collision is low.

I.2.6 Security manager

The security manager is used by the network manager to allocate session keys. This is show in Figure I.7. The network manager is responsible for propagating security keys.

Figure I.7 – Security manager

I.2.7 Detailed model of the network manager

I.2.7.1 General

The detailed model of the network manager is shown in Figure I.8 along with all of the other key components of the architecture. A memory buffer (Packet queue) and packet are also included in the diagram. These will be used to help walk through the model from the point-of-view of routing packets.

The left side of the drawing primarily deals with allocating communication resources. The right side deals with routing. The network manager uses routing to determine how to route packets and it uses communication requirements to determine what network resources shall be assigned. Using both of these, the network manager generates an overall network schedule, which in effect allocates communication resources in terms of superframes and links. After the schedule has been determined, the network manager transfers these configurations items to each network device by using application layer services such as write superframe, write link, write graph.

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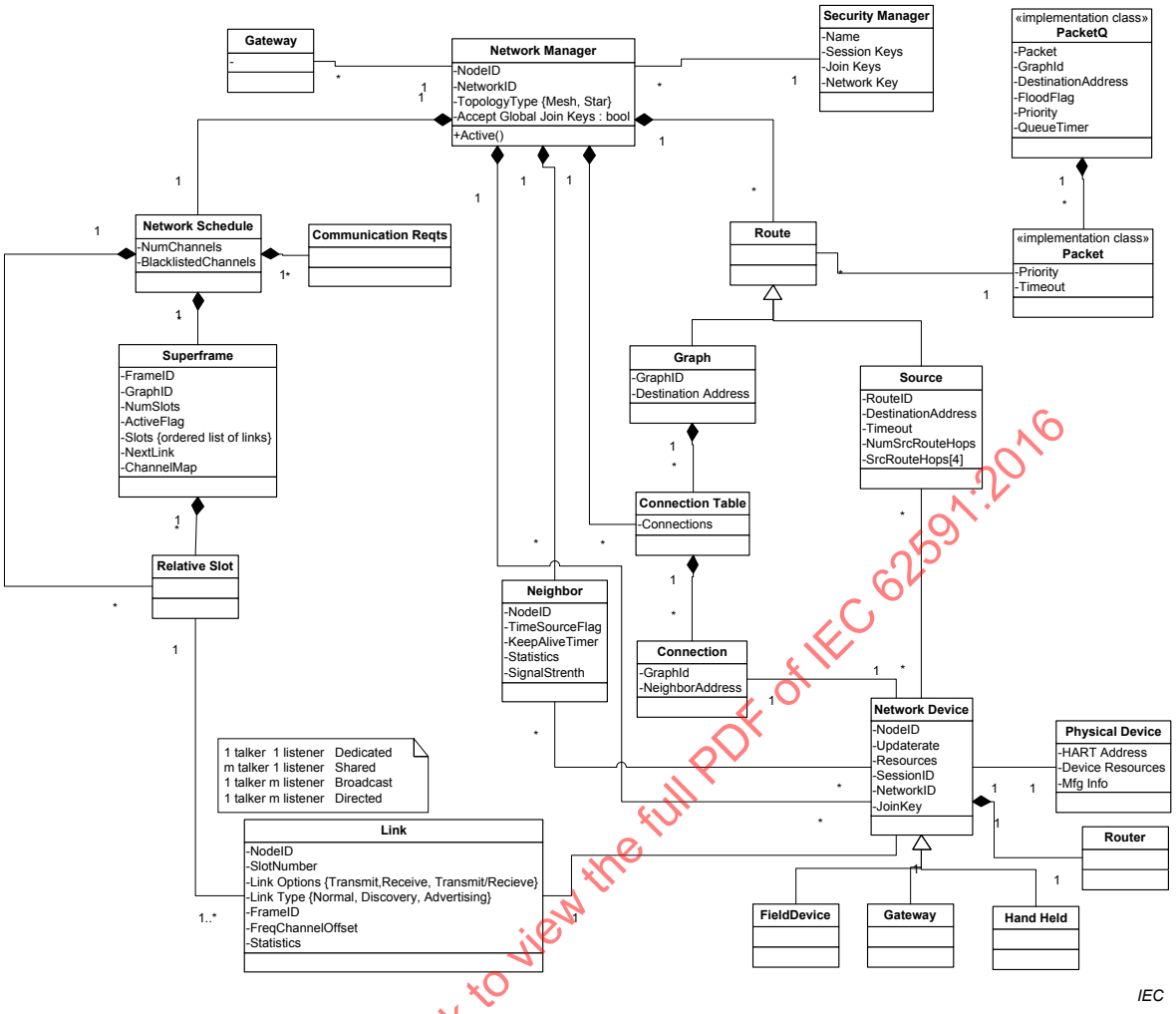

Figure I.8 – Detailed model of the network manager

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When a device wakes up, it first looks at its list of links and selects the next link. If the link option is receive, the device immediately enters into a listen mode. If the link option is transmit or a transmit and receive, the device enters into transmit state. Since the link identifies which device can be transmitted to, the next step is to check if the device has a packet in its Packet queue that can be sent to the device on the other end of the Link. To find a match, the device looks at the routing information in each packet in the Packet queue. If a match is found then the packet is sent. If a match is not found and the Link_type is transmit/receive then the device listens for an incoming packet. If no match is found then the device is returned to sleep mode.

NOTE The above description is a simplified sequence of operation for illustrating how the link schedule is executed by a device.

I.2.7.2 Network addressing

When a network device joins the wireless network, the network manager assigns it a 16-bit address (nickname). The network header of every packet contains source and destination network device addresses, which do not change as packets are routed through the network. It is the responsibility of each network device to terminate packets in which the destination network device address matches the device's own address. Broadcast network device address may be used to address all network devices.

I.2.7.3 Network formation

A key attribute of a wireless network is its ability to self-organize. There are three components of network formation – advertising, joining and resource allocation. As part of advertising, network devices that are already part of the network send packets announcing the presence of the network that they are part of. Advertisement packets include time synchronization information and a unique network_ID. A device trying to join the network listens for these packets and tries to match the advertised network_ID with their own. After at least one advertisement is heard, the new network device can attempt to join the network. The new network device is authenticated to join the network. After a device has joined the network it can request the network manager for allocating network resources.

I.3 Routing

I.3.1 General

A key part of the network manager's functions is to develop the overall routing for the network. In order to put together efficient and optimized routes the network manager needs information about the network, information about communication requirements, and information about the capabilities of the network devices. As this information is discovered, the network manager adjusts the connections in the network until it has a good working system. This subclause summarizes some of the key requirements and presents rules for determining routes.

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I.3.2 Routing requirements

The requirements for the network manager are summarized in Table I.1.

Table I.1 – Routing requirements

Network function	Requirement
Create and manage network route	The network manager maintains an internal representation of the entire network, which in extreme cases could have every node connected to every other node. The network manager prunes the route information down into what it estimates as a reasonable representation of the network. This internal representation is used to generate graph and source routes.
Manage neighbor tables	The network manager collects network statistics and neighbor table information from each device through periodic health reports. The connection and signal level information is used to adjust the routes.
Health reports	The communication information is used to choose between existing connections and make decisions on forming new ones.
Build route tables for graph routing	Graph routing is ideal for both scheduled upstream and downstream communications. Upstream communications include process measurements and alarms. Downstream communications include control changes to actuators. There should not be any circular loops in any route.
Builds source route lists for Source routing	The network manager builds the source routes. There should not be any circular loops in any route.
Build downstream graph	The network manager generates a downstream broadcast and a unicast graph from the gateway to all other network devices.

I.3.3 Routing strategy

A basic routing strategy is summarized below.

a) If there is a one hop path to the gateway it should be used.

b) The minimum number of hops to be considered when constructing the graph is 2.

c) The maximum number of hops to be considered when constructing the initial graph is 4.

d) The ratio of the lowest signal strength on a two hop path to the signal strength on a corresponding one hop path for the two hop path should be considered instead of the one hop path.

e) Use the same rule noted in d) for 3 and 4 hop paths.

f) The signal level threshold to be used when building the graph should be 50% as a starting point. If no paths are found using the specified signal level threshold, then this threshold can be reduced to 0,75 of its previous value and the graph generation retried. This recursion should continue up to four times. If at least one route is still not possible, then it is considered that the node is unreachable.

NOTE The routing algorithm is not specified by this standard.

I.4 Scheduling

I.4.1 General

Scheduling communication resources is one of the important functions that the network manager performs. In order to put together efficient and optimized schedules, the network manager needs information about the network, information about communication requirements, and information about the capabilities of the network devices. As this information is discovered, the network manager continues to adjust the schedule until it has met the requirements. The scheduler in the network manager uses feedback from the operation of the system to tune the schedule. This subclause summarizes some of the key requirements, presents rules for determining routes, and outputs a simple example of a route.

I.4.2 Scheduling requirements

The requirements for the network manager are summarized in Table I.2.

Table I.2 – Scheduling requirements

Network function	Requirement
Assumptions	Network manager has reasonable representation of network graph. Each network device has been configured with a connection table. Network manager knows the update rate of each device. For redundancy, a datum is configured with one transmit and a retry on one path and another retry on another path.
Constraints	Maximum number of concurrent active channels is determined by the number of enabled channels and limited by black-listing. No device can be scheduled to listen twice in a slot. More than one device can transmit to the same device. A broadcast link and dedicated links to each of the listening devices can coexist. On multi-hop path, early hop are scheduled first. The supported update rates are defined as 2^n, where 'n' is a positive or a negative integer value. For example update rate selection can be 250 ms, 500 ms, 1 s, 2 s, 4 s, 8 s, 16 s, 32 s, 60 s or more. Base network management and publish data communications should not exceed 30 % of the available communication bandwidth (100 slots/s max). The network manager takes into account the Timetable requirements. The final schedule (not counting the gateway) should have 50 % free slots (i.e. allocated for retries, listens).
Data superframe	The data superframe length is determined by data scan rate. The network manager allocates slots starting with the fastest to the slowest scan rate. The network manager allocates one link for each en-route network device to the gateway, starting from the furthest end device. It allocates a 2^{nd} dedicated slot on the same path to handle a retry. It allocates a 3^{rd} shared slot on a separate path to handle another retry.

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Network function	Requirement
Management superframe	Management superframe has priority over data superframes. The network management should be 6 400 slots. The network manager traverses the graph by breadth-first search, starting from the gateway, number the devices as N_0, N_1, … N_n. At a minimum, every device shall have a slot for sending Keep-Alive DLPDU and there is a corresponding shared receive slot.
Join process	From the devices furthest from the gateway, the network manager allocates one link for each en-route network device to the gateway for join-request (no redundancy provided). Traversing the graph by breadth-first search, the network manager allocates one link for each en-route network device from the gateway to the end network device for join-response (no redundancy provided). The network manager allocates advertise packets in each device. The number of advertise packets is inversely related to the number of hops away from the gateway.
Neighbor Discovery	The network manager allocates discovery link common to all network devices. The discovery-interval timer is set to enable discovery.
Network management commands	It shares the network management links with join requests and responses.
Command request/response traffic	The network manager allocates shared slots to meet ad-hoc request and response traffic.
Gateway superframe	The gateway superframe should be allocated with a large ID value. The gateway superframe should be 40 slots long. All slots in the gateway's access points should be allocated. The network manager schedules all unallocated slots in the gateway. It alternates each of these slots as transmit, receive; receive slots are shared.
Special purpose superframes	The network manager should allocate superframes to be used by gateway or client to address high throughput demand to satisfy asset management and other applications. This is allocated as a "maintenance" or "block transfer" Timetable type. The network manager should allocate superframes to be used by the handheld and every field device for maintenance purpose. This superframe is used to provide the field device and the handheld with a high-speed connection. The network manager should allocate 4 slots per s (two links in each direction).

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I.4.3 Scheduling strategy

A basic scheduling strategy is summarized below. The scheduling algorithm is not specified by this standard.

a) Scheduling strategy.

b) Starting from slot 0, the devices are assigned to channel offsets.

c) Fastest publish data requirement is allocated first.

d) Publish data destination is always the gateway.

e) Data superframes.

f) The data superframe length is determined by the data scan rate.

g) Slots are allocated starting with the fastest to the slowest scan rate.

h) Starting from the device furthest from the gateway, one link for each en-route network device to the gateway is allocated. A 2nd dedicated slot to handle a retry is also allocated.

i) Each transmission is also scheduled with a retry on another path, if one is available.

j) One network device can only be scheduled to receive once in a slot.

k) Event notification uses same slot allocation scheme as data. If there is publish data operation scheduled, then events can share the same slots. Events are sent infrequently. When event is sent, it can use the retry slots.

l) Management superframe.

m) Management superframe has priority over data superframes.

n) The network management superframe should be 6 400 slots.

o) Advertisement slots are the slots that devices use to allow other devices trying to become part of the network to join through.

p) The graph should be traversed by breadth-first search, starting from the gateway, number the devices as N_0, N_1, … N_n.

q) Every device shall have a slot for a Keep-alive DLPDU. This slot should be shared receive slot on the parent side. If a network device has not sent any packet to its parent within Keep_alive_time interval, it sends a Keep-alive DLPDU after the expiration of that interval.

r) Each device shall have 3 slots every 15 minutes for health reports.

s) Each device shall have at least 1 shared slot every minute for request/response. If an asset management application is started, then the gateway shall allocate communication resources for that application.

Join request

Starting from the device furthest from the gateway, one link should be allocated for each en-route network device to the gateway (no redundancy provided).

a) Join response

b) One link should be allocated for each en-route network device from the gateway to end network device (no redundancy provided)

c) Network management commands and responses

d) The network management links should be shared with join requests and responses.

e) Command request/response

f) The links should be allocated in the same way as join requests.

g) Maintenance superframe

h) Slots for the maintenance superframe should be allocated. This same superframe is set-up in all devices. The superframe should be 1 s in duration and with 4 slots in it.

Gateway superframe

The gateway superframe has a Superframe_ID of 253.

The gateway superframe is a minimum of 40 slots long (400 ms).

The slots should be alternate transmit and receive and should all be shared.

Optimization parameters are:

a) number of hops to the gateway,

b) alternate paths,

c) latency,

d) power utilization and

e) overall throughput.

I.4.4 Networking scheduling example

A simple scheduling example is presented. This example covers a wireless network that consists of one gateway and three field devices as shown in Figure I.9. The gateway is identified as ‘A’ and the three field devices are identified as ‘B’, ‘C’, and ‘D’. The field devices B and C communicate every second; field device ‘D’ communicates every 4 s.

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Schedule

The scheduler first creates paths and then allocates communication bandwidth.

Step 1: Select path to the gateway

B: B->A

C: C->A

D: D->B->A; D->C->A

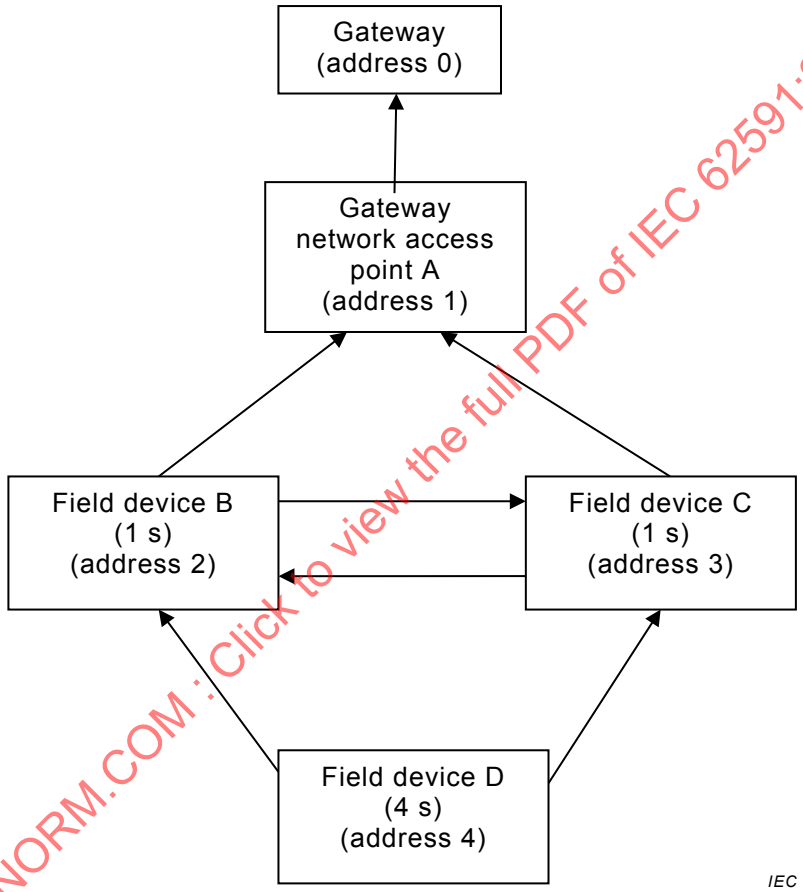

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Figure I.9 – Four network device wireless network

Step 2: Data superframes – see Table I.3 and Table I.4.

Table I.3 – Superframe ID 1: 1 s update rate, superframe length 100

Channel offset	Time Slot								
	0	1	2	3	4	5	6	7	8
0	B->A	B->A							
1			C->A	C->A					
2									

Table I.4 – Superframe ID 4: 4 s update rate, superframe length 400

Channel offset	Time Slot								
	0	1	2	3	4	5	6	7	8
0			D->B	D->B	D->C				
1					B->A	B->A	C->A	C->A	
2									

Step 3: Management superframe – see Table I.5 to Table I.9.

Frame ID 0: Management superframe length 6 000 – once per minute.

Advertisement packets indicate the open links that can be used by joining devices.

Table I.5 – Superframe ID 0: management superframe

Channel offset	Time Slot								
	0	1	2	3	4	5	6	7	8
0									*->A
1							*->B		
2	*->C								
3	*->D								
4									

Table I.6 – Join request (shared with management responses)

Channel offset	Time Slot								
	..	7	9	9	10	11	12	13	14
0									
1				B->A		B->A			
2					C->A				
3		D->B							
4									

Table I.7 – Join response (shared with management requests)

Channel offset	Time Slot								
	..	11	12	13	14	15	..	..	..
0			A->B	A->C	A->B				
1						B->D			
2									

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Table I.8 – Commands

Channel offset	Time Slot								
	..	16	17	18	19	20	..	..	..
0									
1			B->A	B->A					
2		C->A							
3		D->B							
4									

Table I.9 – Command responses

Channel offset	Time Slot								
	..	19	20	21	22	23	..	..	..
0		A->B	A->B	A->C					
1				B->D					
2									

Step 4: Create sub-schedules for each node (link table entries) – see Table I.10 to Table I.13.

Table I.10 – Device A

Frame ID	Time slot	Channel Offset	Device address	Link option	Link_type
1	0	0	B	Receive	Normal
1	1	0	B	Receive	Normal
1	2	1	C	Receive	Normal
1	3	1	C	Receive	Normal
4	4	1	B	Receive	Normal
4	5	1	B	Receive	Normal
4	6	1	C	Receive	Normal
4	7	1	C	Receive	Normal
0	8	0	*	Receive	Advertise
0	9	1	B	Receive	Normal
0	10	2	C	Receive	Normal
0	11	1	B	Receive	Normal
0	12	0	B	Transmit	Normal
0	13	0	C	Transmit	Normal
0	14	0	B	Transmit	Normal
0	16	2	C	Receive	Normal
0	17	1	B	Receive	Normal
0	18	1	B	Receive	Normal
0	19	0	B	Transmit	Normal
0	20	0	B	Transmit	Normal
0	21	0	C	Transmit	Normal

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Table I.11 – Device B

Frame ID	Time slot	Channel Offset	Destination address	Link option	Link_type
1	0	0	A	Transmit	Normal
1	1	0	A	Transmit	Normal
4	2	0	D	Receive	Normal
4	3	0	D	Receive	Normal
4	4	1	A	Transmit	Normal
4	5	1	A	Transmit	Normal
0	6	1	*	Receive	Advertise
0	7	3	D	Receive	Normal
0	9	1	A	Transmit	Normal
0	11	1	A	Transmit	Normal
0	12	0	A	Receive	Normal
0	14	0	A	Receive	Normal
0	15	1	D	Transmit	Normal
0	16	3	D	Receive	Normal
0	17	1	A	Transmit	Normal
0	18	1	A	Transmit	Normal
0	19	0	A	Receive	Normal
0	20	0	A	Receive	Normal
0	21	1	D	Transmit	Normal

Table I.12 – Device C

Frame ID	Time slot	Channel Offset	Device address	Link option	Link_type
0	0	2	*	Receive	Advertise
1	2	1	A	Transmit	Normal
1	3	1	A	Transmit	Normal
4	4	0	D	Receive	Normal
4	6	1	A	Transmit	Normal
4	7	1	A	Transmit	Normal
0	10	2	A	Transmit	Normal
0	13	0	A	Receive	Normal
0	16	2	A	Transmit	Normal
0	21	0	A	Receive	Normal

Table I.13 – Device D

Frame ID	Time slot	Channel Offset	Device address	Link option	Link_type
0	0	3	*	Receive	Advertise
4	2	0	B	Transmit	Normal
4	3	0	B	Transmit	Normal
4	4	0	C	Transmit	Normal

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Frame ID	Time slot	Channel Offset	Device address	Link option	Link_type
0	7	3	B	Transmit	Normal
0	15	1	B	Receive	Normal
0	16	3	B	Transmit	Normal
0	21	1	B	Receive	Normal

I.5 Network manager interface

I.5.1 General

The network manager communicates to network devices through a series of application layer PDUs. The network manager uses AL services to read and write communication settings into network devices. For example the network manager can use these services to create frames and links in devices. In addition the network manager implements all of the data-link layer and the network layer configuration services.

Each service describes a related set of parameters and has an expected action associated with it. For example write, add, modify link contains the parameters needed to add or change a link. Delete link is used to remove a link from the link table in a network device. Several services may be combined into one transaction. For example the network manager could aggregate services for creating a superframe and a link.

The example in Figure I.10 shows two message sequences. In the first sequence, the network manager sends “read superframe” APDU requesting information on a specific superframe. The device responds by sending a response. In the second sequence, the network manager aggregates and sends APDUs to modify the superframe and add links. The network device responds by sending the aggregated results of the request APDUs.

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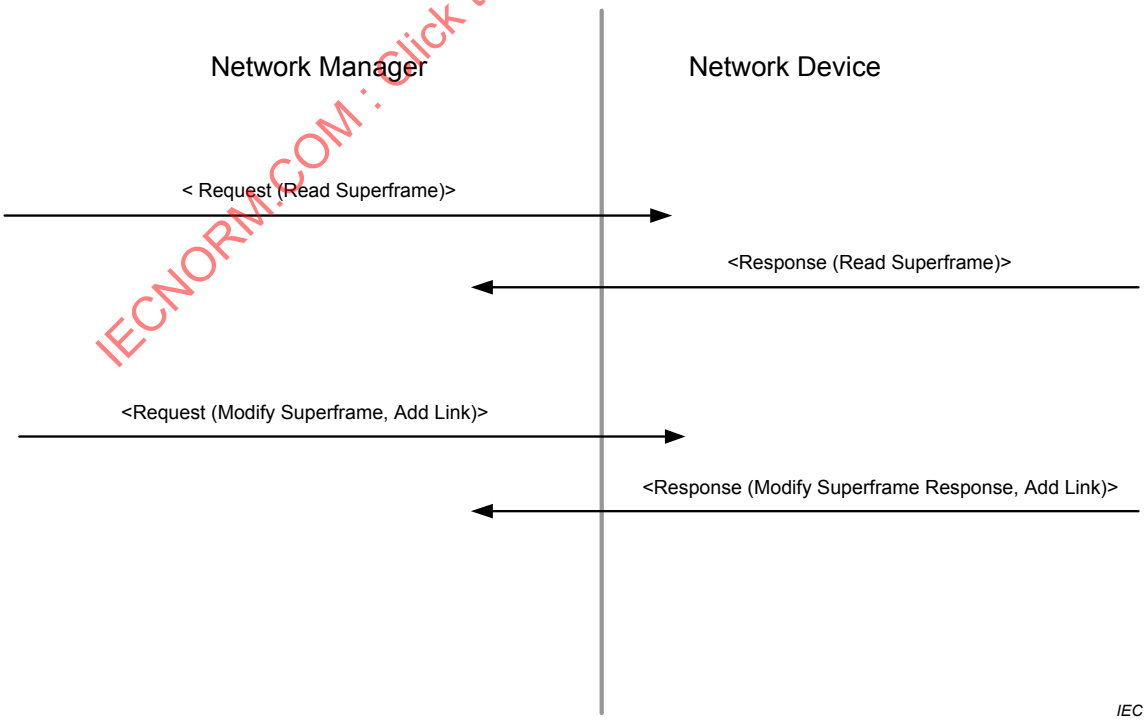

Figure I.10 – APDU sequences

Scenarios describing how to use the network manager interface are summarized in Table I.14.

Table I.14 – Network manager universal commands

Scenario	Description
Initializing a wireless network	Starting up a self-organizing wireless network
Allocating communication resources	Device sends a request to the network manager to increase its communication services.
Adjusting network schedule	Route is changed and schedule is updated.
Health reports	Device sends a health report to the network manager.
Path failure	A path failure is reported to the network manager.
Changing a session key	Network manager changes session keys.
Changing the network keys	Network manager changes the network keys.

I.5.2 Initializing a wireless network

A key characteristic of a wireless network is its ability to automatically start up and self-organize. Before a wireless network can form, a network manager and a gateway have to exist and both shall have created a private connection with each other. As part of its initialization sequence the network manager creates the following:

- network management superframe, and
- network graph.

Then, the network manager activates the first superframe. This establishes the system epoch – ASN 0. The overall initialization sequence is shown in Figure I.11.

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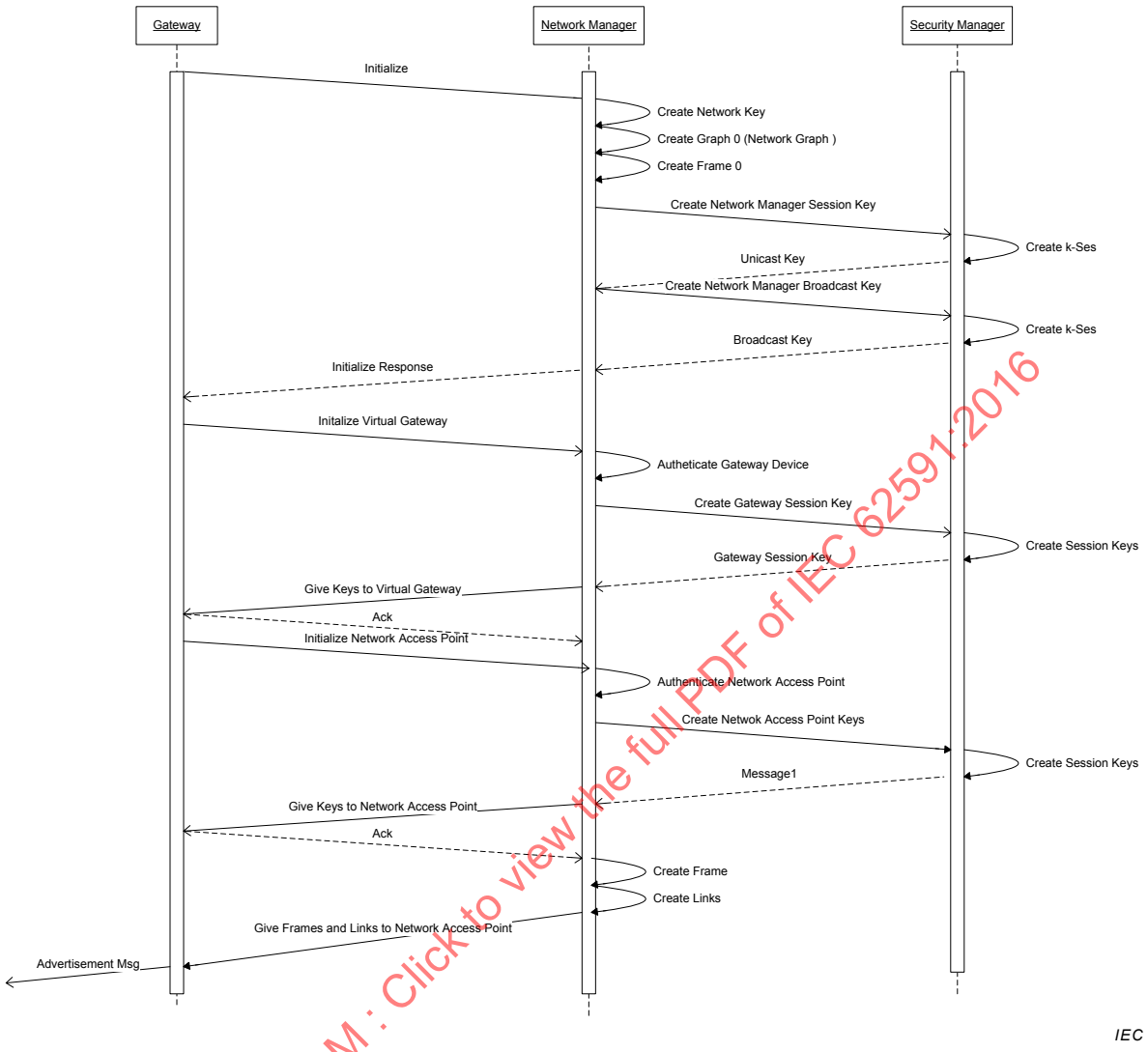

Figure I.11 – Initializing a wireless network

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After the network access point starts to advertise, the other network devices can begin to join the network. As devices join, the network forms. There are three components of network formation: advertising, joining, and resource negotiation. As part of advertising, network devices that are already part of the network may send packets announcing the presence of the network. Advertisement packets include time synchronization information and a unique network_ID. A device that is trying to join listens for these packets. It then tries to match the advertised network_ID with network_ID set in it. After at least one Advertisement packet is heard, the new device can attempt to join the network. A new device joins the network by executing a join sequence.

I.5.3 Allocating communication resources

A device that joins the network does not start generating or receiving non-network-management data until an appropriate amount of network resource is allocated to it. For this purpose, ‘Timetable’ may be requested by a device, or may be created by the network manager and communicated to the device. A Timetable is identified by Timetable type (publish, block transfer, etc.).

To allocate resources for network service, the device sends write, add, modify request to the network manager. When the resources are allocated, the network manager returns a response code indicating what parameters were granted. If appropriate links and graphs already exist in

the network, the network manager may do nothing except send a response. Otherwise, additional links and/or graphs may be created or activated. This sequence is indicated in Figure I.12.

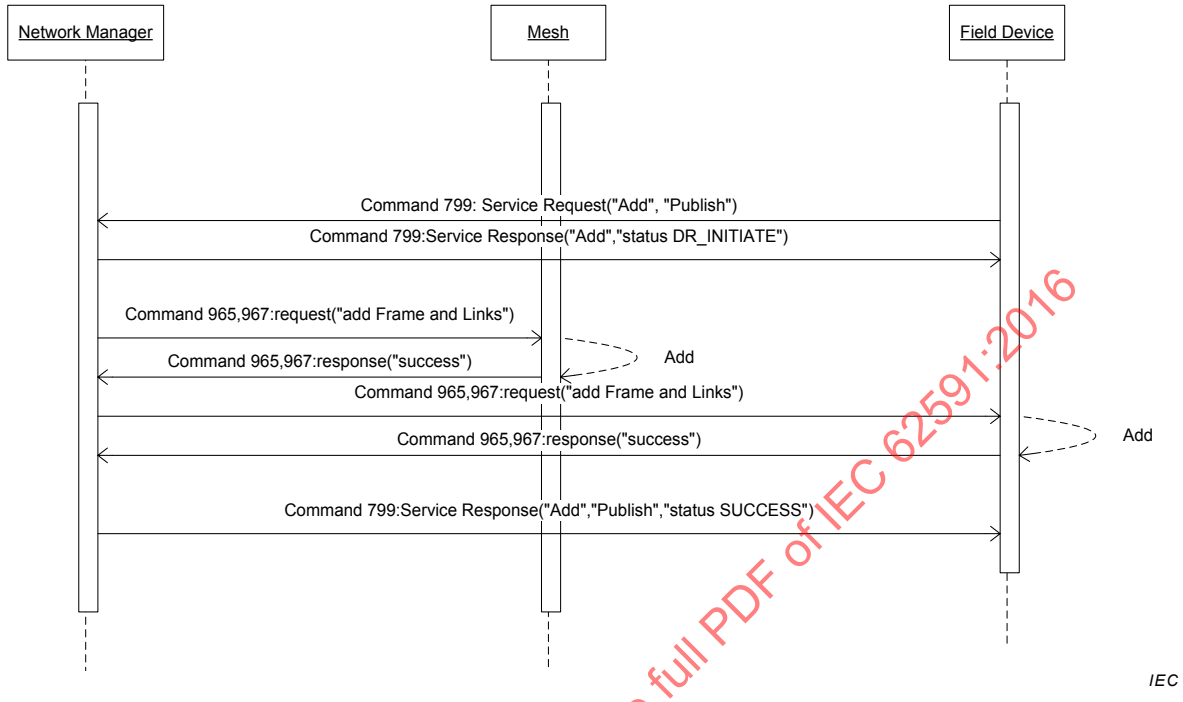

Figure I.12 – Allocating and using network resources

I.5.4 Adjusting network schedule

The overall network schedule is adjusted to address changes in routing, device resource usage (for example batteries running down), and network demand. This is illustrated in Figure I.13.

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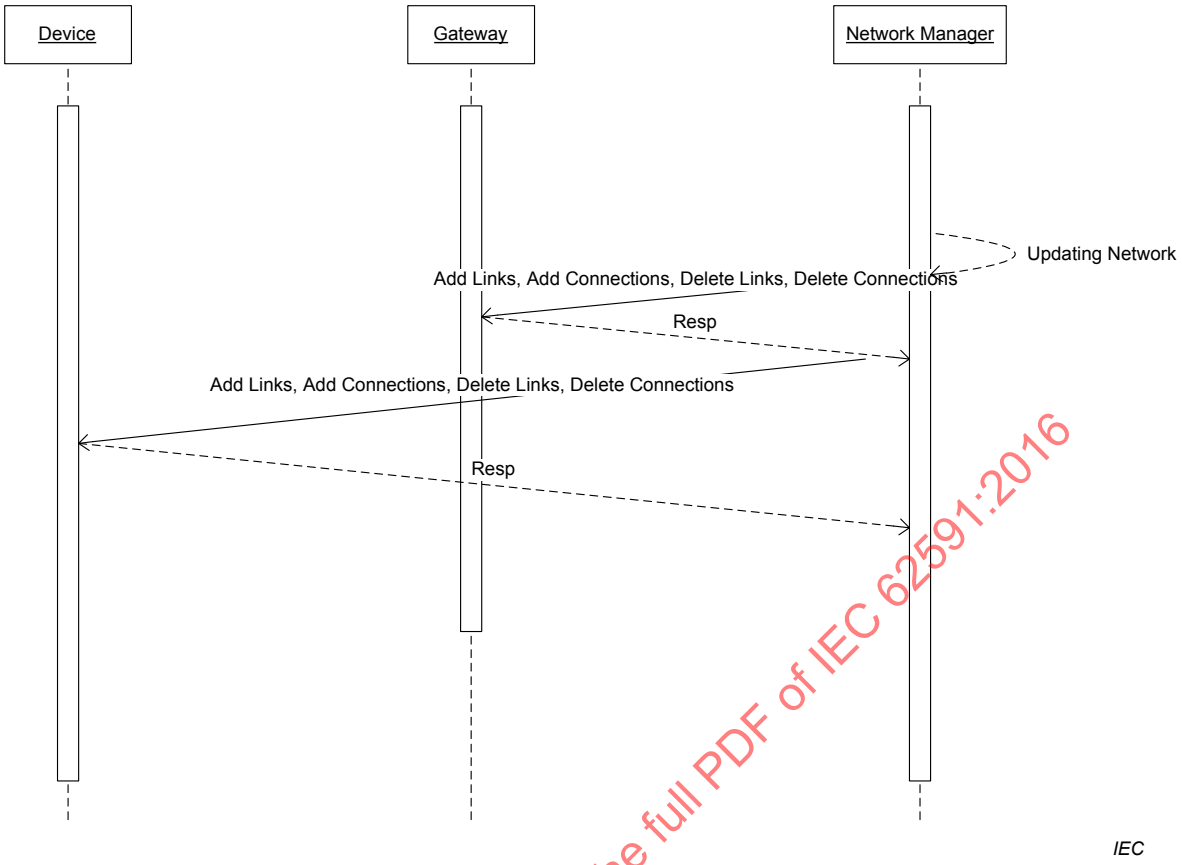

Figure I.13 – Adjusting network schedule

I.5.5 Health reports

Health reports are transferred from network devices to the network manager periodically. These messages are not acknowledged. This is illustrated in Figure I.14. Schedule and network optimization should be performed periodically as well.

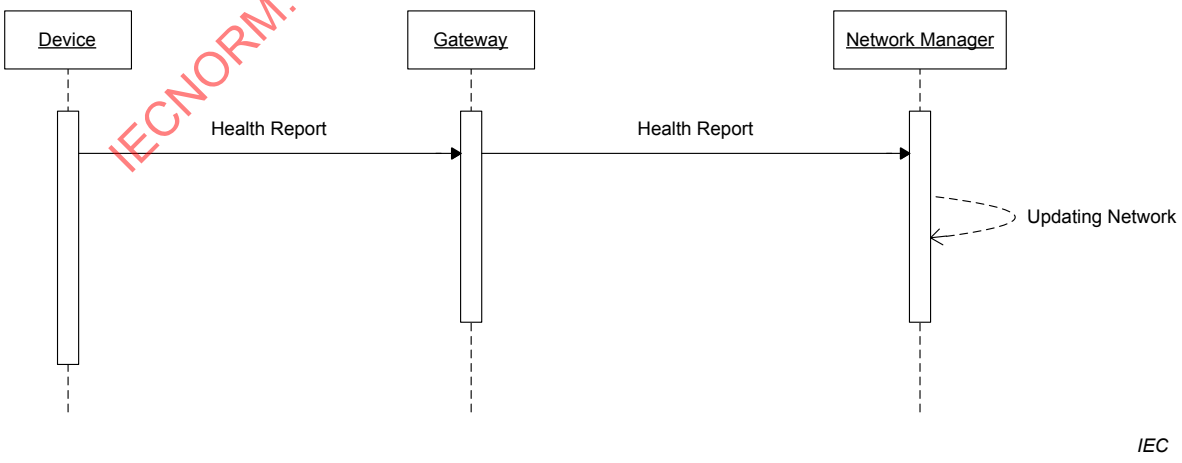

Figure I.14 – Health reports

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Annex J
(informative)

Gateway implementation

J.1 Overview

Gateway device connects the wireless network to a plant automation network, allowing data to flow between the two networks. It provides host applications access to the network devices. The functions to be performed by a gateway in wireless network are:

- The gateway implements a data cache to optimize the overall performance of the network and improve responsiveness to host applications.
- The gateway publishes device variable data that it is caching to other devices in the network.
- The gateway sends acknowledgement to the event notification APDU received by it.
- The gateway provides the tunneling function to transfer the APDU of this standard between the host connected to the gateway and the network connected to the gateway.
- The gateway checks the destination address in the APDU received from the host application. If the destination is the gateway itself, then it sends the response APDU as required by the AL protocol.
- If the destination address in the request APDU from the host application is for another network device, and if the response APDU is cached and is current, the gateway returns the cached response APDU from its real-time database.

The gateway provides a sink or source point for wireless network traffic. The network access point provides the physical connection into the wireless network.

J.2 Gateway model

J.2.1 General

The gateway has several distinct components as shown in Figure J.1. The gateway itself is a type of network device. It makes use of services from the network manager and the security manager to authenticate and join network devices.

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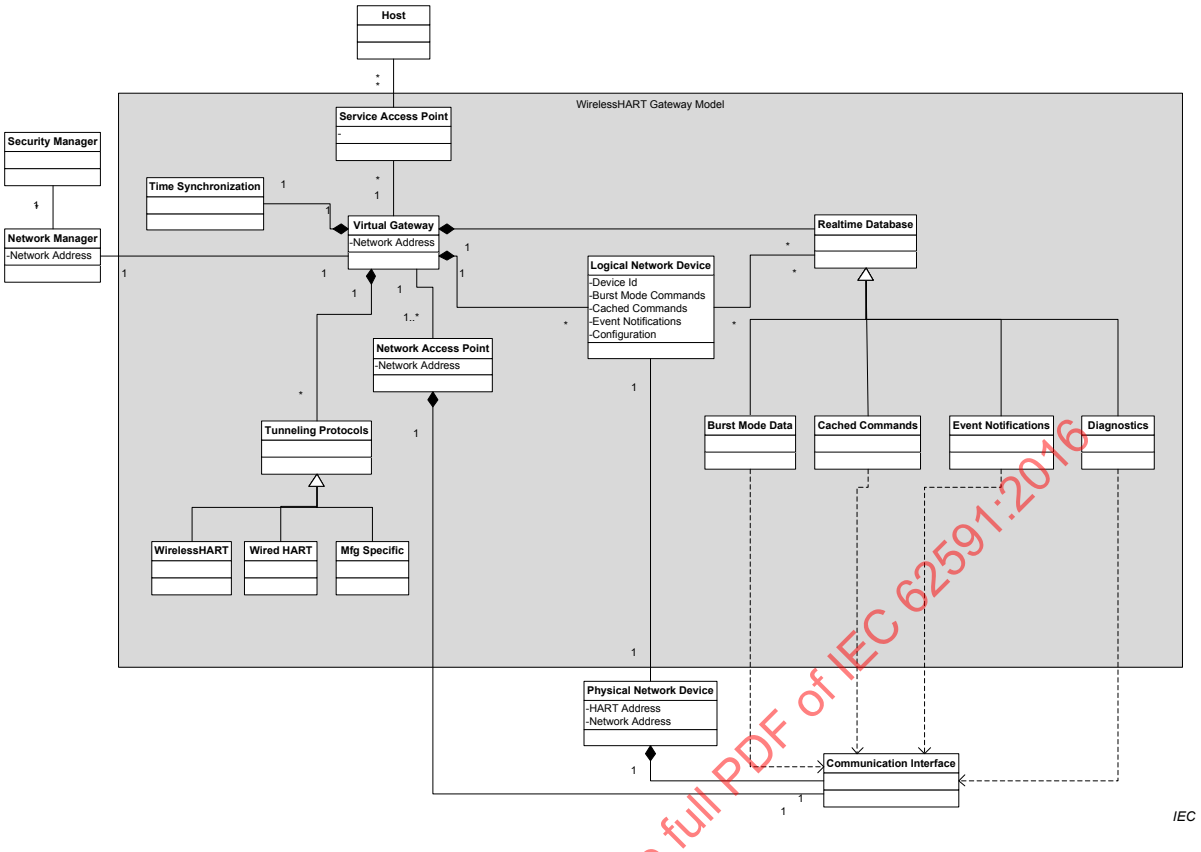

Figure J.1 – General model for gateway

J.2.2 Host interface

The gateway host interface is used to connect client applications outside of the wireless network with the devices connected to the wireless network. The gateway host interface can take many forms. Some of the common ones include:

- Ethernet-to-wireless gateway – a gateway that provides a bidirectional path between industrial Ethernet network and the wireless network.
- Wi-Fi-to-wireless gateway – a variation of an Ethernet-to-wireless gateway that uses IEEE 802.11 a/b/g radio to connect to the plant's network.
- Serial-to-wireless gateway – if plant automation servers and equipment support serial interfaces, a serial-to-wireless gateway can be used to connect to the serial interfaces of these devices.

The gateway is able to cache publish data command responses, commonly used read and write commands, and diagnostics data from the network devices and wireless adapters connected to the network. To take advantage of this caching, the gateway also behaves as a translator. The gateway peeks at requests from the host applications and, if the response data is cached and is current, returns the cached response messages from its real-time database. For example if a host issues HART™ command #0 request to a device in the network, the gateway checks to see if it has a cached command #0 response. If the gateway does not have the response for that device, it forwards the command to the device and returns the resulting response to the host.

J.2.3 Logical network device

The gateway maintains a list of logical network devices. The device information cached in the gateways in turn contains information about the devices such as the list of publish data commands, event notification messages, and cached commands responses that are currently stored there. The logical network device is shown in Figure J.2.

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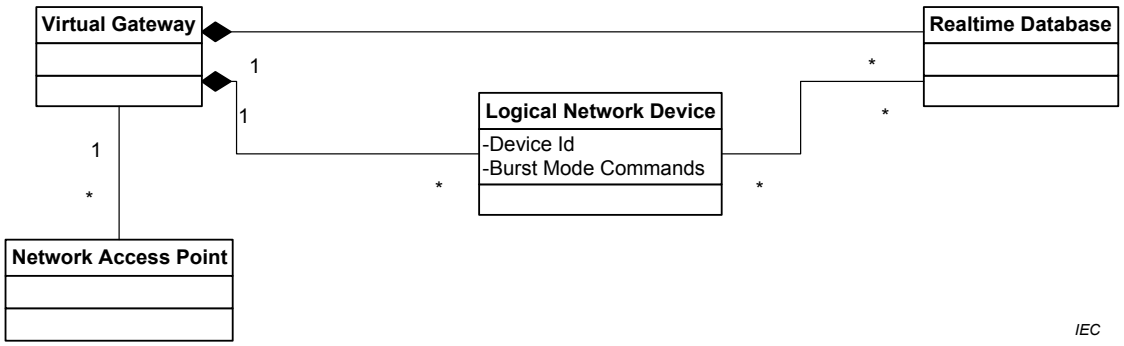

Figure J.2 – Logical network device

The logical network device plays an important role in modeling the system and later in commissioning the system. A logical network device can exist independent of an actual physical network device. It provides a network placeholder that can be used for off-line configuration, simulation, and on-line operation. It also provides the necessary separation for commissioning and device replacement.

J.2.4 Physical network device

A physical network device is an actual device in the network. It discovers neighbors and builds and maintains a neighbor table. This neighbor table is built by the physical device by listening for a specified amount of time on each channel. Each neighbor is recorded with its corresponding received signal strength. This association is shown Figure J.3.

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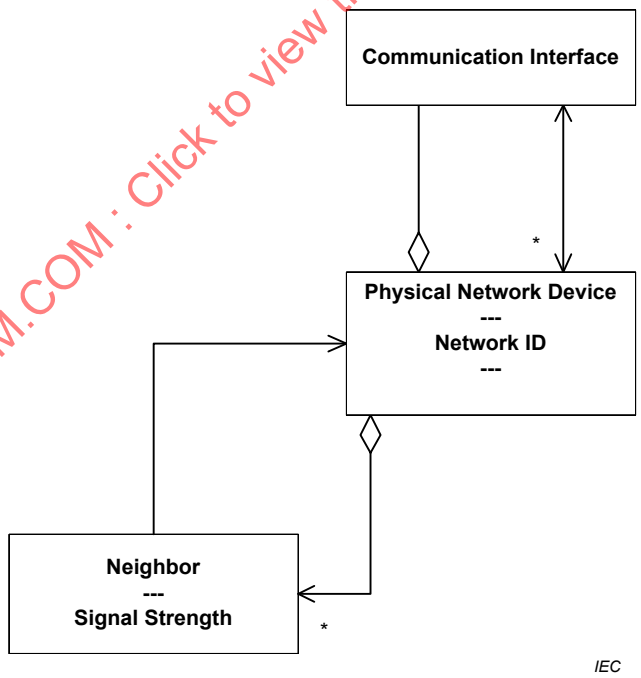

Figure J.3 – Physical network device

J.2.5 Communication interface

J.2.5.1 General

The communication interface provides the required services to communicate with network devices. In the implementation, these communication services are provided by the transport and network layers. The service types are summarized below:

- Request and response,
- Block data transfers,
- Publish data messages,
- Event notification, and
- Diagnostics.

J.2.5.2 Request and response

The request and response service provides a method for the network manager and host applications to send request messages to a network device and to receive its response message. If the response takes longer than a specified value, the gateway sends either a “delayed response” or a "timeout" response to the host application. In all cases, the host application expects a confirmed response message from the network device.

The network manager considers these communications as unscheduled and ad-hoc. Therefore, the network manager makes a base of bandwidth is available to accommodate request and response traffic. The gateway is responsible for requesting resources for this service, increasing and decreasing the bandwidth it requests as application demands vary.

J.2.5.3 Block transfers

Block transfers are supported both to the network devices and through an adapter to its sub-device. This supports transmission of large data sets with automatic segmentation and re-assembly the destination.

J.2.5.4 Publish data messages

The publish data messages are used to send data on a periodic schedule or on an exception basis. A publish data message consists of the response packet for the specified command. The publish data rate is configurable, based on application needs. For control applications, the publish data rate is determined by control loop or sequence execution requirements (for example the process time constant). In some cases, more than one host application will subscribe to the same published data. In these cases, the update rate is determined by the fastest requested data rate.

Publish data responses are cached inside the gateway in a real-time database. This provides a mechanism for multiple readers to access the same data; decouples the applications; and reduces network traffic.

J.2.5.5 Event notification

The event notification services provide support for the communications of events and alarms. This is a guaranteed message delivery service. The gateway is responsible for acknowledging and caching event notification messages.

J.2.5.6 Diagnostics

This service is used to transfer diagnostic information about the network to the host.

J.2.6 Cached response messages

J.2.6.1 Network status

Each network device maintains diagnostics. The diagnostics are periodically published via HART™ commands to the network manager. The network manager maintains the complete set of device and network diagnostics. Hosts can query the gateway or the network manager for network level diagnostics.

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J.2.6.2 Publish data command response

The database caches all of the publish data command response messages.

J.2.6.3 Event notification command response

The database caches all of the event notification response messages.

J.2.6.4 Cached command response

The database caches the latest response messages for several HART™ commands.

J.2.6.5 Delayed response command response

For HART™ request and response commands, the gateway maintains a complete list of all outstanding commands that have been sent to devices for which a response has not yet been received in return. Delayed response commands are purged if they exceed a 24 hour timeout.

J.3 Gateway management

J.3.1 Addressing

At the wireless gateway and the host, each field device is identified by its 40-bit unique ID. In addition, the network manager maintains a unique 16-bit address (nickname) for each network device. Some devices, for example those connected through an adapter, do not have a nickname. In all cases the gateway maintains a table of 40-bit unique IDs, nicknames and device type information. This table is used by the gateway to translate addresses between host or clients and the network.

J.3.2 Retry mechanisms

Result of the host application request to the gateway may be classified as one of the following.

- Success – a valid response message is generated within the prescribed timeout window.
- Busy – the gateway received the request but is unable to respond at the present time.
- Delayed response – the gateway received the request and has started processing it.
- Error – the gateway received the message but detected an error that prevents it from being processed.

The number of times that a gateway retries before it returns Busy or an Error can be configured.

J.3.3 Power-on-reset

The gateway performs the following sequence when it is powered on.

a) Calculate the power outage time. If the power outage time is less than 15 minutes, sets an internal “WARM_START” flag. If the power outage time is greater than 15 minutes, sets an internal “COLD_START” flag. If power outage time cannot be determined, sets an internal “COLD_START” flag.

b) Looks for network access points and forms connections with it.

c) If a network manager is found with the same network_ID as configured in the gateway, it connects to that network manager.

d) Synchronizes its clock with an external time source such as a GPS receiver. The gateway will synchronize its clock with the external time source and, at least once per hour, broadcast a UTC time messages.

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e) NOTE This is a separate mechanism from Keep-alive DLPDUs, which are used to keep the networks understanding of the ASN in-sync.

f) Initialize host interfaces – the gateway can now begin returning information to host applications.

g) If it is “WARM_START” then following sequence is executed.

h) Discovers the networks absolute slot number (ASN).

i) Checks the connections to all network devices in the graph table by sending commands 0 and 20 to each of the devices.

j) For each adapter, it executes the "Join sequence for adapter sub-devices". Updates the devices status to match the response returned from HART™ command #75 "Poll sub-device".

k) Commences normal operations.

J.3.4 Network access point reset

When a network access point is reset, it completely clears its memory and restarts. It looks for the gateway. After it has found the gateway, it joins the network through the gateway and then begins looking for neighbors on the network side.

NOTE The network access point can be reset by sending HART™ Command 42 to it.

J.3.5 Gateway reset

Resetting the gateway is treated the same as its “COLD_START”. The gateway sets its internal gateway reset flag, clears all of its buffers, and informs the network manager that it is being reset. The gateway reset flag is not cleared until network communications have been re-established. While the reset sequence is underway, the gateway responds to all commands to field devices with “Busy” code. Any existing delayed responses and block mode transfers are cleared and no new ones are accepted until the reset sequence has been completed. The following summarizes the actions taken by the gateway.

a) Sets reset flag.

b) Deletes any outstanding block mode transfers and sends back error response.

c) Deletes any outstanding delayed response and sends back error response.

d) Sends a HART™ command ‘03xxx reset device’ to the network manager to inform the network manager that the gateway is being reset.

e) Clears all tables and buffers.

f) Initialize host interfaces.

g) Re-connects with the network manager.

h) Gets re-configured by the network manager.

i) Sends Identify FAL PDU, Command 0, and Read long tag FAL PDU, Command 20, to each device to build the device information cache.

j) For each adapter, executes the "Join sequence for adapter sub-devices".

k) Re-establishes periodic update messages with all devices.

l) Clear reset flag.

NOTE The gateway can be reset by using Perform device reset service, Command 42.

J.3.6 Re-build publish data periodic data

When a gateway’s REBUILD flag is set, all cached responses for a specified device are cleared. In the case of a wireless adapter, this implies that all buffers for all devices connected to that adapter will also be cleared. The gateway can use Identify FAL PDU, Command 0 to test the connection to any network device.

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J.3.7 Gateway self test

The Gateway may do the following after it receives Perform self test FAL PDU, Command 41 from the host.

a) Verify the ROM checksum and set a flag, if this check fails.

b) Verify the non-volatile memory contents and set a flag, if this check fails.

c) Send HART™ command #41 response message.

These ROM check and non-volatile memory verification functions may also be performed periodically by the gateway.

J.3.8 Adding new network device

Whenever the gateway receives a new network device in its route table from the network manager, the gateway sends that device a Command 0 and Command 20 requests. The response messages from the just added device are cached for that device in the gateway. The gateway can determine if the responding device is a wireless adapters (protocol bridge device), by examining bit 2 (protocol bridge device) of octet number 8 of the response.

J.3.9 Device configuration change status notifications

Whenever the gateway receives a configuration change status from a device, it sends HART™ command #0 and command #20 requests to that device. The response messages are then cached for that device in the gateway. The configuration change counter is stored as part of the command #0 response. If the device is a wireless adapter, then the gateway repeats the "Join sequence for adapter sub-devices" connected to the wireless adapter.

J.4 Gateway superframe

The gateway communicates with the network devices via its access points. The access point should have activity scheduled for every slot. Not utilizing every slot represents wasted opportunities. For example if the access points have nothing else to send or receive, it should advertise and perform shared listens.

The network manager should assign unused access points to advertise faster than ChannelSearchTime. In doing so, devices within the signal range of the access point and trying to join will be able to do so in shorter time.

Generally, a dedicated superframe should be assigned by the network manager (for example superframe number 253). By allocating a high-numbered Superframe_ID, other transmit and receive links can be used to transmit or receive higher priority messages.

J.5 Gateway change notification services

The gateway can return change notification messages to the host or the client, when a change in a network device is detected. The notification provides an indication that a value or status has changed, but does not include the actual changed value(s). When the host or the client receives a change notification, it is expected to issue a read the associated information request to the gateway.

NOTE Not all host interfaces can support change notifications.

Table J.1 summarizes items for which the host or the client can receive change notification.

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Table J.1 – Required command responses

Notification type	Fastest notification rate in s	Description
Publish data	0,250	The gateway checks the cache on a device-by-device basis for publish data changes (for example response to HART™ command #9). If there is any change in the data value, an item is added to the change notification list.
Event notification	1	Every 1 s the gateway checks the cache on a device-by-device basis for event notification updates. If there is any update, an item is added to the change notification list.
Application process status	5	Every 5 s the gateway checks the cache on a device-by-device basis for application process status changes. If there any change in the application process status, an item is added to the change notification list. If publish data is enabled, the rate will be increased up to the publish data rate, because the application process status is always sent with the publish data message.
Device configuration	60	Every 60 s the gateway checks the cache on a device-by-device basis for device configuration changes (monitors HART™ command #0 and command #20 responses; checks configuration change bit and configuration change counter). If there is any change in the device configuration, an item is added to the change notification list. Since this can also be handled with each publish data, the notification should only be sent if no publish data message has been sent.
Network topology	60	Every 60 s the gateway checks with the network manager to find if there has been any network topology change. If there is any change in the network topology, an item is added to the change notification list.
Network schedule	60	Every 60 s the gateway checks with the network manager to find if there has been any network schedule change. If there is any change in the network schedule, an item is added to the change notification list.

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The Gateway supports at least eight (32 recommended) separate change notification lists. These change notification lists are for host-side support and there is separate list for every client.

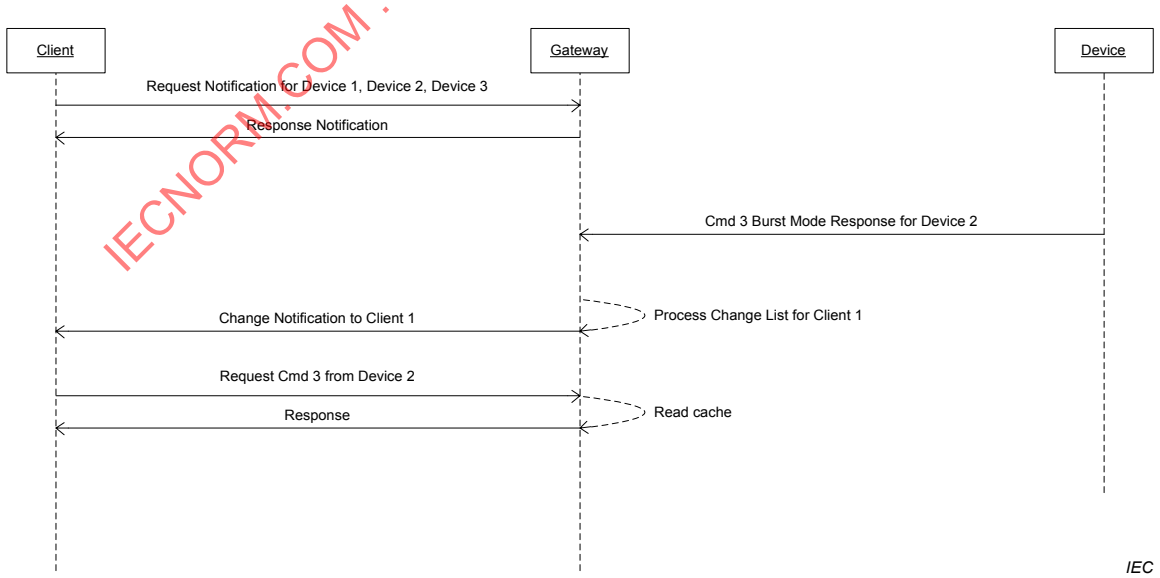

Figure J.4 – Managing notification services

Figure J.4 shows the sequence used by a client to request the gateway to monitor several devices. The overall sequence occurs in the following order.

a) Client-1 requests change notification messages for three devices – device-1, device-2, and device-3. The client does this by sending HART™ command #140 request to the gateway.

b) The gateway grants the request and sets up a change notification service for Client-1. The gateway returns a HART™ command response message indicating that the change notification request was successful.

c) Device-2 sends a HART™ command #3 response using publish data update. The gateway caches this response message for device-2 and sets the change notification bits for Device-2.

d) The gateway processes the change notification list for client-1. It adds HART™ command 3 for device-2 to its change notification list; sends a HART™ command #142 to client-1 indicating the changes that have occurred. It then clears the change notification bits for client-1.

e) Client-1 receives the change notification message from the gateway and reads the cached HART™ command #3 response from the gateway's cache.

J.6 HART™ commands interface

J.6.1 General

The gateway provides an interface between the host applications and the wireless network. The gateway:

- always uses extended addressing (except command #0);
- caches publish data response message data and "Application process status" data;
- caches selected HART™ command read and write messages;
- caches event notification response messages;
- supports client-side service requests for request and response, change notification, publish data, block mode transfers, delayed response messages and high throughput services;
- passes through command requests and responses addressed to and from devices in the network;
- automatically requests increments and decrements in communication bandwidth between the gateway and field devices in response to host application demands.

The gateway retains its configuration during reset and power failure, but does not retain the network schedule. The retained parameters include, but are not limited to:

- unique ID and nickname for all access points;
- network_ID;
- Join_key;
- tag, descriptor and date;
- retry and timeout limits for busy and other errors.

J.6.2 Host to gateway command request and response

The HART™ commands from a host addressed to the gateway are:

- command #0 – read unique ID in short or extended format provided the address matches that of the gateway in either case;
- command #11 – read unique ID associated with tag, and command #21 – read unique ID associated with Long_tag, if the tag and address match those of the gateway;
- all other commands in extended 40-bit addressing format if the address matches that of the gateway.

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If a communications error is detected, the gateway responds with a communication error response.

If a command number is unknown, the gateway responds with “command not implemented”.

During active reset operation, the gateway responds with “busy”.

J.6.3 Pass-through of HART™ command request and response

Pass-through service allows a HART™ command request from a host to a specific field device to pass-through the gateway and then through the network to the destination device and for the command response to return through the network to the gateway and pass-thru to the host. Following rules apply for this pass-through.

- All commands have to be in extended 40-bit addressing format.
- If the command matches one in the gateway cache, the gateway returns the cached response message.
- If the response is not cached, the gateway forwards the request to the field device. When the gateway receives the response, it returns the response from the field device to the host and if it is one of the commands that the gateway is expected to cache, then it caches the response.
- The host can flush completed delayed responses.
- If a communications error is detected, the gateway responds to the host on the device’s behalf with the appropriate communication error response.

J.6.4 Caching publish data command response messages

The dynamic data cache in the gateway updates and records each time a device sends publish data message response including the data validity flags, byte count, response bytes, data bytes, total numbers of updates and the extended status bytes.

J.6.5 Gateway status error flag bits

The gateway supports the error flag bits shown in Table J.2.

Table J.2 – Gateway status flags

Error	Description
Cold-start	It is set when the gateway is powered-up or reset and the amount of time the gateway has been unavailable is more than 15 minutes. It is cleared when the gateway completes its start-up sequence.
Warm-start	It is set when the gateway is powered-up and the amount of time the gateway has been unavailable is less than 15 minutes. It is cleared when the gateway completes its start-up sequence. This shall be an internal state in the gateway.
Configuration-changed	It is set whenever the gateway parameters are changed by the host and it is cleared by receiving HART™ command #38 request.
Malfunction	OR of HARD_FAULT bits (see HART™ command #48 and variable definition).
More status available	Read additional device status service, Command 48, should be used to get the status.

J.6.6 Gateway additional status flags

In responding to HART™ command #48, the gateway only reports the current state of its various flags.

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J.6.7 Gateway capacities

The gateway also provides certain capacity to support devices. The guidelines for the capacities are summarized in Table J.3.

Table J.3 – Gateway capacity guidelines

Parameter	Tiny gateway (10 devices)	Small gateway (50 devices)	Large gateway (250 devices)
Minimum Number of Sessions	30	110	510
Minimum Number of Transport	30	110	510
Minimum Number of Route	15	60	128
Minimum Number of Neighbors	12	50	128
Minimum Number of Superframes	12	12	12
Minimum Number of Links	50	100	500
Minimum Number of Graphs	25	60	128
Minimum Number of Graph-Neighbor	40	200	1 000
Minimum Number of Packet Buffers	25	100	500
Minimum Number of Publish Data Messages	30	200	1 000
Minimum Number of Cached Messages	75	400	2 000
Minimum Number of Publish Event Messages	25	100	500
Total Number of Devices (Wireless Adapters + Field Devices)	10	50	250
Clients	4	8	32

J.6.8 Gateway commands

The gateway supports several gateway specific commands, supports pass-through messages, supports publish data and block mode transfers and caches several read and write commands. The commands are specified in 9.3.6.

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Annex K
(informative)

Handheld device

K.1 Overview

Handheld device is used in the installation and maintenance of a network device. It is portable equipment operated by the plant personnel. There are four approaches to connect a handheld device to the network device.

a) Handheld device is connected through a plant automation network via another network such as Ethernet or wireless. This handheld device communicates with the network devices via the gateway device in the same way as external plant automation client does. It appears as another host application connected to the network.

b) Handheld device is connected to the maintenance port in the network device. The handheld can communicate with the attached network device, but it cannot communicate with any other device in the network.

c) Wireless network capable handheld device is connected to the network. The handheld device appears as another device in the network. In this mode the handheld can only communicate with the gateway and the network manager. This mode is used to write keys into the handheld device and to view diagnostic and system health information of the network. This mode of operation is referred to as "connected as a network device."

d) Wireless network capable handheld device is connected to a field device via the network. The handheld device is restricted to communicate only with that field device. Special provisioning is used to ensure that the handheld is restricted to one hop and one device at a time. This mode of operation is referred to as "connected as a maintenance device."

K.2 Maintenance port connection

The handheld device can configure and interrogate the network device when connected to the maintenance port of that device. The field device allows reading of the device parameters and writing of parameters required for provisioning via the maintenance port. Any write request that can only be sent by the network manager is not available via the maintenance port. When connected via the maintenance port the handheld does not have access to the wireless network.

K.3 Network device connection

K.3.1 General

There are two reasons to connect a handheld device into the wireless network as a network device:

a) to install session keys, and

b) to view network diagnostics and health reports.

To join a wireless network as a network device, the user will need to first install the network_ID and the Join_key into the handheld itself. This can be done in one of several ways, including connecting the handheld up to the gateway via Ethernet to initialize the network and to allocate the initial keys for the handheld. The initializing of the network and the gateway are implementation specific. After the handheld has its network_ID and Join_key, it will join the network in the same way as any other device joins the network.

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K.3.2 Install session keys

The handheld will need a session key to communicate with another network device. After joining to the network, the handheld has to send a request to the network manager to allocate session keys. There is separate session key for each device that the handheld will communicate with. The network manager installs these keys into the handheld and the devices. The session keys and their nonce counters are initialized to the same number at creation.

K.3.3 View network diagnostics and health reports

After the handheld has connected itself to the wireless network as a network device, it can request the network manager to allocate it additional communication resources to communicate with the gateway. The handheld can send requests to the gateway and to the network manager to read diagnostic and health report information. The handheld will not be able to communicate with other devices on the network when connected in this manner (device-to-device connections are not allowed).

K.4 Network connection as a maintenance device

After a network is up and running, a maintenance technicians may want to connect wireless network capable handheld device to an individual installed field device via the network to gather device specific information, run diagnostics, check device calibration, etc. To support these activities, the network manager will allow the handheld to connect up to one device at a time using a special superframe that has been installed into each device. The sequence for connecting up to the field device is as follows.

a) The handheld is connected to the network either directly or through the gateway and it obtains sessions (including the keys) to communicate with the selected network device.

b) The human user walks out into the plant and gets close to the selected network device.

c) Handheld goes into the listen mode looking for device advertisement packets.

d) Handheld locates the selected device and identifies links on which it can communicate with the selected device. It sends a command to this device requesting additional bandwidth, using one of these links.

e) The device sends a request to the network manager to activate its maintenance superframe.

f) The network manager activates the high speed handheld superframe.

g) The device and the handheld now communicate using this high speed handheld superframe.

Several prerequisites are necessary to support this scenario.

a) The network manager installs a well-known high-speed handheld superframe in each device and into the handheld.

b) The handheld and the selected device get a peer-peer session key.

c) The handheld uses HART™ commands #806 and #807 to activate and deactivate the maintenance superframe.

The handheld device is restricted to using only the maintenance superframe for communication with the selected device.

The handheld device supports publish data and block mode transfers and caches several read and write commands. The commands are specified in 9.3.6.

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Annex L
(informative)

Application of WirelessHART Commands

L.1 Provisioning

L.1.1 General

Fundamentally, a WirelessHART Field Device only requires a valid Join Key and the correct Network ID in order to join the WirelessHART Network. These two data items may be written to the Field Device, for example, during the manufacture of the Field Device; while connected via the maintenance port to the Gateway; or by the instrument technician during the commissioning of the Field Device. There are several additional services and commands to further support and customize the initial connection to the network including.

- Write Join_key service allows the 128-bit security key to be written to the Field Device. To further enhance security, Network Managers should change the join key after the Field Device joins.
- Write network_ID service and Read network_ID service identifies the network the device is to join.
- Read join status service allows the Field Device's progress toward joining the network.
- Write active_search_shed_time service can be used to improve the Field Device's chances of finding and joining the network quickly.
- While fine-tuning is generally not necessary, Write join mode configuration service and Read join mode configuration service can be used to control or fine tune join parameters.
- Write radio power output service and Read radio power output service can be used to specify the Transmit Power.

NOTE Subclause L.1.2 and subclause L.1.3 describe the basic and optional provisioning procedures.

L.1.2 Basic Provisioning

Subclause L.1.2 summarizes the basic steps for connecting a Field Device to a WirelessHART network. First the device shall be provisioned by:

- using Write Join_key service, Command 768, to write the Join Key to the Field Device. The join key shall match the value provided in the Gateway. If the value is not correct join attempts will fail;
- write the Network ID to the Field Device by using Write network_ID service, Command 773. The Network ID shall match the ID of the network the device is to join;
- perform optional provisioning (as needed).

The configuration for a join can be read to read the Network ID by using Read network_ID service, Command 774, and to read the join mode configuration by using Read join mode configuration service, Command 772. The join key can never be read from the device to avoid someone stealing the join key to introduce rogue devices or other attacks against a WirelessHART network.

L.1.3 Joining

The Field Device is now ready to join this network. Initial introduction of the Field Device to the network can be performed as follows.

- When the device has been installed and is ready to join the network, “Join now” is written using Write join mode configuration service, Command 771. The device will then scan the frequencies for advertisements and network traffic from the specified network. The

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parameters Active Search Time and Number of Join Retries determine how long the device will listen for the network and how often a join is attempted.

- The device's progress toward joining the network can be monitored using Command 769. Polling Command 769 provides the Join Status, the progress of a join attempt, number of detected neighbors and acquired advertisements. It also includes the active search time remaining.
- The device is joined once the Network Manager answers the Join Request and writes the security keys and normal communication parameters (Network Manager route, Superframe, links, time source neighbor.)

L.1.4 Enabling Faster Network Detection and Joining

Advertisements are sent periodically on random frequencies and joining device shall be on the right frequency at the right time to hear the advertisements. Consequently, joining can take some time as the joining device listens for advertisements. Using Write active_search_shed_time service, Command 770, the probability of network detection and thus the joint time may be improved by increasing the frequency of advertisement transmissions. Increasing the advertisement rate consists of the following steps.

- Issuing Write active_search_shed_time FAL PDU Command 770 to the Gateway or via the maintenance port to a Field Device already in the network. In either case the recipient (Gateway or Field Device) shall forward the command to the Network Manager.
- The Network Manager replies to Write active_search_shed_time service, Command 770, and increases the advertisement rate[2] for the interval indicated by "Active Advertising Shed Time".
- The new Field Device receives advertisements quickly and joins the network.
- Write active_search_shed_time FAL PDU Command 770 is issued once again (with Active Advertising Shed Time = 0) and the Network Manager advertisement rate is reduced for normal network operation.

L.1.5 Adjusting Transmit Power

Optionally, prior to joining the network, the Write radio power output service, Command 797, may be used to configure the Field Device's transmit power. For more information, see L.7.4.

L.2 Managing Superframes and Links

WirelessHART is a channel hopping, redundant mesh network. Superframes (and the Links they contain) specify the actual communication connections between devices within the mesh. Superframes and Links are Data-Link Layer functions with Links specifying communication opportunities and the Superframe (container) they reside in determine the frequency at which the communication opportunity arises. Three services and commands can be used to create and manage a Superframe:

- Read superframe list service, Command 783;
- Write superframe service, Command 965;
- Delete superframe service, Command 966.

Superframes can be enabled and disabled by the Network Manager as needed. While disabled modifications can be performed to the Superframe and all of the Links for the Superframe can be created. Then the Superframe can be quickly enabled and disabled when bandwidth demand changes. For example, a preconfigured (but disabled) Superframe can be enabled by one command being broadcast along a graph to provide extra bandwidth for a surge in request/response traffic to a device in the network.

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2 Higher advertisement rates can increase the power consumption of the network.

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Superframe contains the specified number of slots and. once enabled, the Superframe shall continuously repeat. As the slot time occurs all Links assigned to that slot in the Superframe shall be evaluated (see *TDMA Data-Link Layer Specification*).

Links are contained within a Superframe and are assigned to a slot. All devices shall all multiple Links to be assigned to a single slot. The Link specifies a communication opportunity within a Superframe. Three commands can be used to manage Links:

- Read link list service, Command 784;
- Write link service, Command 967;
- Delete link service, Command 968.

Links are identified by the unique combination (e.g., concatenation) of the Superframe ID, Slot Number, Neighbor Nickname associated with a Link. The Neighbor Nickname shall be ignored when receiving a packet (i.e., only DLPDU Destination Address is relevant when receiving a packet). The Network Manager may Add or Delete a Link (modification of an existing Link is not allowed).

If the Network Manager Adds a link with a hereto-unknown Neighbor the device shall add Link and it shall add the specified Neighbor to its Neighbor Table (see *TDMA Data-Link Layer Specification*). Deleting the last link to a neighbor deletes the neighbor from the Neighbor Table.

If the Network Manager deletes a Superframe the device shall also delete all links contained in the (deleted) Superframe.

L.3 WirelessHART Handheld Support

Universal support for HART-enabled Handhelds (wired and wireless) is a critical end-user requirement and support for Handhelds in HART-enabled products is essential. Network Managers, Gateways, Field Devices and other Wireless Devices shall support and interoperate with WirelessHART Handhelds.

A Network Manager shall create the Handheld Superframe (see Table F.23 Superframe Mode Flags) in all devices (e.g., Field Device and Adapters). The Handheld and device shall communicate directly with each other using the Handheld Superframe. Devices shall not forward to the network any packets received from the Handheld. Any packet from the Handheld with a Network Layer destination other than the device shall be discarded.

Two commands are used by the Handheld to initiate communications with the device to be serviced:

- Read handheld superframe service, Command 806, read the status of the Handheld Superframe.
- Write handheld superframe service, Command 807, is used to activate (and deactivate) the Handheld Superframe as needed.

To enable Handheld use in a WirelessHART installation:

- Network Manager (using guidance and keys from the Security Manager) shall establish a session in the device and Handheld to enable secure communications between them (see Request session service, Command 823).
- Network Manager shall create a matching "Handheld Superframe" (with Links) in the device and Handheld.
- Once on site, Handheld shall monitor and synchronize itself to network communications. Initial communications between Handheld and the device shall be via an advertised

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Superframe (of Handheld choosing). The Superframe_ID selected by the Handheld shall be the Graph ID in the NPDU.

- The Handheld shall identify the Handheld Superframe in the device and activate it in the device to be serviced. The Handheld shall also activate its corresponding Superframe.
- Upon request devices (e.g., Field Device and Adapters) shall immediately enable the Handheld Superframe.
- The Handheld and device shall communicate directly with each other using the Handheld Superframe. Graph ID in NPDU shall be Superframe_ID.

Terminating communications between the Handheld and device:

- Upon detecting a path down to the Handheld the device shall assume the Handheld is no longer available. When this happens the device shall: a) deactivate the Handheld Superframe; and b) forward the Path Down Alarm to the Network Manager.

L.4 Specifying and Managing Routes

Routes and Graphs are Network Layer functionality and the routing of network packets is a fundamental Network Manager responsibility. In WirelessHART, Graph Routing is the fundamental methodology used for routing of communications. The following three commands are used to establish and manage the routes that shall be used by a Field Device when it creates a network packet:

- Read route list service
- Write route service
- Delete route service

The Field Device shall use the Route specification corresponding to the destination device when creating a new network packet. The Route information is embedded in the network packet allowing it to be transferred over multiple hops to the desired destination (e.g., another Field Device). Only the Network Manager is allowed to create, modify or delete a Route.

A Graph Route is a redundant, multi-path, unidirectional route from the source device to the destination device. The Graph consists of nodes and edges. The nodes are Field Devices. The Network Manager constructs the Graph Route specifying the graph edges at each Field Device (node) along the route. In other words the edges identify neighbors to whom a Field Device shall use when forwarding a network packet along a Graph. Remember that

- A Route is used when a device creates a network packet and
- Graphs are used to route network packets (both generated by the device and those forwarded by the device on behalf of another).

Consequently, the Network Manager will write graph edges to a Field Device that are not specified in any of the Routes used when the device creates a network packet. Three commands are used by the Network Manager to manage Graph Routes:

- Read graph list service
- Read join status service
- Write active_search_shed_time service

Only graph edges for outbound network packets are written to the Field Device. Graph edges shall be used (by the device) to identify the set of neighbors to which a network packet maybe forwarded. Superframes and Links determine when the network packet may actually be transmitted.

Routes may also be specified using Source Routing. Source Routing specifies each hop that the network packet shall take to reach its final destination. Since it does not provide

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redundant paths, Source Routing is not reliable and should not be used for recurring communications (e.g., routine request/response or burst-mode traffic). Source Routing is useful for ad-hoc routes that are only used for less than 60 minutes or for probing communication paths. The following three commands are used to manage Source Routes:

- Read source route service (Optional)
- Write source route service (Optional)
- Delete source route service (Optional)

The implementation of Source Routes in Field Devices is optional.

L.5 Security

L.5.1 General

Security is fundamental to WirelessHART and essential to prevent malicious attacks on WirelessHART network. WirelessHART uses industry standard[3] AES-128 symmetric-key encryption. WirelessHART includes:

- Encryption of all Network Layer PDUs (NPDU) to ensure end-end communication confidentiality;
- Join keys used to encrypt all join requests/responses;
- Session keys used to encrypt end-end communication; and
- Data-Link level "Network (Data-Link) Keys" used to ensure the integrity of communications on a hop-by-hop basis.

Commands in this subsection facilitate the management of keys and sessions and enables controlled access to the network. In addition two commands allow for future enhancements to WirelessHART security:

- Write security level supported service and
- Read security level advertised service.

These two commands allow the security level supported by the Network Manager to be disclosed to devices joining the network. While today only "Joined-Keyed" (see Table F.29) is supported security best practices may evolve over time. These commands allow for potential evolution.

L.5.2 TDMA Data-Link Key Management

An AES-128 Network (Data-Link) Key is used to authenticate (but not encipher) the DLPDU. The following command allows the key to be written/changed.

- Write network key service

All devices in the WirelessHART network shall use the same Network (Data-Link) Key.

L.5.3 Session Key Management

There are 5 commands used to manage sessions.

For security, WirelessHART is session oriented thus enabling private and secure communication between a pair of network addresses. Three commands are used by the Network Manager to manage session in devices:

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[3] e.g., FIPS PUB 197 (FIPS 197) by the US National Institute of Standards and Technology (NIST).

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- Read session list FAL PDU service allows the sessions is a device to be read;
- Write session FAL PDU service allows the session creation or modification (e.g. changing the session key); and
- Delete session FAL PDU service that removes a session.

In addition there are two additional session management-related commands:

- Request session FAL PDU service is used by (for example) Handheld to request a session with a device. Typically a Handheld is provisioned (e.g., based on service/work orders) to allow one or more devices be serviced. This command allows the session for the device to be provided to the Handheld. When this command is used the Network Manager shall also configure the session in the device to be serviced to enable communication with the Handheld.
- Sessions correspond to end-end connections supported by a device. Read session extended service allows the end-end connections in a device to be read via the Gateway.

L.5.4 Access Control

The following four commands control criteria Gateways use for allowing devices to join the network. Devices that are part of the network can cause more damage than those that are not in the network. Consequently, it is very important to only allow trusted devices into the network. These services control the level of trust required for admission to the network.

- Write network access mode service
- Read network access mode service
- Read join key mode service
- Write join key mode service

Gateways may contain access control lists. Write network access mode service and Read network access mode service allow the use of black lists, white lists to be specified. These commands even allow the network to be locked down so no new devices may join the network. Depending on the Network Access Mode (see Table F.31) authentication beyond confirming the Join key can be specified. For example:

- only devices on the Whitelist can be allowed to Join. If the whitelist is empty no devices are allowed to join;
- those on the Blacklist are not allowed to join. Field devices should support blacklists to prevent join requests from un-welcome devices. In other words, if a device detects a join request from a blacklisted device the join request shall be discarded (i.e., not forwarded); or
- only devices on the Network List (see Table F.30) are allowed to join.

Once joined, the device is added to the Active List (i.e., allowed to be used by Host Applications and for plant operation) and the Network List.

Often a network does not have access control enabled when it is first being commissioned. When the network deployment is complete and access control is to be asserted, Transfer network list to white list service is used to create or update the Whitelist. Write network access mode service and Read network access mode service control whether whitelists and blacklists shall be used for network access control.

The Join Key Mode (see Table F.44) may also be relaxed. By default, each device should have its own, unique join key. The Join Key Mode commands allow (at the risk of reduced security) the Join Key to be either the "well-known" key or a key common to all devices. This allows a customer to get the devices quickly provisioned to the network and then once the devices are on they can transition the network to a random network wide join key.

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When Join Key Mode is relaxed, the Network Access Mode should be set to Quarantine, Whitelist or Lockdown. While in Quarantine mode all devices not previously in the network (i.e., not in the Network List) are Quarantined and shall by authenticated by the network operator.

In other words, using these four commands with new networks it is possible to relax security to facilitate simple rapid network commissioning and, once the network is established, tighten security to make the network operational.

L.5.5 Simple Key Management

The following four commands provide simple key management. The first three commands simplify creation and management of join keys. The last command (Change Key Now) allows all keys to be changed periodically. Security is enhanced by periodically changing the keys.

- Generate key service
- Read device join key service
- Write device join key service
- Change key now service

Generate Key is a simple service that generates and returns a key. This key could be used with the Write join key mode service and Write device join key service to provision a device for joining the network. Best practice would be for the host application to be connected and communicating with both the Gateway and the Field Device (via its maintenance port using Write Join_key service). This simplifies provisioning and the actual key value never displayed to the user.

Alternatively, the Read device join key service can be used. This generates a random Join Key and configures the Network Manager to allow the Field Device to join the network. Using the response the host application can provision the Field Device (via its maintenance port using Write Join_key service).

In the worst-case scenario both of these approaches allow the Join key to be displayed to the user. The user can write the join key to the Field Device (e.g., using a Handheld) at a later time. In any case, once a device joins the network its Join Key should be changed by the Network Manager.

NOTE This best practice ensures no human knows the Join Key.

The Change key now service allows a Host Application to force a key change (e.g., in reaction to a security concern or to comply with the plant's security policy).

These services along with the services Read device list, Add device list entry and Delete device list entry (for whitelist/blacklist management) and the services Write network access mode and Read network access mode (for managing the network access mode) provide the application interfaces for Host Applications to implement plant security strategy.

L.6 Device Lists

Gateway and Network Manager shall maintain and provide access to device lists. These lists are wireless-specific; used to enumerate devices associated with a Network; and manage device access to the Network. Services used to access device lists include:

- Read device list service read a device list;
- Add device list entry service adds a device to active, white, black, or network list;
- Delete device list entry service deletes the device list;

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- Transfer network list to white list service transfers the network list to the white list.

Table F.30 enumerates the lists (e.g., active, network, white and black lists). These lists are WirelessHART-centric and shall only identify WirelessHART devices. WirelessHART Adapter connected devices, for example, shall never be included in a device list. See Read Sub-Device Identity Summary service to identify all devices that may be accessed via a given WirelessHART Gateway. Read Sub-Device Identity Summary service shall identify and list all devices (i.e., the "Live List") in the Active Device List plus all devices connected to WirelessHART Adapters.

Whenever a device attempts to join the network its Join Key is authenticated. If access control (see Table F.31) is enabled the Whitelist and Blacklist are consulted. For security procedures and requirement see Clause L.5.

When a device disappears from the Active Device List (e.g., due to a loss of connection[4]), the device is not removed from the Network list. Consequently, the Network list should be capable of containing more devices then the Gateway will support. This allows, for example, for device replacement even when the Gateway is at its capacity. The device remains on the Network list until removed using Delete device list entry FAL PDU service.

When the device is not in the Active or Quarantined Device List, it can be removed directly from the Network List (i.e., if the device is not connected to the network). Otherwise the device shall be decommissioned first. Quarantined devices and Access Points are also included in the Network list. The Gateway shall maintain KPI statistics for all devices on the Network list. KPI Statistics shall be only kept until the power is cycled on the Gateway. Once the Gateway power is cycled, the statistics shall be reset/cleared.

When a device is removed from the Active Device List via Delete device list entry FAL PDU service (e.g., when depot-level service is required) the device is decommissioned and dropped from the network. The device is decommissioned by: sending Command 771 with Join Mode Code set to "Don't attempt to Join"; and sending Perform device reset FAL PDU service. Once restarted the device shall not attempt to re-join the network.

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L.7 Network Management Commands

L.7.1 General

The Network Manager is responsible for the system-wide operation of the network. In other subsections specific networking functions are addressed (e.g. security, routing, and mesh inter-connectivity). This subsection identifies commands and requirements for a variety of Network Management functions including:

- Bandwidth Management
- Network Maintenance
- Coexistence
- Device Management

L.7.2 Bandwidth Management

Congestion is perhaps the most serious threat to network stability. Bandwidth management is a key tool used by the Network Manager to manage network congestion. The following commands are used to request, allocate and manage the timetables used to manage bandwidth:

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4 A device is not connected (dropped from the Active list) upon either (1) detecting a Transport Layer failure; (2) reception of Path Down Alarm on all connections to the Field Device; or (3) the Gateway session does not exist.

- Request timetable service
- Read timetable list service
- Delete timetable connection service
- Read timetable by id service
- Write timetable service

Command 799 requests are generated by the requesting device and sent to the Network Manager (or Gateway if generated by a host application). The Network Manager may respond immediately is the requested bandwidth is known to be available or after compete a Delayed Response. Once the device has bandwidth (the full amount requested or something less) packets using the bandwidth are generated at up to that allocation.

Once the bandwidth is no longer needed the device shall return it to the Network Manager using Command 801. If the Network Manager needs to reduce network congestion it can use Command 973 to modify the current timetable configuration.

If the device does not have the full amount of bandwidth it wants it shall periodically, once per Health Report interval, issue a Command 799 to ask for more bandwidth. While the bandwidth is reduced the device shall still continue to publish process data at the best speed possible consistent with the timetable setting.

The Network Manager also has flow controls that can be used to reduce network congestion. Network congestion (in the extreme) can cause a network-wide failure. Flow control can modulate communication traffic thus ensuring network survival. Both excessive congestion and flow control may result in packet loss. The flow controls are managed using the following commands:

- Read receive Priority_threshold service
- Write receive Priority_threshold service

For example, Write receive Priority_threshold service may be used by a Network Manager to block "Alarm" or "Normal" priority messages across all or part of the network to immediately reduce congestion.

L.7.3 Network Maintenance

There are a number of network management commands allowing, for example, join priorities, timers (discovery, keep-alive, etc.) and other general maintenance of the network by the Network Manager. These commands include:

- Write timer interval service
- Read timer interval service
- Read packet hop-to-live service
- Write packet hop-to-live service
- Read join_priority service
- Write join_priority service
- Read back-off exponent service
- Write back-off exponent service

Write timer interval service and Read timer interval service read and write timers that control a variety of time values that can be used to tune Field Device network behavior. Table F.19 contains the list of timers that may be fine-tuned. Other specifications define the timers themselves (e.g., health report intervals, keep alive times, etc.) and specify default values that enable reliable, responsive network behavior "out-of-the-box".

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In general, no WirelessHART packet is ever discarded (i.e., once it is created in the originating device it will travel the network until it reaches its final destination). However there are two safeties that prevent packets from wandering the network indefinitely: "Time-To-Live" (TTL) and "Maximum PDU Age". The former (TTL) can be managed using commands 808 and 809. This allows TTL to be set for example to a large value when installing a device in a long large stringy network. TTL is included in an NPDU field whose value is initialized when the PDU is created and decremented upon each hop the packet takes across the network. When TTL reaches 0 the packet shall not be forwarded to another device (see *Network Management Specification* for more information). The Maximum PDU Age is managed using Commands 795 and 796. This allows time-based criteria to be established by the Network Manager to specify packet disposal to complement the TTL criteria.

Join Priority indicates to devices joining a WirelessHART network the preferred neighbor to join to. In general, Network Managers should set the join priority to a lower value the closer a device is to an Access Point. Commands 810 and 811 are used by the Network Manager to manage the Join Priority advertised by the Field Device.

WirelessHART enables flexible communication bandwidth utilization to allow on-demand use by devices in the form of "Shared Slots". Shared Slots allow multiple devices the opportunity to transmit a packet in the same slot. Should a collision occur the devices will "back-off" a random number of Shared Slots. Commands 819 and 820 allow the maximum back-off interval to be set.

L.7.4 Coexistence

Coexistence is a key WirelessHART requirement and strength. WirelessHART has both the ability to perform successfully in the presence of interference from other networks and protocols and the features to share the RF space. The following commands allow WirelessHART's sharing of the RF space to be tailored on an installation-by-installation basis:

- Read CCA mode service and Write CCA mode service can be used to manage the Clear Channel Assessment (CCA) settings in the device. CCA is an optional coexistence feature that allows a device to monitor the RF space and defer communications if the RF space is in use.
- Read channel blacklist service and Write channel blacklist service allow one or more RF channels to be blacklisted. Blacklisting reserves RF channels for use by other protocols and become effective only upon rebooting the network. Commands 817 and 818 are Gateway commands (i.e., the Gateway is the proxy for the Network Manager). Field Devices learn the Blacklist from advertisements detected during the join process.
- Write radio power output service and Read radio power output service allow the Field Device's Transmit Power to be adjusted based on the mesh density or to meet regulatory requirements.

For the IEEE 802.15.4 Physical Layer blacklisting and CCA generally provide limited benefits in practice. The modulation used by IEEE 802.15.4 is generally both tolerant and unobtrusive to other (at least IEEE compliant) protocol/modulation standards (e.g., IEEE 802.11 WiFi).

In most cases, due the frequency hopping and very short messages used by WirelessHART, the maximum transmit power should be used. This generally improves communications and enables long distances between nodes. However, it may be beneficial for the Transmit Power to be reduced, for example, in high-density networks (thousands of devices within a 100 m diameter).

L.7.5 Device Management

It is incumbent on the Network Manager to manage all of the device's network related properties and attributes. The commands in this section are used to manage a variety of device properties that do not fit well in the other subsections. These commands include:

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- Read device nickname service and Write device nickname service allow the Network Manager to manage the device's short (16-bit) address. This Nickname shall be set before the device can finish joining the network. Consequently, Command 962 is one of the first commands from the Network Manager to a device.
- Read wireless device capabilities service provides s summary of the basic capabilities and capacities of the device. Network Manager should issue this command shortly after the device joins the network
- Read neighbor attribute flag service and Write neighbor attribute flag service for the Network Manager to set which neighbor is a clock source. Devices shall have a neighbor as a clock source to ensure they remain synchronized to the network. Command 971 shall be one of the first commands issued by the Network Manager when a device joins the network.
- Read neighbor attribute flag service and Write neighbor attribute flag service allow the calendar time (i.e. time of day) to be correlated to network time (driven by the ASN).
- Disconnect device service is issued by the Network Manager to force a device off the network. Depending on the device's configuration (see join mode codes in Table F.36) the device may not attempt to rejoin the network.
- Write network suspend service and Read device suspend settings service allow devices to be suspended. Suspending allows a device to be instructed to drop off the network and become quiescent for a time. Once time has lapsed the device shall rejoin the network. Joining the network is very power intensive. Consequently, the suspension interval should be for many hours. If interaction with the device is not needed for a shorter time it is more power-efficient for the device to remain in-network.
- Write status counter mode service allows the device to be configured for rollover or saturating status counters. All devices shall default to rollover counters.

L.8 Network Health Reporting and Status

In addition to supporting plant applications, WirelessHART also provides continuous measurements and statistics on the RF environment the network is operating in. Periodic reports and as-needed alarms provide critical information allowing the Network Manager to groom and tune the WirelessHART network. All Field Devices shall support three periodic reports:

- Report device health service provides the device's communication statistics;
- Read neighbor health list service includes statistics indicating the quality of the communication with neighbors; and
- Read neighbor signal level service reports signal levels for neighbors.

These reports shall be published at the period specified by the "Health Report" time (see Table F.18 and Write timer interval service and Read timer interval service). Furthermore, the three commands may be dispatch as needed by Host Applications (e.g., Gateways and Network Managers)

In addition, Field Devices shall spontaneously generate alarms when specified communication errors occur. Command requests shall not be generated by Applications for these commands. Should a Field Device receive a command request for one of the alarm commands it shall answer with "Access Restricted". The alarm services include:

- Report path down alarm service indicates the Field Device is having difficulty maintaining contact with one of its linked neighbors;
- Report source route failed alarm service indicates a packet did not reach its final destination (e.g., one of the hops in the specified source route was unsuccessful);
- Report graph route failed alarm service indicates a packet did not reach its final destination (the packet reached the end of the graph route and could not be forwarded);

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- Report transport layer failed alarm service indicates that the Transport Layer fails when retries to the peer end-destination are not successful. The Field Device has lost contact with one of its peer devices.

L.9 Gateway Commands

L.9.1 General

Implementation of all commands in Clause L.9 is required for all Gateways.

L.9.2 Device Identification

The only mandatory non-ambiguous way to identify and track (over time) a HART-enabled Field Device is using its Unique ID. Using TAG, I/O connection, or location in a network topology are (while important) problematic for identification purposes. The I/O System Commands are based on the Field Device Unique ID.

However, some reports (e.g., health reports, topology listings etc.) only contain the Field Device nickname (i.e., its WirelessHART network short address). Consequently, Host Applications be able to identify Field Devices using either the Unique ID or Nickname. Two commands are provided for this purpose.

- Read network device identity using Unique ID service
- Read network device identity using nickname service

Read network device identity using Unique ID service accesses the Nickname and Tag given the Unique ID. Conversely, if the Host Application knows the nickname (e.g., from Read device's neighbor health service response), Read network device identity using nickname service provides the Unique ID and Tag given the Nickname.

L.9.3 Network Information and Statistics

Access is provided to detailed WirelessHART network topological and performance data. The four commands providing this access include:

- Read device's neighbor health service provides statistics on communication performance between a Field Device and its neighbors.
- Read network topology information service enables piecewise construction of a network diagram (topology).
- Read network device statistics service returns comprehensive summary of configuration, performance and KPIs for the Field Device.
- Read network statistics service summarizes overall network health, performance and KPIs.

Using Read device's neighbor health service and Read network topology information service a "picture" of the connections between Field Devices and communication routes (more specifically, graph routes) through the network can be constructed[5]. For example, Read device's neighbor health service allows the neighbors a Field Device communicates with to be identified. This can be used to create diagram of the physical network topology. Read network topology information service then can be used to overlay the communication routes on to the topology.

Read network device statistics service and Read network statistics service provide KPIs and performance statistics. Read network statistics service summarizes overall network KPIs and

[5] With a little creativity, the reliability of the interconnections can be imaged (e.g. by adding a third dimension or colour proportional to signal levels and communication reliability).

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network health. Read network device statistics service provides a wide-range of Field Device-level statistics (more than 25 in all) on configuration, communications and performance. In effect, Read network statistics service provides a system level view of network performance while Read network device statistics service allows detailed inspection of performance in one region of the network.

L.9.4 Network Management

While the Network Manager's prime directive is to ensure reliable, uninterrupted operation of the network, end user application objectives should provide guidance to on network operation and optimization. Four commands allow guidance to be provided to the Network Manager:

- Write network device's scheduling flags service and Read network device's scheduling flags service specify the application-specific role of a Field Device; and
- Read network constraints service and Write network constraints service provide network operation optimization guidance.

Write network device's scheduling flags service and Read network device's scheduling flags service provides additional information to Network Managers about individual Field Devices. For example, an end-user can specify that a Field Device is a leaf node by setting the “Non-routing Device” bit. Another possibility is a device is transient; or if the device is a rail car that periodically enters and exits a network, the “Transient” bit could be set. If Command 842 is not received for a Field Device the Network Manager shall assume all Scheduling Flags are reset (i.e., the Field Device shall not receive any special consideration by the Network Manager).

End-user application objectives shall be considered as the Network Manager configures and maintains the network. While Commands 742 and 843 provide guidance at the Field Device-level, Read network constraints service and Write network constraints service provide guidance to the Network Manager at the network-level. For example, using Command 845, an end-user can assign low communication latency priority over battery life.

L.9.5 Cache Management

All Gateways shall cache command responses to ensure timely access to Field Device process data and status. Four commands allow limited Host Application control gateway caching. These commands are:

- Flush cached responses for a device service
- Read stale data setpoints service
- Write stale data timer service
- Write stale data count setpoint service

The first service called Flush cached responses for a device service flushes the current cache for the specified Field Device. The use of the command can drastically affect the normal communication performance and, consequently, is not recommended for normal host operation.

The last three services are "stale data" services providing a Host Application control over the Gateway marking process data and status in the cache as Stale or Bad. Read stale data setpoints service reads the stale data settings and Write stale data timer service and Write stale data count setpoint service allow the settings to be configured.

Stale data is assessed in a two-step process using a timer and a counter. Every time data is updated late (or not at all) the Stale Data Counter is incremented until the Stale Data Counter saturates. The Stale Data Counter shall not rollover. The Stale Data Counter shall continue to be updated even when a device drops out of the network.

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When the Stale Data Counter becomes too large the Process Data Status is marked "Bad" and the Stale Data Alarm is asserted (see Read network device statistics service). The Stale Data Alarm shall remain asserted until the data is updated on-time thus resetting the Stale Data Counter and the Stale Data Alarm.

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Annex M
(informative)

Regional modification for compliance with ETSI standards

M.1 General

Profile 9/2 in 9.3 restricts the usage of the spectrum to the 2,4 GHz ISM band, see 9.3.4.3.1.

Additional requirements apply in Europe to wide band radio frequency transmitting equipment operating in this 2,4 GHz ISM band. Some of these European requirements can be met by complying with two Harmonized Standards from ETSI, EN 300 328 and EN 300 440-2.

This Annex M provides additional requirements for compliance of WirelessHART (IEC 62591) devices operating in the 2,4 GHz ISM band with these two ETSI standards:

- EN 300 440-2 is applicable for equipment (devices) with a maximum transmit power between 0 dBm and 10 dBm EIRP (see Clause M.2);
- EN 300 328 is applicable for equipment (devices) with a maximum transmit power between 10 dBm and 20 dBm EIRP (see Clause M.3).

NOTE In this Annex M, the term “devices” refers to electronics with radios operating according to the appropriate standard; these include but are not limited to wireless transmitters, gateways, and wireless adapters.

M.2 Compliance with EN 300 440-2

Table M.1 specifies the additional requirements which allow WirelessHART devices operating in the 2,4 GHz ISM band to satisfy the transmit power limitation requirements of EN 300 440-2.

NOTE EN 300 440-2 V1.4.1 is listed as a Harmonized Standard under the R&TTE Directive 1999/5/EC, which will be superseded by the Radio Equipment Directive 2014/53/EU.

Table M.1 – Applicable EN 300 440-2 requirements list

Parameter	EN 300 440-2 requirements	Additional requirements
Maximum Transmit Power	10 dBm (10 mW) EIRP	Devices shall be configured to emit less than 10 dBm EIRP, that means less than 10 dBm electrical power with an antenna gain of 0 dBi. If the antenna gain is different to 0 dBi, then the resulting EIRP shall be less than 10 dBm by an adequate electrical power adjustment. This requirement overwrites the requirement about electrical power given in 9.3.4.3.5.

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M.3 Compliance with EN 300 328

M.3.1 General

EN 300 328 contains requirements for wide band modulating equipment including equipment that uses wide band modulation schemes other than frequency hopping.

WirelessHART (IEC 62591) devices should be categorized as non-FHSS equipment according to EN 300 328 V1.9.1, 4.3.2.

EN 300 328 specifies several alternative methods that can be selected as a basis for compliance with general requirements.

Depending on how Profile 9/2 in 9.3 restricts the values that may be set in the parameter CCA mode (see Table F.40), WirelessHART (IEC 62591) can be categorized as adaptive or non-adaptive, according to EN 300 328 V1.9.1, 4.3.2.6:

- adaptive if CCA mode is restricted to a value that indicates energy detect is used;
- non-adaptive if CCA mode is restricted to a value that indicates energy detect is not used.

Subclauses M.3.2 and M.3.3 specify the additional requirements which allow WirelessHART devices operating in the 2,4 GHz ISM band to satisfy various requirements of EN 300 328 for these two methods.

NOTE EN 300 328 V1.9.1 is listed as a Harmonized Standard under the R&TTE Directive 1999/5/EC, which will be superseded by Radio Equipment Directive 2014/53/EU.

M.3.2 Adaptive

Table M.2 specifies the additional requirements for WirelessHART devices categorized as non-FHSS, adaptive.

Table M.2 – Applicable EN 300 328 requirements list for adaptivity

Parameter	EN 300 328 requirements	Additional requirements
Maximum Transmit Power	20 dBm (100 mW) EIRP	Devices shall be configured to emit less than 10 dBm ± 3 dBm EIRP according to 9.3.4.3.5.
Maximum Power Spectral Density	10 mW/MHz EIRP	Devices shall be configured to emit less than 13 dBm max EIRP according to 9.3.4.3.5. DSSS [a] shall be used according to IEEE 802.15.4-2011, Clause 10. With these two requirements the limit of 10 mW/MHz EIRP can be achieved.
Frame Based Equipment	Clear Channel Assessment (CCA) > 20 µs	CCA mode shall always be enabled by setting the corresponding parameter to Mode 1, see Table F.40. According to IEEE 802.15.4, the CCA time shall be greater than 20 µs. This requirement overwrites the requirement given in 9.3.4.2.

[a] DSSS is according to IEEE 802.15.4-2011, 8.1 direct sequence spread spectrum (DSSS) PHY employing offset quadrature phaseshift keying (O-QPSK) modulation. O-QPSK PHY is mandatory when operating in the 2,4 GHz band according to IEEE 802.15.4-2011, 10.2.1. Subclauses 4.2.1 and 9.3.4.1 require DSSS. The power spectral density mask is defined in IEEE 802.15.4-2011, 10.3.2.

M.3.3 Non-Adaptive

Table M.3 specifies the additional requirements for WirelessHART devices categorized as non-FHSS, non-adaptive.

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Table M.3 – Applicable EN 300 328 requirements list for non-adaptivity

Parameter	EN 300 328 V1.9.1 requirements	Additional requirements
Maximum Transmit Power	20 dBm (100 mW) EIRP	Devices shall be configured to emit less than 10 dBm ± 3 dBm EIRP according to 9.3.4.3.5.
Maximum Power Spectral Density	10 mW/MHz EIRP	Devices shall be configured to emit less than 13 dBm max EIRP according to 9.3.4.3.5. DSSS [a] shall be used according to IEEE 802.15.4-2011, Clause 10. With these two requirements the limit of 10 mW/MHz EIRP can be achieved.
Duty Cycle, Tx-sequence, Tx-gap	For non-adaptive equipment with maximum EIRP above 10 dBm: The Duty Cycle shall be equal to or less than the maximum value declared by the supplier. Tx-sequence time ≤ 10 ms. The minimum Tx-gap time following a Tx-sequence shall be equal to the duration of that proceeding Tx-sequence with a minimum of 3,5 ms.	No additional requirement needed. The requirements are fulfilled by the following characteristics. Worst case Duty Cycle is 43 % according to Table 34. The maximum Tx-sequence time for a WirelessHART packet is 4,256 ms in a 10 ms time slot according to TsMaxPacket, see Table 34. The minimum Tx-gap is ≥ 5,744 ms of a transmission of a device under test (DUT) according to Figure M.1. Also a sequence of an ACK in slot 1 followed by a packet in slot 2 has a minimum Tx-gap of ≥ 4,384 ms according to Table 34 and the visualization in Figure M.2.
Medium Utilization Limit	For non-adaptive equipment with maximum EIRP above 10 dBm: Maximum Medium Utilization factor = 10 %.	Devices shall be configured to emit less than 13 dBm according to 9.3.4.3.5 (10 dBm + 3 dBm tolerance) and with the worst case duty cycle (43 %, according to Table 34 and the visualization in Figure M.1), then the MU factor will be less than 10 %.
[a] DSSS is according to IEEE 802.15.4-2011, 8.1 direct sequence spread spectrum (DSSS) PHY employing offset quadrature phaseshift keying (O-QPSK) modulation. O-QPSK PHY is mandatory when operating in the 2,4 GHz band according to IEEE 802.15.4-2011, 10.2.1. Subclauses 4.2.1 and 9.3.4.1 require DSSS. The power spectral density mask is defined in IEEE 802.15.4-2011, 10.3.2.		

Figure M.1 show the Parameters given in Table 34 in a graphical form. As shown in Figure M.1, the maximum transmission time is 4,256 ms within a 10 ms time slot. This equates to a duty cycle of less than 43 %.

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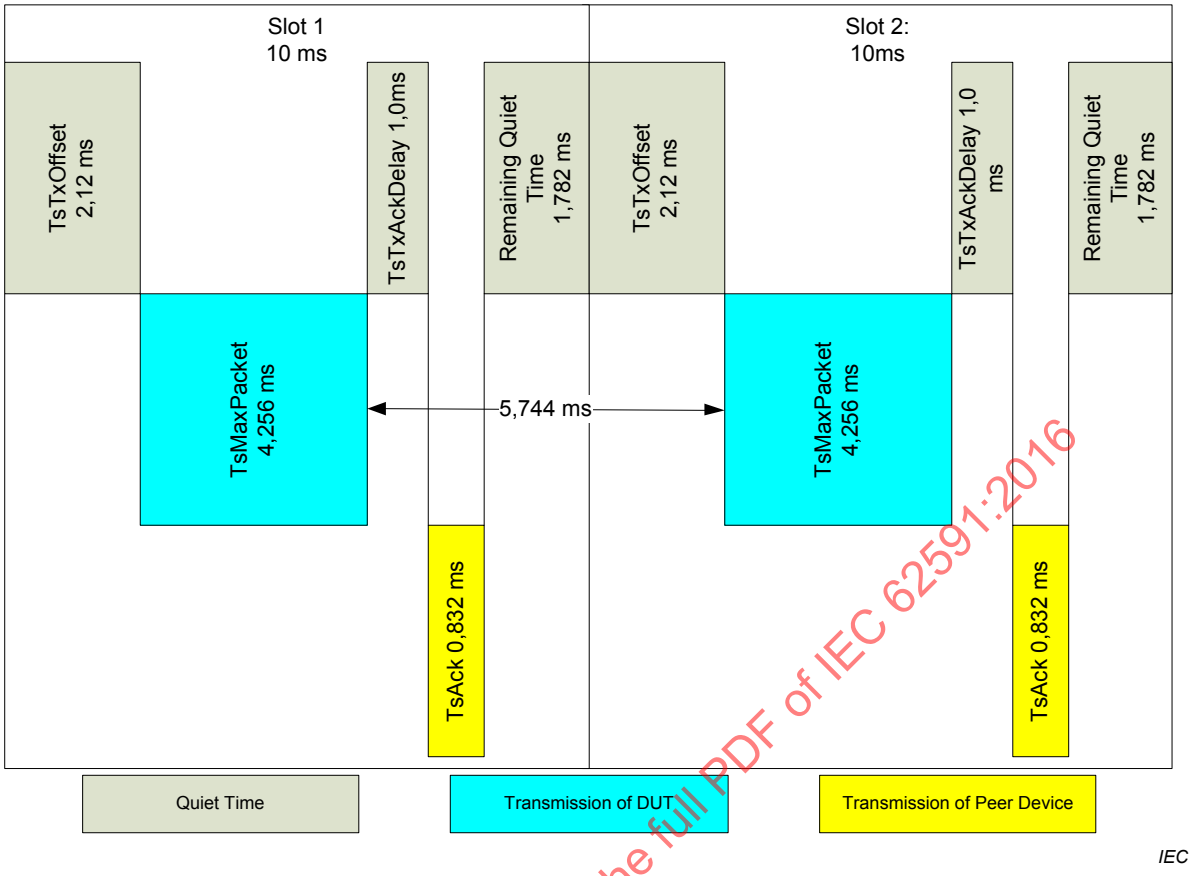

Figure M.1 – Consecutive Transmit Sequence

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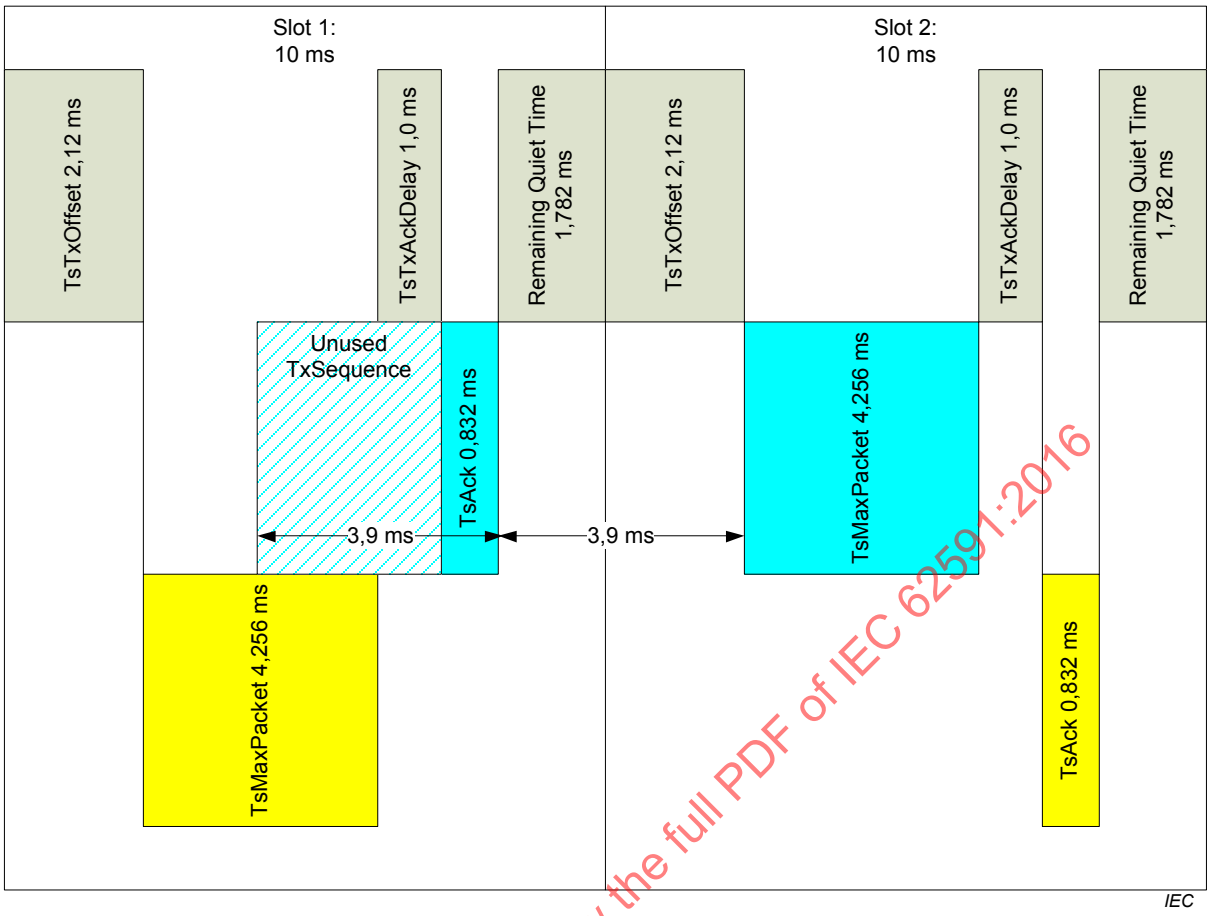

Figure M.2 – ACK-Transmit Sequence

The Duty Cycle of a WirelessHART device cannot exceed 43 % based on a 10 ms timeslot and a maximum transmission time for a WirelessHART packet of 4,3 ms in a 10 ms time slot according to Table 34. This results in a MU factor value of less than 10 % as required.

MU = 13 dBm EIRP × 43 % < 9 %.

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RÉSEAUX INDUSTRIELS – RÉSEAU DE COMMUNICATIONS SANS FIL ET PROFILS DE COMMUNICATION – WirelessHART™

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Cette deuxième édition annule et remplace la première édition parue en 2010. Cette édition constitue une révision technique.

Cette édition inclut les modifications techniques majeures suivantes par rapport à l'édition précédente:

- amélioration des statistiques de performance grâce à l'utilisation d'indicateurs de performances clés (KPI, de l'anglais *Key Performance Indicator*). Ces améliorations entraînent une extension des données statistiques fournie par les passerelles. Par exemple le service Lire statistiques d'appareil de réseau a été étendu et le service Lire statistiques réseau a été ajouté pour fournir un résumé des performances du réseau;

- ajout de la détection des données périmées (voir les services Lire Points de consigne de péremption des données, Ecrire Temporisateur de données périmées et Ecrire Points de consigne de péremption des données). Ces services normalisent les rapports de passerelles dans le cas où des données de processus ou des événements n'arriveraient pas à la passerelle en temps opportun. Par exemple, les applications hôtes recevront le code de réponse "Echec d'actualisation" en cas de péremption des données de processus dans la commande de réponse;
- ajout de commandes de passerelles;
- ajout d'un état de mise en quarantaine;
- extension des modes CCA pour une meilleure correspondance avec l'IEEE 802.15.4;
- ajout de clarifications sur la gestion des listes blanches et des listes noires;
- ajout de clarifications concernant le rattachement (par exemple, ne nécessite qu'un voisin);
- ajout de clarifications concernant l'utilisation des liaisons de rattachement, la gestion des tables et les défauts;
- corrections et actualisations.

L'attention du lecteur est attirée sur le fait que l'Annexe M énumère tous les articles traitant des différences à caractère moins permanent inhérentes à certains pays, concernant le sujet de la présente norme.

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
65C/835/FDIS	65C/842/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

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Le contenu du corrigendum de mars 2021 a été pris en considération dans cet exemplaire.

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INTRODUCTION

La présente Norme internationale fournit la spécification, les définitions et le profil pour un réseau de communications sans fil. Elle complète l'IEC 61158-5-20, l'IEC 61158-6-20 où un certain nombre de services et de commandes sont spécifiés, ainsi que l'IEC 61784-1, où une commande universelle de profil de communication CP 9/1 est spécifiée.

Le présent document suit la structure et les conventions de la série IEC 61158 (par exemple pour la séparation des définitions de services de DL et la spécification du protocole DL) ainsi que les conventions de l'IEC 61784-1. La série IEC 61158 spécifie différents réseaux de communication. Ceux-ci sont structurés en différents Types. Le Type 20 est attribué aux technologies de la Hart™[1] Communication Foundation (HCF). Pour les autres affectations des numéros de Type, voir l'IEC 61158-1.

L'IEC 61784-1 et l'IEC 61784-2 définissent des familles de profils de communication (CPF) et, au sein d'une famille, un à n Profils de communication. Le numéro de CPF attribué aux technologies de la HCF est CPF 9. Pour les autres affectations des numéros de CPF, voir l'IEC 61158-1.

Un nouveau numéro de projet, IEC 62591, a été attribué aux améliorations de Type 20 et au CP 9/2 correspondant, de sorte que ce document contient le Type 20 spécifique équivalent à la série de normes IEC 61158 et le profil spécifique CPF 9 en utilisant les mêmes conventions que celles de l'IEC 61784-1. Les quatre sous-parties spécifiques au Type, ainsi que le profil correspondant, sont définis dans différents articles du présent document.

Le protocole de Type 20 prend en charge des communications numériques bidirectionnelles pour des appareils de mesure et de commande de processus. Les applications comprennent l'interrogation de variables de processus, l'accès cyclique aux données de processus, le réglage de paramètres et le diagnostic, et ce, à distance. Le présent document définit la spécification qui comprend le protocole de communications de terrain de Type 20 pour les appareils sans fil. La spécification du protocole de Type 20 repose largement sur le Modèle de communications OSI à 7 couches.

La Commission Electrotechnique Internationale (IEC) attire l'attention sur le fait qu'il est déclaré que la conformité avec les dispositions du présent document peut impliquer l'utilisation d'un brevet concernant les revendications des brevets énumérés ci-après dans les articles normatifs.

US 8676219 [HCF]	Combined Wired and Wireless Communications with Field Devices in a Process Control Environment
US 8798084 [HCF]	Increasing Reliability and Reducing Latency in a Wireless Network
US 8325627 [HCF]	Adaptive Scheduling in a Wireless Network
US 8660108 [HCF]	Synchronizing Timeslots in a Wireless Communication Protocol
US 8169974 [HCF]	Suspending Transmissions in a Wireless Communication Network
US 8670746 [HCF]	Enhancing Security in a Wireless Network
US 8670749 [HCF]	Enhancing Security in a Wireless Network

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US 8451809 [HCF]	Wireless Gateway in a Process Control Environment Supporting a Wireless Communication Protocol
US 8570922 [HCF]	Efficient Addressing in Wireless HART Protocol
US 8942219 [HCF]	Support for Network Management and Device Communications in a Wireless Network
US 8406248 [HCF]	Priority Based Scheduling and Routing in a Wireless Network
US 8892769 [HCF]	Routing Packets on a Network Using Directed Graphs
US 8230108 [HCF]	Routing Packets on a Network Using Directed Graphs
US 8356431 [HCF]	Scheduling Communication Frames in a Wireless Network

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RÉSEAUX INDUSTRIELS – RÉSEAU DE COMMUNICATIONS SANS FIL ET PROFILS DE COMMUNICATION – WirelessHART™

1 Domaine d'application

La présente Norme Internationale spécifie un réseau de communication sans fil en complément du Type 20 de l'IEC 61158-3-20, de l'IEC 61158-4-20, de l'IEC 61158-5-20, de l'IEC 61158-6-20, ainsi qu'un profil de communication CP 9/2 en complément de la famille CPF 9 de l'IEC 61784-1.

La présente norme spécifie ce qui suit:

- Définition de service de la couche physique et spécification de protocole,
- Service et protocole de la couche liaison de données,
- Service et protocole de la couche application,
- Gestion de réseau,
- Sécurité,
- Profil de communication,
- Procédures sans fil, et
- Passerelle.

2 Références normatives

Les documents suivants sont cités en référence de manière normative, en intégralité ou en partie, dans le présent document et sont indispensables pour son application. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC 61158-1:2014, *Réseaux de communication industriels – Spécifications des bus de terrain – Partie 1: Présentation et lignes directrices des séries IEC 61158 et IEC 61784*

IEC 61158-2, *Réseaux de communication industriels – Spécifications des bus de terrain – Partie 2: Spécification et définition des services de la couche physique*

IEC 61158-3-20:2014, *Réseaux de communication industriels – Spécifications des bus de terrain – Partie 3-20: Définition des services de la couche liaison de données – Eléments de Type 20*

IEC 61158-4-20:2014, *Réseaux de communication industriels – Spécifications des bus de terrain – Partie 4-20: Spécification du protocole de couche liaison de données – Eléments de Type 20*

IEC 61158-5-20:2014, *Réseaux de communication industriels – Spécifications des bus de terrain – Partie 5-20: Définition des services de la couche application – Eléments de Type 20*

IEC 61158-6-20:2014, *Réseaux de communication industriels – Spécifications des bus de terrain – Partie 6-20: Spécification du protocole de la couche application – Eléments de Type 20*

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IEC 61784-1:2014, *Réseaux de communication industriels – Profils – Partie 1: Profils de bus de terrain*

IEC 61784-2:2014, *Réseaux de communication industriels – Profils – Partie 2: Partie 2: Profils de bus de terrain supplémentaires pour les réseaux en temps réel basés sur l'ISO/IEC 8802-3*

ISO/IEC 7498-1, *Technologies de l'information – Interconnexion de systèmes ouverts (OSI) – Modèle de référence de base: Le modèle de base*

ISO/IEC 7498-3, *Technologies de l'information – Interconnexion de systèmes ouverts (OSI) – Modèle de référence de base: Dénomination et adressage*

ISO/IEC/IEEE 60559, *Information technology – Microprocessor Systems – Floating-Point arithmetic* (disponible en anglais seulement)

ISO/IEC 8824 (toutes les parties), *Information Technology – Abstract Syntax Notation One (ASN.1)* (disponible en anglais seulement)

ISO/IEC 8859-1, *Information technology – 8-bit single-byte coded graphic character sets – Part 1: Latin alphabet No. 1* (disponible en anglais seulement)

ISO/IEC 9545, *Technologies de l'information – Interconnexion de systèmes ouverts (OSI) – Structure de la couche application*

ISO/IEC 10731, *Technologies de l'information – Interconnexion de systèmes ouverts (OSI) – Modèle de référence de base – Conventions pour la définition des services OSI*

IEEE Std 802-2001, *IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture* (disponible en anglais seulement)

IEEE Std 802.15.4-2011, *IEEE Standard for Local and metropolitan area networks – Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)* (disponible en anglais seulement)

IEEE Std 802.15.4e:2012, *IEEE Standard for Local and metropolitan area networks – Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs) – Amendment 1: MAC sublayer*

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3 Termes, définitions, symboles, abréviations et conventions

Pour les besoins du présent document, les termes suivants tels que définis dans ces publications s'appliquent.

3.1 Termes et définitions du modèle de référence

3.1.1 Termes et définitions issus de l'ISO/IEC 7498-1 et termes issus de l'ISO/IEC 7498-3

La présente norme est basée en partie sur les concepts développés dans l'ISO/IEC 7498-1 et dans l'ISO/IEC 7498-3 et utilise les termes suivants qui y sont définis.

a) syntaxe abstraite

b) entité d'application

c) invocation d'entité d'application

d) processus d'application

e) invocation de processus d'application
f) unité de données de protocole d'application
g) élément de service d'application
h) transaction d'application
i) unité de données de protocole DL
j) unité de données de service DL
k) entité DL (N=2)
l) données utilisateur DLS
m) unité de données de protocole NL
n) unité de données de service NL
o) entité NL (N=3)
p) données utilisateur NLS
q) contexte de présentation
r) système ouvert réel
s) unité de données de protocole TL
t) unité de données de service TL
u) entité TL (N=4)
v) données utilisateur TLS
w) syntaxe de transfert

3.1.2 Termes et définitions issus de l'ISO/IEC 9545

a) association d'applications
b) contexte d'application
c) nom de contexte d'application
d) invocation d'entités d'application
e) type d'entité d'application
f) invocation de processus d'application
g) type de processus d'application
h) élément de service d'application
i) élément de service de contrôle d'application

3.1.3 Termes et définitions issus de l'ISO/IEC 8824

a) identificateur d'objet
b) type
c) valeur
d) type simple
e) type structuré
f) type composant
g) marqueur
i) true
j) false
k) type entier
m) type "chaîne d'octets"
n) type null

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o) type séquence
p) séquence de type
q) type choix
r) type marqué
s) tout type
t) module
u) production

3.1.4 Termes et définitions de l'ISO/IEC 8825-1

a) encodage (d'une valeur de donnée)
b) valeur de donnée
c) octets d'identification (la présente norme utilise le singulier)
d) octet(s) de longueur (la présente norme utilise à la fois le singulier et le pluriel)
e) octets de contenu

3.2 Termes et définitions spécifiques

3.2.1
nombre d'intervalles absolus
nombre de tous les intervalles de temps qui ont eu lieu depuis que le réseau a été constitué

Note 1 à l'article: Ce nombre est toujours incrémenté et n'est jamais remis à un nombre fixe quelconque ou à zéro. Sa valeur courante est toujours le numéro de séquence de l'intervalle de temps courant. Sa valeur maximale est (2^{40}-1), après quoi il repasse par zéro.

3.2.2
acquitter
donner une réponse explicite de liaison de données pour la réception réussie d'une DLPDU adressée et non diffusée à partir d'un appareil d'origine de DLE et la seconde DLPDU d'une transaction à deux DLPDU

3.2.3
adaptateur
appareil de réseau qui permet la connexion et la communication avec un appareil de terrain qui n'a pas de connexion directe à un réseau de Type 20

3.2.4
DLPDU d'annonce
DLPDU invitant de nouveaux appareils sur le réseau

Note 1 à l'article: Lorsqu'un appareil souhaite se rattacher à un réseau, il se met à l'écoute pour détecter ces DLPDU et utilise alors l'information contenue dans la DLPDU pour se synchroniser au réseau et lancer le processus de rattachement.

3.2.5
canal analogique
signal électrique à variations continues reliant un appareil de terrain au reste du système d'acquisition ou de contrôle de données

Note 1 à l'article: Certains appareils de terrain prennent en charge plusieurs canaux analogiques (entrée ou sortie).

Note 2 à l'article: Chaque canal analogique émet une seule variable dynamique à destination ou en provenance de l'appareil de terrain.

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3.2.6
application
fonction ou structure de données pour laquelle des données sont consommées ou produites

[SOURCE: IEC 61158-6-9:2014: 3.2.1]

3.2.7
domaine d'application
classification du processus d'application reposant sur une exigence de priorité et de capacité de communication

3.2.8
objet d'application
classe d'objets qui gère et assure l'échange de messages sur le réseau et dans l'appareil réseau, lors de l'exécution

Note 1 à l'article: Plusieurs types de classes d'objets d'application peuvent être définis.

[SOURCE: IEC 61158-6-9:2014, 3.2.3]

3.2.9
relation d'applications
association de type coopératif entre deux invocations d'entités d'application (application-entity-invocation) ou plus, dans un but d'échange d'informations et de coordination de leur action conjointe

Note 1 à l'article: Cette relation est activée soit par l'échange d'unités de données de protocole d'application, soit àla suite d'activités de préconfiguration.

[SOURCE: IEC 61158-6-9:2014, 3.2.8]

3.2.10
point d'extrémité de relation d'applications
contexte et comportement d'une relation d'applications tels que vus et maintenus par l'un des processus d'application impliqués dans la relation d'applications

Note 1 à l'article: Chaque processus d'application impliqué dans la relation d'applications conserve son propre point d'extrémité de relation d'applications.

3.2.11
temps ASN
temps représenté sous la forme d'un nombre d'intervalles de temps absolus; toute instance temporelle est égale au nombre d'intervalles de temps absolus an niveau de l'instance en question

3.2.12
attribut
description d'une caractéristique visible de l'extérieur d'un objet

Note 1 à l'article: Les attributs d'un objet contiennent des informations afférentes à des parties variables d'un objet. Ils fournissent généralement des informations de statut ou régissent le fonctionnement d'un objet. Des attributs peuvent aussi avoir une incidence sur le comportement d'un objet. Les attributs se répartissent en attributs de classes et attributs d'instances.

3.2.13
disponibilité
pourcentage de paquets qui parvient à la passerelle dans la période où l'appareil est en mode rafale

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3.2.14
comportement
indication de la façon dont un objet réagit à des événements particuliers

Note 1 à l'article: Sa description inclut la relation entre des valeurs d'attributs et des services.

3.2.15
diffusion
processus d'envoi d'une PDU à tous les appareils reliés au réseau et capables de recevoir la transmission

3.2.16
adresse de diffusion
adresse utilisée par un maître pour envoyer une commande à tous les appareils

3.2.17
occupé
état d'un appareil actif en train de réaliser différentes tâches et qui ne peut pas exécuter une commande à l'instant en question

3.2.18
canal
bande de fréquences RF utilisée pour transmettre un signal modulé transportant des paquets

3.2.19
mise de canal en liste noire
méthode pour mettre un canal RF hors service

3.2.20
saut de canal
variation régulière de la fréquence d'émission ou de réception pour combattre les perturbations et les évanouissements

3.2.21
décalage de canal
valeur spécifique à la liaison fournie par le gestionnaire de réseau, utilisée pour calculer le canal à utiliser lors du saut de canal

3.2.22
classe
ensemble d'objets, qui représentent tous le même type de composant système

Note 1 à l'article: Une classe est une généralisation de l'objet, un modèle qui permet de définir des variables et des méthodes. Tous les objets d'une classe ont une forme et un comportement identiques, mais leurs attributs contiennent en général des données différentes.

3.2.23
attribut de classe
attribut partagé par tous les objets au sein de la même classe

3.2.24
code de classe
identifiant unique attribué à chaque classe d'objets

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3.2.25
service spécifique à une classe
service défini par une classe d'objets particulière pour accomplir une fonction requise qui n'est pas remplie par un service commun

Note 1 à l'article: Un objet spécifique à une classe est unique pour la classe d'objets qui le définit.

3.2.26
évaluation de canal libre
ensemble d'essais effectués pendant que le canal RF est utilisé afin d'éviter de lancer une transaction

Note 1 à l'article: Elle est effectuée en écoutant le canal avant d'envoyer la première DLPDU d'une transaction. Si un signal est détecté, la transaction est différée jusqu'à un intervalle de temps TDMA ultérieur.

3.2.27
client
a) objet qui utilise les services d'un autre objet (serveur) pour accomplir une tâche

b) émetteur d'un message auquel un serveur réagit, par exemple, rôle d'un point d'extrémité de relation entre applications, dans lequel ce dernier envoie des unités APDU de demande de service confirmé à un point d'extrémité de relation entre applications jouant le rôle de serveur

[SOURCE: IEC 61158-6-9:2014, 3.2.17]

3.2.28
coexistence
état dans lequel toutes les solutions de communication sans fil d'une installation utilisant un medium commun satisfont à toutes les exigences de communications de leur application

Note 1 à l'article: Cette définition de la coexistence est cohérente avec celle de l'IEEE 802.15.2-2003.

[SOURCE: IEC 62657-2:2013, 3.1.12]

3.2.29
conformité, conforme à
résultat d'un examen systématique du degré de satisfaction d'un produit, d'un processus ou d'un service aux exigences spécifiées

Note 1 à l'article: Ce terme et sa définition sont dérivés du terme “évaluation de la conformité” tel que défini par l'IEC 60050-151-16-14:2001.

3.2.30
connecté
appareil qui a émis une demande de rattachement

3.2.31
conformité, conforme à
données ou informations appartenant ou ayant trait à une norme, qui correspondent aux exigences d'une autre norme, loi ou document de base

3.2.32
trajet d'acheminement
flux unidirectionnel d'unités APDU à travers une relation d'applications

3.2.33
cyclique
terme utilisé pour décrire des événements qui se produisent d'une manière régulière et répétitive

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3.2.34
appareil
entité contenant une mise en œuvre d'un bus de terrain de Type 20

Note 1 à l'article: Le terme appareil et appareil WirelessHART sont synonymes de l'expression "équipements radio et équipements terminaux de télécommunication" (R&TTE, de l'anglais Radio and Telecommunications Terminal Equipment) et du terme «équipements» utilisé dans certaines normes harmonisées comme l'EN 300 328.

3.2.35
identifiant d'appareil
numéro de série pour un appareil qui est unique parmi toutes les instances d'un même type d'appareil

3.2.36
profil d'appareil
ensemble d'informations et de fonctionnalités liées à l'appareil et assurant la cohérence entre appareils similaires du même type

3.2.37
type d'appareil étendu
type d'un appareil selon le fabricant, comme spécifié au Tableau 6 de l'IEC 61158-6-20:2014

3.2.38
variable d'appareil
données définies de manière unique au sein d'un appareil de terrain et toujours associées à une information de processus cyclique

Note 1 à l'article: Une valeur de variable d'appareil varie en fonction des changements et variations du processus auquel l'appareil est relié.

3.2.39
découverte
processus consistant à trouver un nouveau voisin en écoutant la DLPDU spéciale qui indique la présence de l'appareil

3.2.40
liaison de découverte
liaison utilisée pour émettre et recevoir la DLPDU spéciale qui indique la présence de l'appareil

3.2.41
variable dynamique
connexion entre un processus et un canal analogique

Note 1 à l'article: Un appareil peut contenir des variables primaires, secondaires, tertiaires et quaternaires. Ces variables sont réunies sous le nom de variables dynamiques.

3.2.42
point d'extrémité
l'une des entités en communication impliquées dans une connexion

3.2.43
erreur
discordance entre une valeur ou un état calculé(e), observé(e) ou mesuré(e) et la valeur ou l'état spécifié(e) ou théoriquement correct(e)

3.2.44
code d'erreur
identification d'un type spécifique d'erreur dans une classe d'erreurs

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3.2.45
appareil de terrain
appareil de réseau relié au processus ou à l'équipement de l'installation

Note 1 à l'article: Il se connecte directement au capteur ou actionneur ou accomplit une fonction de commande de processus et il est directement connecté à la couche physique de Type 20.

3.2.46
canal de fréquence
attribution du spectre de fréquences dans une bande de fréquences donnée

3.2.47
passerelle
appareil de réseau contenant au moins une interface d'hôte telle qu'une interface série ou Ethernet, faisant office de point d'entrée ou de point de sortie permettant la communication entre des applications hôtes et des appareils de terrain

3.2.48
graphe
ensemble de trajets orientés parmi des appareils de réseau, de manière à ce qu'au moins deux itinéraires soient possibles pour aller d'un appareil d'origine à un appareil de destination

3.2.49
Graph_ID
identifiant utilisé pour indiquer une entrée de graphe spécifique

3.2.50
rattaché
l'appareil est en communication avec le gestionnaire de réseau et a au moins reçu: la clé réseau, son surnom, la session de monodiffusion du gestionnaire de réseau, une supertrame et des liaisons à partir du gestionnaire de réseau, des arêtes de graphe, un voisin source de temps et un itinéraire vers l'application hôte de terminal portatif de gestionnaire de réseau installée sur un appareil portable

3.2.51
supertrame de terminal portatif
supertrame spécifique utilisée pour le diagnostic

3.2.52
norme harmonisée
norme européenne répertoriée au journal officiel de la Commission européenne (CE)

3.2.53
saut
mouvement d'un paquet directement entre deux voisins adjacents dans une transaction de réseau sans la participation d'aucun autre nœud du réseau

3.2.54
saut de vie résiduelle
champ dans l'en-tête réseau de chaque paquet qui spécifie le nombre de sauts résiduels qu'un paquet peut parcourir avant d'être rejeté

3.2.55
rattacher
processus par lequel un appareil de réseau est authentifié et autorisé à participer au réseau

Note 1 à l'article: Un appareil est considéré rattaché lorsqu'il dispose de la clé réseau, d'une session de gestionnaire de réseau et d'une supertrame normale (de non-rattachement) ainsi que de liaisons.

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3.2.56
join_key
clé de sécurité utilisée pour démarrer le processus de rattachement

3.2.57
latence
temps mis par un paquet pour franchir la connexion réseau, de l'expéditeur vers le destinataire

3.2.58
liaison
spécification de communication pleine et entière entre appareils adjacents dans un réseau; elle comprend les paramètres de communication nécessaires pour déplacer une DLPDU d'un saut

Note 1 à l'article: Une liaison est une fonction d'appariement d'adresses de source et de destination, d'affectation de décalages de canaux et d'intervalles de temps, de sens de communication, de communication spécialisée ou partagée et de type. Des liaisons sont attribuées à des supertrames comme partie intégrante du processus de programmation.

3.2.59
contrôle de liaison logique
la plus élevée des deux sous-couches de la couche liaison de données, utilisée pour la détection d'erreurs, le contrôle de débit, le verrouillage de trame et l'adressage

3.2.60
long_tag
chaîne restreinte à 32 caractères du jeu de l'alphabet latin-1 de l'ISO servant à identifier un appareil de terrain

3.2.61
courant de boucle
valeur mesurée en mA en série avec l'appareil de terrain

Note 1 à l'article: Le courant de boucle est un signal analogique quasi continu de 4 mA à 20 mA utilisé pour communiquer une seule valeur entre le système de contrôle et l'appareil de terrain. Les appareils en mode tension utilisent des "Volts CC" comme unités techniques lorsque des valeurs de "courant de boucle" sont utilisées.

3.2.62
port de maintenance
interface dans l'appareil réseau utilisée pour la mise configuration

Note 1 à l'article: Cette interface est utilisée pour écrire la "Join_key" et l'identifiant réseau ainsi que pour surveiller le processus de rattachement.

3.2.63
informations de gestion
informations accessibles par le réseau qui aident à la gestion du fonctionnement du système de bus de terrain, y compris la couche application

Note 1 à l'article: La gestion inclut des fonctions telles que la commande, la surveillance et le diagnostic.

3.2.64
identifiant (ID) de fabricant
énumération de 2 octets identifiant le fabricant qui a produit un appareil

Note 1 à l'article: Un fabricant est tenu d'utiliser la valeur qui lui est attribuée et n'est pas autorisé à utiliser la valeur attribuée à un autre fabricant.

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3.2.65
maître
appareil qui lance une activité de communication en envoyant une APDU de demande à un appareil et attendant une PDU de réponse

3.2.66
contrôle d'accès au support
la plus basse des deux sous-couches de liaison de données, utilisée pour contrôler l'accès au canal de communication

3.2.67
multidiffusion
envoi d'un paquet à plusieurs appareils sur le réseau en utilisant une seule émission

3.2.68
voisin
nœud adjacent sur le réseau dont le niveau de signal reçu (RSL) qui en est issu suggère que la communication est possible au moins dans un sens

3.2.69
table des voisins
liste de tous les appareils que l'appareil considère comme voisins

Note 1 à l'article: Il emmagasine aussi les attributs du voisin.

3.2.70
réseau
série de nœuds reliés par un type donné de support de communication

Note 1 à l'article: Les trajets de connexion entre les nœuds d'une paire peuvent comporter des répétiteurs, des routeurs et des passerelles.

3.2.71
appareil de réseau
appareil ayant une connexion de couche physique directe au réseau

Note 1 à l'article: Chaque appareil de réseau a une adresse unique utilisée pour la communication avec l'appareil. Les appareils de réseau incluent l'appareil de terrain, le point d'accès (à savoir la passerelle), l'adaptateur et le terminal portatif.

3.2.72
network_ID
identifiant utilisé pour indiquer un réseau auquel sont raccordés tous les appareils qui communiquent entre eux

3.2.73
gestionnaire de réseau
entité chargée de configurer le réseau, de programmer la communication entre les appareils de réseau, de gérer les tables de routage et de surveiller et rapporter la santé du réseau

3.2.74
surnom
identifiant attribué à un appareil pour qu'il soit unique au sein du réseau auquel l'appareil est connecté

3.2.75
nœud
appareil logique ou physique adressable attaché au réseau

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3.2.76
nonce
nombre non répétitif dont la construction le rend unique vis-à-vis du paquet courant; il assure que d'anciennes communications ne peuvent pas être réutilisées pour des attaques par rejeu

Note 1 à l'article: Le nonce est nécessaire pour maintenir la sécurité des paquets et garantir l'authenticité de l'expéditeur ainsi que l'intégrité des paquets.

3.2.77
paquet
bits regroupés et formatés émis simultanément à travers le support physique

3.2.78
taux d'erreurs sur les paquets
pourcentage d'échecs d'émissions vers un appareil, fourni voisin par voisin

3.2.79
paquets en retard ou perdus
nombre de paquets en retard ou perdus rapporté par chaque appareil

3.2.80
paramétrage
configuration d'un appareil de terrain de façon à ce qu'il fonctionne correctement dans une installation donnée

3.2.81
portail
combinaison d'une passerelle, d'un gestionnaire de réseau et d'un ou plusieurs points d'accès

3.2.82
configuration
fait de configurer un appareil de terrain pour son intégration au réseau

3.2.83
trajet
liaison de communication directe entre deux appareils voisins sur le réseau maillé

3.2.84
données utiles
contenu d'un message de données en cours d'émission

3.2.85
tube
connexion de communication virtuelle, sécurisée et bidirectionnelle entre appareils homologues

3.2.86
adresse d'interrogation
nombre entier utilisé pour identifier un appareil

Note 1 à l'article: L'adresse d'interrogation est utilisée pour construire une adresse d'un seul octet.

3.2.87
point d'extrémité d'AR prédéfini
point d'extrémité d'AR défini localement dans l'appareil sans utilisation du service création

Note 1 à l'article: Les relations AR prédéfinies qui ne sont pas préétablies sont établies avant utilisation.

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3.2.88
point d'extrémité d'AR préétabli
point d'extrémité d'AR mis en l'état établi pendant la configuration des AE qui contrôlent ses points d'extrémité

3.2.89
itinéraire
séquence de trajets unidirectionnels d'un appareil à un autre reliant un appareil d'origine à un appareil de destination

3.2.90
identifiant (ID) d'itinéraire
identifiant utilisé pour indiquer un itinéraire spécifique

3.2.91
serveur
<rôle> communication d'un AREP dans lequel ce dernier renvoie une APDU de réponse de service confirmée au client qui a émis la demande

3.2.92
serveur
<objet> système qui fournit des services à un autre objet (client)

3.2.93
service
opération ou fonction accomplie par un objet et/ou une classe d'objets à la demande d'un autre objet et/ou d'une autre classe d'objets

Note 1 à l'article: Il est défini un jeu de services communs et il est prévu des dispositions permettant de définir des services spécifiques à l'objet. Les services spécifiques à un objet sont ceux qui sont définis par une classe d'objets particulière pour accomplir une fonction requise qui n'est pas accomplie par un service commun.

3.2.94
identifiant (ID) de session
identifiant utilisé pour indiquer une entrée de session spécifique

3.2.95
esclave
appareil qui déclenche une activité de communication seulement après avoir reçu une PDU de demande provenant d'un appareil maître et qui est tenu d'envoyer une réponse à la demande en question

3.2.96
intervalle de temps
durée fixe qui peut être utilisée pour la communication entre voisins

3.2.97
supertrame
ensemble d'intervalles de temps qui se répètent à une fréquence constante, chaque intervalle de temps étant associé à une liaison

3.2.98
Superframe_ID
identifiant utilisé pour indiquer une entrée de supertrame spécifique

3.2.99
marqueur
chaîne ASCII de 8 caractères utilisée pour identifier un appareil de terrain

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3.2.100
accès multiple par répartition dans le temps
technique de contrôle d'accès au support qui utilise des intervalles de temps lorsqu'il peut y avoir des communications entre appareils

Note 1 à l'article: Il assure des communications déterministes sans collision.

3.2.101
transaction
échange de trames consécutives connexes entre deux entités homologues de contrôle d'accès au support, requis pour une émission réussie

Note 1 à l'article: Une transaction est constituée soit a) d'une émission de PhPDU à partir d'un appareil d'origine, soit b) d'une PhPDU provenant de l'appareil d'origine suivie d'une seconde PhPDU d'acquittement de niveau liaison provenant de l'appareil de destination.

3.2.102
débit
nombre moyen de paquets par seconde émis ou reçus par l'association gestionnaire de réseau/passerelle

3.2.103
temps de transmission
durée nécessaire à un paquet pour aller de la source à la destination au niveau de la couche DLL

3.2.104
monodiffusion
envoi d'un paquet vers un seul appareil sur le réseau

3.2.105
Identifiant unique
identifiant attribué à un appareil qui est unique parmi toutes les instances des appareils conformes à la présente norme et conformes au Profil de communication CP 9/2 utilisant un nom d'organisation identique, comme spécifié en 9.3.1

3.2.106
utilisation
pourcentage de capacité recommandée couramment consommé

3.3 Abréviations

ACK	Acquittement, Acknowledge
AE	Entité d'application, Application entity
AL	Application layer, couche d'application, Application layer
AP	Processus d'application, Application process
APDU	Unité de données de protocole d'application, Application protocol data unit
APO	Objet d'application, Application Object
AR	Relation d'applications, Application relationship
AREP	Point d'extrémité de relation d'applications, Application relationship endpoint
ARPM	Machine protocolaire de Relations d'applications, Application Relationship Protocol Machine
ASCII	Code standard américain pour l'échange d'informations, American Standard Code for Information Interchange
ASE	Elément de service d'application, Application Service Element
ASN	Nombre d'intervalles absolus, Absolute Slot Number
BACK	Acquittement de rafale, Burst acknowledge
CCA	Evaluation de canal libre, Clear channel assessment

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Cnf	Confirmation, Confirmation,
CP	Profil de communication, Communication Profile
CPF	Famille de profils de communication, Communication Profile Family
CRC	Contrôle de redondance cyclique, Cyclic redundancy check
dBm	Rapport de puissance en décibels (dB) de la puissance mesurée, référencé à 1 mW, 0 dBm =1 mW, 10 dBm= 10 mW, 20 dBm= 100 mW, 30 dBm= 1 W(dB)
DL	Couche liaison de données (utilisée comme préfixe), Data-link layer
DLE	Entité de liaison de données (instance active locale de la couche liaison de données), DL-entity
DLL	Couche Entité de liaison de données, Data-link layer
DLM	Gestion de liaison de données, DL-management
DLMS	Service de gestion de liaison de données, DL-management service
DLPDU	Unité de données de protocole de liaison de données, Data-link protocol data unit
DLS	Service de liaison de données, DL-service
DLSDU	Unité de données de service de liaison de données, DL-service-data-unit
DR	Réponse différée, Delayed response
DRM	Mécanisme de réponse différée, Delayed response mechanism
DSSS	Etalement du spectre en séquence directe, Direct sequence spread spectrum
DUT	Appareil en essai, Device under test
EUI-64	Identifiant unique étendu (64 bits de longueur), Extended unique identifier (64 bits long)
FAL	Couche application de bus de terrain, Fieldbus application layer
FSMP	Machine protocolaire de services FAL, FAL Service Protocol Machine
HCF	Fondation de communication HART™, HART™ Communication Foundation
HTL	Saut de vie résiduelle, Hop to live
ID	Identifiant, Identifier
IEC	Commission Electrotechnique Internationale, International Electrotechnical Commission
Ind	Indication, Indication,
ISM	Industriel, scientifique et médical, Industrial, scientific and medical
UIT-T	Union Internationale des Télécommunications – Secteur de la Normalisation des Télécommunications, International Telecommunication Union – Telecommunication Standardization Sector
KPI	Indicateur de performance clé, Key Performance Indicators
LLC	Contrôle de liaison logique, Logical link control
LSB	Octet de poids faible, Least significant byte
MAC	Contrôle d'accès au support, Medium access control
MIC	Code d'intégrité de message, Message integrity code
MSB	Octet de poids fort, Most significant byte
NL	Couche réseau, Network layer
NL-	Couche réseau (utilisée comme préfixe), Network layer
NLE	Entité de couche réseau (instance locale active de la couche réseau), NL-entity
NLM	Gestion de couche réseau, NL-management
NLMS	Service de gestion de couche réseau, NL-management service
NLS	Service de couche réseau, NL-service
NLSDU	Unité de données de service de couche réseau, NL-service-data-unit
NPDU	Unité de données de protocole de couche réseau, NL-protocol-data-unit
NSDU	Unité de données de service de couche réseau, NL-service-data-unit
O-QPSK	Modulation par déplacement de phase quadrivalente décalée, Offset Quadrature Phase-Shift Keying
OSI	Interconnexion de systèmes ouverts, Open Systems Interconnect

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OUI	Identifiant propre à une organisation, Organizationally Unique Identifier
PER	Taux d'erreurs sur les paquets, Packet Error Rate
PDU	Unité de données de protocole, Protocol data unit
PhE	Entité PhL (instance locale active de la couche physique), PhL-entity
PhL	Couche physique (utilisée comme préfixe), Physical layer
PhPDU	Unité de données de protocole de couche physique [ISO/IEC 7498-1], PhL-protocol-data-unit
PhS	Service de couche physique [ISO/IEC 7498-1], Physical layer service
PHY	Couche physique [IEEE 802.15.4], Physical layer
QoS	Qualité de service, Quality-of-service
Req	Demande, Request
RF	Radiofréquence, Radio Frequency
RSL	Niveau de signal reçu, Received signal level
Rsp	Réponse, Response
RSV	Réservé, Reserved
SAP	Point d'accès au service, Service access point
SN	Bit de signe, Sign bit
SOM	Début de message, Start of message
STX	Début d'une transaction, Start of transaction
AMRT	Accès multiple par répartition dans le temps, Time Division Multiple Access
TL	Couche transport, Transport layer
TL-	Couche transport (utilisé comme préfixe), Transport layer
TLE	Entité de couche transport (instance locale active de la couche transport), TL-entity
TLM	Gestion de couche transport, TL-management
TLMS	Service de gestion de couche transport, TL-management service
TLS	Service de couche transport, TL-service
TMPM	Machine protocolaire de mapping de couche transport, Transport layer Mapping Protocol Machine
TPDU	Unité de données de protocole de couche transport, TL-protocol-data-unit
TSDU	Unité de données de service de couche transport, TL-service-data-unit
VFD	Appareil de terrain virtuel, Virtual field device

3.4 Conventions

3.4.1 Conventions utilisées pour les services DL

La présente norme utilise les conventions descriptives données dans l'ISO/IEC 10731.

Le modèle de service, les primitives de service et les diagrammes de séquence temporelle utilisés sont des descriptions totalement abstraites; ils ne constituent pas une spécification pour une mise en œuvre.

Les primitives de service, utilisées pour représenter les interactions utilisateur de service/fournisseur de service (voir ISO/IEC 10731), acheminent des paramètres qui indiquent les informations disponibles dans l'interaction entre utilisateur et fournisseur.

La présente norme utilise un format de tableau pour décrire les paramètres de composants des primitives de service des couches Physique, Liaison de données, Réseau, Transport et Application. Les paramètres qui s'appliquent à chaque groupe de primitives sont présentés dans des tableaux dans la suite de la présente norme. Chaque tableau comporte jusqu'à six colonnes, contenant le nom du paramètre de service et une colonne pour chacune des primitives et des sens de transfert des paramètres utilisés par le service:

– les paramètres d'entrée de la primitive "request";

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- les paramètres de sortie de la primitive de demande;
- les paramètres de sortie de la primitive "indication";
- les paramètres d'entrée de la primitive "response"; et
- paramètres de sortie de la primitive "confirm".

Un paramètre (ou une partie de celui-ci) est énuméré dans chaque rangée de chaque tableau. Pour les services locaux, seule est utilisée la primitive de demande avec paramètres d'entrée et de sortie. Dans les colonnes appropriées de la primitive de service, un code est utilisé pour spécifier le type d'usage du paramètre sur la primitive et le sens de paramètres spécifié dans la colonne:

M le paramètre est obligatoire pour la primitive.

U le paramètre est une option de l'utilisateur et peut ou peut ne pas être fourni, cela dépendant de l'usage dynamique de l'utilisateur DLS. Lorsqu'il n'est pas fourni, une valeur par défaut est supposée pour le paramètre

S un seul paramètre dans un groupe de paramètres utilisant ce code est requis.

C le paramètre est conditionné à d'autres paramètres ou à l'environnement de l'utilisateur de DLS.

CU le paramètre est une option utilisateur conditionnelle et peut être autorisé ou ne pas être autorisé, en fonction d'autres paramètres ou de l'environnement de l'utilisateur DLS. Lorsqu'il est autorisé, il peut être fourni ou pas être fourni, en fonction de l'usage dynamique de l'utilisateur DLS. Lorsqu'il est autorisé mais n'est pas fourni, une valeur par défaut est supposée pour le paramètre.

(blanc/vide) le paramètre n'est jamais présent

Certaines entrées sont en plus qualifiées par des éléments entre parenthèses. Ceux-ci peuvent être:

a) une contrainte spécifique au paramètre

(=) indique que le paramètre équivaut du point de vue de la sémantique au paramètre dans la primitive de service située immédiatement à sa gauche dans le tableau;

(≤) indique que le jeu de valeurs de paramètres a un ordre implicite et que la valeur du paramètre est inférieure ou égale à celle du paramètre dans la primitive de service située immédiatement à sa gauche dans le tableau (c'est-à-dire à gauche d'une ou deux colonnes);

(≥) indique que le jeu de valeurs de paramètres a un ordre implicite et que la valeur du paramètre est supérieure ou égale à celle du paramètre dans la primitive de service située immédiatement à sa gauche dans le tableau (c'est-à-dire à gauche d'une ou deux colonnes);

b) une indication qu'une certaine note s'applique à l'entrée;

(n) indique que la note "n" suivante contient des informations complémentaires relatives au paramètre et à son utilisation.

3.4.2 Conventions utilisées pour le protocole DL (diagramme d'états)

La présente norme utilise un diagramme pour représente un diagramme d'état. La convention suivante est utilisée.

- Les rectangles étiquetés représentent les états dans lesquels un composant peut se trouver.
- Les transitions d'état sont des lignes orientées. Elles montrent l'état qu'un composant quitte et l'état auquel il passe.
- Une transition est étiquetée avec les événements qui l'ont provoquée et les actions correspondantes (elle peut être vide). Les événements (au-dessus de la ligne) provoquant la transition sont séparés des actions résultantes (en-dessous de la ligne) par une ligne horizontale.

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- Un tilde (" ~ ") signifie le complément à un ou la négation.

3.4.3 Conventions utilisées pour le service Couche application

3.4.3.1 Vue d'ensemble

La Couche application de bus de terrain (FAL) est définie comme étant un jeu d'éléments de service d'application (ASE) orientés objets. Chaque ASE est spécifié dans un paragraphe distinct. Chaque spécification d'ASE est constituée de deux parties, à savoir sa spécification de classe et sa spécification de service.

La spécification de classe définit les attributs de la classe. La spécification de services définit les services fournis par l'ASE.

3.4.3.2 Conventions utilisées pour les définitions de classes

Les définitions de classes sont décrites à l'aide de modèles. Chaque modèle est constitué d'une liste d'attributs de la classe. Un exemple du modèle est montré ci-dessous:

ASE de FAL:			**Nom de l'ASE**
CLASSE:			Nom de la classe
ID de CLASSE:			#
CLASSE PARENT:			Nom de la classe parent
ATTRIBUTS:			
1	(o)	Attribut-clé:	identificateur numérique
2	(o)	Attribut-clé:	nom
3	(m)	Attribut:	nom d'attribut(valeurs)
4	(m)	Attribut:	nom d'attribut(valeurs)
4.1	(s)	Attribut:	nom d'attribut(valeurs)
4.2	(s)	Attribut:	nom d'attribut(valeurs)
4.3	(s)	Attribut:	nom d'attribut(valeurs)
5.	(c)	Contrainte:	expression de la contrainte
5.1	(m)	Attribut:	nom d'attribut(valeurs)
5.2	(o)	Attribut:	nom d'attribut(valeurs)
6	(m)	Attribut:	nom d'attribut(valeurs)
6.1	(s)	Attribut:	nom d'attribut(valeurs)
6.2	(s)	Attribut:	nom d'attribut(valeurs)
SERVICES:			
1	(o)	OpsService:	nom du service
2.	(c)	Contrainte:	expression de la contrainte
2.1	(o)	OpsService:	nom du service
3	(m)	MgtService:	nom du service

(1) L'article "ASE FAL:" est le nom de l'élément ASE de la couche FAL (ASE FAL) qui fournit les services pour la classe spécifiée.

(2) L'article "CLASSE:" est le nom de la classe spécifiée. Tous les objets définis à l'aide de ce modèle seront une instance de cette classe. La classe peut être spécifiée par la présente norme ou par un utilisateur de la présente norme.

(3) L'article "CLASS ID:" est un numéro qui identifie la classe spécifiée. Ce numéro est unique au sein de l'ASE de FAL qui fournira les services pour cette classe. Lorsqu'il est qualifié par l'identité de son ASE de FAL, il identifie sans ambiguïté la classe relevant du domaine d'application de la FAL. La valeur "NUL" indique que la classe ne peut pas être instanciée. Les identifiants de classe entre 1 et 255 sont réservés par la présente norme pour identifier des classes normalisées. Ils ont été attribués pour conserver la compatibilité avec des normes nationales existantes. Les identifiants de classe allant de 256 à 2048 sont alloués pour identifier les classes définies par l'utilisateur.

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(4) L'article "CLASSE PARENTE:" est le nom de la classe parente pour la classe spécifiée. Tous les attributs définis pour la classe parent et hérités par celle-ci sont hérités pour la classe définie et ils n'ont donc pas à être redéfinis dans le modèle pour cette classe.

NOTE La classe parent "TOP" indique que la classe définie est une définition de classe initiale. La classe parent "TOP" est utilisée comme point de départ à partir duquel toutes les autres classes sont définies. L'usage de "TOP" est réservé pour les classes définies par la présente norme.

(5) L'étiquette "ATTRIBUTS" indique que les entrées suivantes sont des attributs définis pour la classe.

a) Chacune des entrées d'attribut contient un numéro de ligne dans la colonne 1, un indicateur obligatoire (m) / facultatif (o) / conditionnel (c) / sélecteur (s) dans la colonne 2, une étiquette de type d'attribut dans la colonne 3, un nom ou une expression conditionnelle dans la colonne 4, et, facultativement, une liste de valeurs énumérées dans la colonne 5. Dans la colonne suivant la liste de valeurs, la valeur par défaut pour l'attribut peut être spécifiée.

b) Les objets sont normalement identifiés par un identificateur numérique et/ou par un nom d'objet. Dans les modèles de classe, ces attributs clés sont définis sous l'attribut clé.

c) Le numéro de ligne définit la séquence et le niveau d'imbrication de la ligne. Chaque niveau d'imbrication est identifié par période. L'imbrication est utilisée pour spécifier

i) des champs d'un attribut structuré (4.1, 4.2, 4.3),

ii) des attributs conditionnés à un énoncé de contrainte (5). Les attributs peuvent être obligatoires (5.1) ou facultatifs (5.2) si la contrainte est vraie. Tous les attributs facultatifs n'exigent pas des énoncés de contraintes comme le fait l'attribut défini en (5.2),

iii) les champs sélection d'un attribut de type choix (6.1 et 6.2).

(6) L'étiquette "SERVICES" indique que les entrées suivantes sont des services définis pour la classe.

a) Un (m) dans la colonne 2 indique que le service est obligatoire pour la classe, alors qu'un (o) indique qu'il est facultatif. Un (c) dans cette colonne indique que le service est conditionnel. Lorsque tous les services définis pour une classe sont facultatifs, l'un au moins doit être sélectionné quand une instance de la classe est définie.

b) L'étiquette "OpsService" désigne un service opérationnel (1).

c) L'étiquette "MgtService" désigne un service de gestion (2).

d) Le numéro de ligne définit la séquence et le niveau d'imbrication de la ligne. Chaque niveau d'imbrication est identifié par période. L'imbrication dans la liste de services sert à spécifier des services conditionnés à un énoncé de contrainte.

3.4.3.3 Conventions utilisées pour les définitions des services

3.4.3.3.1 Généralités

La présente norme utilise les conventions descriptives données dans l'ISO/IEC 10731.

Le modèle de service, les primitives de service et les diagrammes de séquence temporelle utilisés sont des descriptions totalement abstraites; ils ne constituent pas une spécification pour une mise en œuvre.

3.4.3.3.2 Paramètres de service

Les primitives de service sont utilisées pour représenter les interactions entre utilisateur de service et fournisseur de service (ISO/IEC 10731). Elles acheminent des paramètres qui indiquent des informations disponibles dans l'interaction entre utilisateur et fournisseur.

NOTE 1 Voir la Note en 3.4.3.3.3 relative à la non-inclusion des paramètres de service appropriés à la spécification de protocole ou à la spécification d'interface de programmation ou à la spécification de mise en œuvre, mais pas à une définition de service abstrait.

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La présente norme utilise un format de tableau pour décrire les paramètres de composants des primitives de service. Les paramètres qui s'appliquent à chaque groupe de primitives de service sont présentés dans des tableaux dans la suite de la présente norme. Chaque tableau comprend jusqu'à six colonnes: une colonne pour le nom du paramètre de service, et une colonne pour chacune des primitives et sens de transfert des paramètres utilisés par le service. Les six colonnes possibles sont

1) le nom du paramètre;
2) les paramètres d'entrée de la primitive "request" (demande);
3) les paramètres de sortie de la primitive "request" (demande);

NOTE 2 Il s'agit d'une fonctionnalité rarement utilisée. Sauf spécification contraire, les paramètres de primitive 'demande' sont des paramètres d'entrée.

4) les paramètres de sortie de la primitive "indication";
5) les paramètres d'entrée de la primitive "response" (réponse); et
6) les paramètres de sortie de la primitive "confirm" (confirmation).

NOTE 3 Les primitives "demande", "indication", "réponse" et "confirmation" sont aussi respectivement appelées primitives "requestor.submit", "acceptor.deliver", "acceptor.submit", et "requestor.deliver" (voir ISO/IEC 10731).

Un paramètre (ou un composant de celui-ci) est énuméré dans chaque rangée de chaque tableau. Dans les colonnes appropriées de la primitive de service, un code est utilisé pour spécifier le type d'usage du paramètre sur la primitive spécifiée dans la colonne:

M le paramètre est obligatoire pour la primitive

U le paramètre est une option de l'utilisateur et peut ou peut ne pas être fourni, cela dépendant de l'usage dynamique de l'utilisateur du service. Lorsqu'il n'est pas fourni, une valeur par défaut est supposée pour le paramètre.

C le paramètre est conditionné à d'autres paramètres ou à l'environnement de l'utilisateur du service.

– (blanc/vide) Le paramètre n'est jamais présent

S le paramètre est un élément sélectionné.

Certaines entrées sont en plus qualifiées par des éléments entre parenthèses. Ceux-ci peuvent être

a) une contrainte spécifique au paramètre:

indique que le paramètre équivaut du point de vue de la sémantique au paramètre dans la primitive de service située immédiatement à sa gauche dans le tableau,

b) une indication qu'une certaine note s'applique à l'article:

"(n)" indique que la note "n" suivante contient des informations complémentaires relatives au paramètre et à son utilisation.

3.4.3.3.3 Procédures de service

Les procédures sont définies en termes des

- interactions entre entités d'application via l'échange d'unités de données de protocole d'application de bus de terrain, et
- interactions entre un fournisseur de services de couche application et un utilisateur de service de couche application dans le même système, via l'invocation de primitives de service de couche application.

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Ces procédures sont applicables à des instances de communication entre systèmes qui prennent en charge des services de communication à contrainte temporelle au sein de la couche application de bus de terrain.

NOTE Les services de la Couche liaison de données définissent des jeux de services abstraits. Il ne s'agit ni de spécifications de protocole, ni de spécifications de mise en œuvre, ni de spécifications d'interface de programmation concrète. Par conséquent il y a des limites à la mesure dans laquelle les procédures de service définies à l'Article 5 peuvent être mandatées. Les aspects de protocole qui peuvent varier parmi différentes spécifications de protocole ou différentes mises en œuvre qui instancient les mêmes services abstraits ne sont pas appropriés pour être inclus dans ces définitions de service, excepté au niveau d'abstraction qui est nécessairement commun à toutes ces expressions. Dans le présent document, l'Article 7 est l'équivalent de la sous-série IEC 61158-5.

Par exemple, le moyen par lequel des fournisseurs de service apparient des unités de données protocolaires (PDU) de demande et de réponse est approprié pour la spécification dans la norme de spécification de protocole de la sous-série IEC 61158-6, mais pas dans une norme de définition de services abstraits de la série IEC 61158-5. De même, les méthodes de mise en œuvre locales par lesquelles un fournisseur de service ou utilisateur de service apparie des primitives de demande et de confirmation, ou des primitives d'indication et de réponse, sont appropriées pour une spécification de mise en œuvre ou pour une spécification d'interface de programmation, mais pas pour une norme de service abstrait ou pour une norme de protocole, excepté à un niveau d'abstraction qui est nécessairement commun à tous les modes de réalisation de la norme de spécification. Dans tous les cas, la définition abstraite n'est pas autorisée à spécifier outre mesure la réalisation d'instanciations plus concrètes.

Des informations supplémentaires sur les procédures de service conceptuelles d'une mise en œuvre d'un protocole qui réalise les services de l'une des définitions de service abstrait de la sous-série IEC 61158-5 peuvent être consultées dans l'IEC 61158-1:2014, Article 9.

3.4.4 Conventions utilisées pour le protocole AL

3.4.4.1 Concept général

La couche FAL est définie comme un jeu d'éléments ASE orientés objet. Chaque ASE est spécifié dans un paragraphe distinct. Chaque spécification d'ASE est constituée de trois parties: ses définitions de classe, ses services et sa spécification de protocole. Les deux premières sont décrites à l'Article 7 et dans la sous-série de normes IEC 61158-5 La spécification du protocole pour chacun des éléments ASE est donnée à l'Article 8 et dans la sous-série de normes IEC 61158-6.

Les définitions de classe définissent les attributs pris en charge par chaque ASE. Les attributs sont accessibles à partir d'instances de la classe en utilisant les services d'ASE de gestion spécifiés à l'Article 7 et dans la sous-série de normes IEC 61158-5. La spécification de services définit les services fournis par l'ASE.

La présente norme utilise les conventions descriptives données dans l'ISO/IEC 10731.

3.4.4.2 Conventions utilisées pour les définitions de classes

Les définitions de mise en correspondance de la couche Liaison de données sont décrites à l'aide de modèles. Chaque modèle est constitué d'une liste d'attributs de la classe. La forme générale du modèle est définie en 3.5.2 de l'IEC 61158-5-20:2014.

3.4.4.3 Conventions utilisées dans les diagrammes d'états

Les conventions utilisées dans les diagrammes d'états sont décrites au Tableau 1.

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Tableau 1 – Conventions utilisées pour les diagrammes d'états

#	Etat courant	Evénement / condition => action	Etat suivant
Nom de cette transition	L'état courant auquel s'applique cette transition d'états	Evénements ou conditions qui déclenchent cette transaction d'états => Les actions qui sont entreprises lorsque les événements ou conditions ci-dessus sont rempli(e)s. Les actions sont toujours indentées sous les événements ou conditions	L'état qui suit la réalisation des actions entreprises dans le cadre de cette transition

Les conventions utilisées dans les diagrammes d'états sont les suivantes:

:= La valeur d'un élément à gauche est remplacée par la valeur d'un élément à droite. Si un élément à droite est un paramètre, il provient de la primitive montrée comme un événement d'entrée.

xxx Un nom de paramètre.

Exemple:

Identifier:= reason

signifie que la valeur d'un paramètre 'raison' est attribuée à un paramètre appelé 'Identifiant.'

"xxx" indique une valeur fixe.

Exemple:

Identifier:= "abc"

signifie que la valeur "abc" est attribuée à un paramètre nommé 'Identifiant.'

= Une condition logique pour indiquer qu'un élément à gauche est égal à un élément à droite.

< Une condition logique pour indiquer qu'un élément à gauche est inférieur à un élément à droite.

> Une condition logique pour indiquer qu'un élément à gauche est supérieur à un élément à droite.

<> Une condition logique pour indiquer qu'un élément à gauche n'est pas égal à un élément à droite.

&& "ET" Logique

|| indique le "OU" logique

Cette construction permet l'exécution d'une séquence d'actions dans une boucle au sein d'une même transition. La boucle est exécutée pour toutes les valeurs de Start_value (valeur de début) à End_value (valeur de fin).

Exemple:

for (Identifier:= start_value to end_value)

actions

endfor

Cette construction permet l'exécution d'actions alternatives dépendant d'une certaine condition (qui pourrait être la valeur d'un certain identifiant ou le résultat d'une action précédente) au sein d'une même transition.

Exemple:

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```
Si (condition)
        actions
sinon
        actions
endif
```

Il est fortement recommandé aux lecteurs de se référer aux paragraphes concernant les définitions des attributs des points d'extrémité de relation d'applications (AREP), aux fonctions locales et aux définitions des FAL-PDU pour appréhender les machines protocolaires. Les lecteurs sont censés avoir une connaissance suffisante de ces définitions et celles-ci sont utilisées sans autres explications.

3.4.4.4 Diagramme de classes

3.4.4.4.1 Généralités

Le langage UML est utilisé dans le présent document pour montrer le diagramme de classes. Le but d'un diagramme de classes est de montrer les objets et leurs relations dans un système. Dans un diagramme de classes, les objets sont des classes (par opposition à un diagramme d'instance où les objets sont des instances de classes). Il existe plusieurs formes de relations, notamment les associations, les généralisations/spécialisations, les regroupements et les dépendances.

3.4.4.4.2 Classes

Les classes contiennent trois compartiments disposés verticalement. Le compartiment supérieur est le nom de la classe. Le compartiment médian énumère les attributs de la classe. Le compartiment inférieur énumère les opérations de la classe. Pour tracer un élément classe sur un diagramme de classes, le compartiment supérieur est obligatoire et les deux compartiments inférieurs sont facultatifs. Le compartiment inférieur n'est pas indispensable dans un diagramme dont le but est seulement de montrer la relation entre des classes. Il n'est pas nécessaire de montrer tous les attributs dans tous les dessins où la classe est utilisée. La Figure 1 illustre une classe de supertrame avec des opérations supprimées. Dans la Figure 1, le nom de la classe est "Supertrame". La classe est illustrée avec trois attributs, Superframe_ID, NumSlots (Nombre d'intervalles de temps) et "Active".

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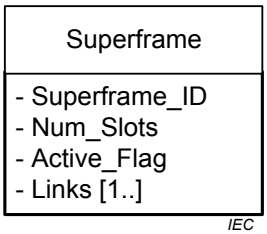


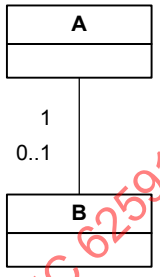
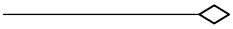
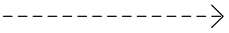
Anglais	Français
Superframe	Supertrame

Figure 1 – Exemple de classe de supertrame

3.4.4.4.3 Relations

Les formes des relations utilisées dans le présent document sont récapitulées au Tableau 2.

Tableau 2 – Notation des relations entre classes

Relation	Fonction	Notation
Association bidirectionnelle	Une association bidirectionnelle est indiquée par une ligne en trait continu entre les deux classes.	
Association unidirectionnelle	Dans une association unidirectionnelle, deux classes sont reliées, mais une seule classe sait que la relation existe. Cela est indiqué par une ligne fléchée entre les deux classes.	
Association indiquant la multiplicité	La multiplicité spécifie le nombre d'instances d'une classe qui peuvent être reliées à une instance d'une autre classe. Dans cet exemple, 0..1 indique qu'une instance de 'A', si elle existe, peut avoir zéro ou une instance de 'B' qui lui est associée (B peut ne pas avoir été encore créé).	
Généralisation	Une relation plus spécifique et une description plus générale, utilisées pour l'héritage.	
Regroupement de base	Relation partie-tout – le cycle de vie d'une classe partie est indépendant du cycle de vie de la classe entière.	
Regroupement composite	Relation partie-tout, le cycle de vie d'une classe partie est dépendant de l'objet contenant.	
Dépendance	Montre une relation entre deux éléments de modèle; elle indique qu'un objet dépend d'un autre objet pour un certain comportement.	

3.4.4.4.4 Héritage

Un important concept en conception orientée objet est l'héritage. L'héritage se réfère à la capacité d'une classe (classe enfant) à hériter de la fonctionnalité identique d'une autre classe (superclasse) et ensuite à ajouter sa propre nouvelle fonctionnalité. Pour modéliser une relation d'héritage sur un diagramme de classes, une ligne en trait continu est tirée de la classe enfant (la classe héritant du comportement) avec une pointe de flèche fermée (ou triangle) pointant vers la superclasse. La Figure 2 illustre une classe de supertrame modélisée comme un type spécialisé de graphe.

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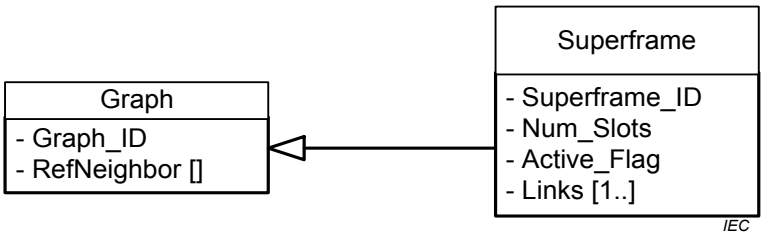
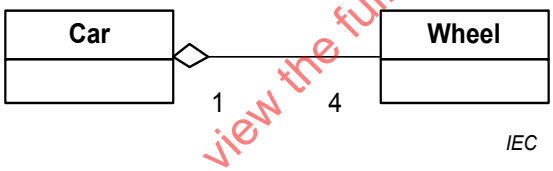


Anglais	Français
Graph	Graphe
Superframe	Supertrame

Figure 2 – Exemple de relation d'héritage

3.4.4.4.5 Regroupement de base

Un autre concept important en conception orientée objet est le regroupement. Le Regroupement sert à modéliser une relation "tout à ses parties". Il existe deux formes de regroupements: le regroupement de base et le regroupement composite. Dans les relations de regroupements de base, le cycle de vie d'une classe partie est indépendant du cycle de vie de la classe entière. Comme illustré à la Figure 3, la voiture est une entité entière et la roue est une partie de l'ensemble Voiture. La roue peut être créée à l'avance et demeurer dans un entrepôt avant d'être montée sur une voiture au cours de l'assemblage.



Anglais	Français
Car	Voiture
Wheel	Roue

Figure 3 – Exemple de regroupement de base

3.4.4.4.6 Regroupement composite

L'autre forme de regroupement est le regroupement composite, habituellement appelé tout simplement "composition". La Figure 4 illustre la relation entre une supertrame et ses liaisons. Dans ce cas, une liaison ne peut pas exister sans la supertrame. La composition est tracée sous la forme d'un losange plein.

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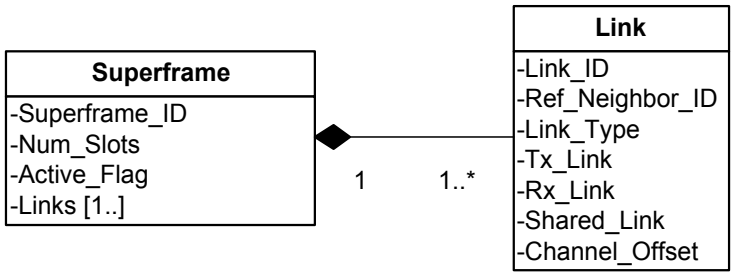

Anglais	Français
Superframe	Supertrame
Link	Liaison

Figure 4 – Exemple de regroupement composite

3.4.4.4.7 Multiplicité

La multiplicité montre le nombre d'instances d'une classe qui peuvent être reliées à une instance d'une autre classe. Le Tableau 3 énumère les exemples d'indicateurs de multiplicité avec leurs significations.

Tableau 3 – Notation de la multiplicité

Valeurs de multiplicité potentielles	
Indicateur	**Signification**
0..1	Zéro ou un
1	Un seul
0..*	Zéro ou plus
*	Zéro ou plus
1..*	Un ou plus
1..2	Un ou deux
4	Seulement quatre
0..5	Zéro à cinq

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4 Spécification de la couche physique et définition de services

4.1 Généralités

Le présent document spécifie la couche physique (PhL) sans fil de Type 20 en complément de la PhL câblée de Type 20 spécifiée dans l'IEC 61158-2.

4.2 Définition de services de couche physique

4.2.1 Aperçu général

Les appareils de Type 20 utilisent les fréquences radioélectriques (RF) pour communiquer entre eux. La distance entre deux appareils peut être de 100 mètres ou plus; elle dépend de la puissance de l'émetteur, du type d'antenne et de l'absence d'obstacles entre les deux appareils. Les appareils conformes au Type 20 peuvent être alimentés en énergie par le secteur, une batterie d'accumulateurs, des appareils de récupération d'énergie (par exemple solaires, vibrations, etc.) ou une combinaison de ceux-ci.

La présente norme définit la PhL de Type 20. Elle est utilisée pour les appareils mettant en œuvre la communication sur réseaux maillés sans fil telle que définie par la présente norme. La PhL prend en charge la méthode de signalisation, l'intensité du signal, la sensibilité des appareils et l'environnement pour envoyer des bits sur les supports réseau. Cette spécification de PhL sans fil repose sur la couche physique DSSS à 2 450 MHz, ainsi que sur l'utilisation de la modulation par déplacement de phase quadrivalente décalée (O-QPSK) définie par l'IEEE STD 802.15.4-2011. La présente norme définit les services que la couche physique fournit aux couches supérieures de la présente norme pour envoyer et recevoir des données sur les supports. Elle définit également les paramètres de gestion locaux utilisés pour commander le fonctionnement de la PhL.

La PhL de la présente norme traite de caractéristiques radio constituant une connexion réseau. Elle s'associe à toute partie de la structure réseau qui ne traite d'informations d'aucune manière. Elle est chargée d'envoyer les bits à travers les supports réseau. Elle ne définit pas la nature d'un bit ou la manière de l'utiliser, mais simplement la manière dont il est envoyé. La PhL est chargée d'émettre et de recevoir les données.

4.2.2 Services de Couche Physique

4.2.2.1 Fonctionnalités des services de la couche physique

La PhL fournit les services suivants:

- Service de contrôle – il prend en charge l'activation ou la désactivation de l'entité de PhL (PhE) et l'accomplissement d'une évaluation de canal libre du support sous-jacent.
- Service messages – il prend en charge le transfert de données utilisateur du service de couche physique (PhS) depuis un utilisateur origine du PhS jusqu'à un utilisateur destination du PhS, et
- Service de gestion de PhL – il prend en charge la configuration de la PhL.

4.2.2.2 Séquence de primitives

Les relations que les primitives de chaque type à l'interface utilisateur du PhS et d'une PhE avec des primitives au niveau de l'utilisateur du PhS et des autres PhE pour des cas exempts d'erreurs sont récapitulées dans les diagrammes de la Figure 5.

Avant d'utiliser la PhE, l'utilisateur du PhS doit l'activer comme présenté dans la séquence a). La séquence c) montre la transmission de PhPDU de la PhL-entity (PhE) source à la PhE de destination. La transmission commence par une évaluation de canal libre comme présenté dans la séquence b). A destination, la réception commence par une indication "Délimiteur de début reçu par la Ph" après réception du délimiteur de début par la PhE. La réception sans erreurs se termine avec une indication de données Ph. S'il y a une erreur de réception, la PhE au niveau de la destination l'indique par un paramètre de statut et ne délivre pas de données utilisateur de services de couche physique (PhS).

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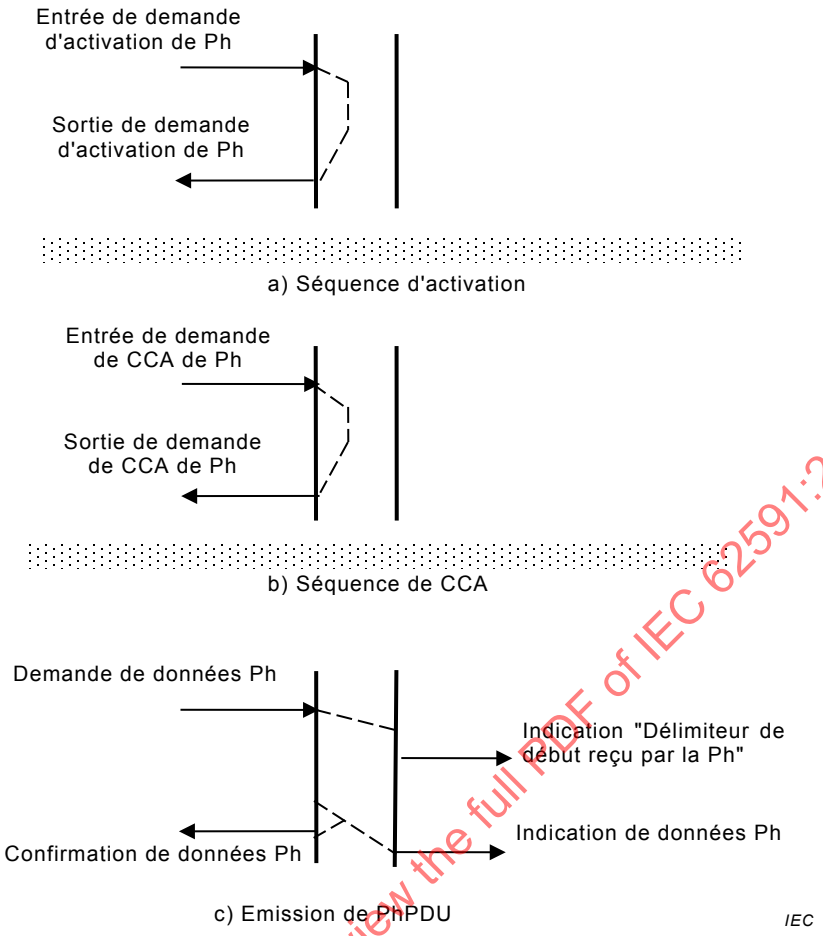

Figure 5 – Séquences de service de couche physique

4.2.2.3 Service d'activation de Ph

4.2.2.3.1 Types de primitives et de paramètres

Le Tableau 4 indique les types de primitives et les paramètres nécessaires au service d'activation de PhL. Ce service est utilisé pour activer ou désactiver la PhE et la placer en mode émission ou réception sur le canal de fréquence spécifié. Le service de "demande" n'est couronné de succès que si le canal est à l'état "repos".

Tableau 4 – Primitives et paramètres d'activation de Ph

	Demande	
Nom de paramètre	Entrée	Sortie
Canal	M	M
Etat	M	M

4.2.2.3.2 Paramètres

4.2.2.3.2.1 Canal

Il spécifie l'un des canaux disponibles pour lesquels ce service est utilisé.

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4.2.2.3.2.2 Etat

Dans la primitive de demande, il spécifie l'état dans lequel il convient que le canal se trouve, lorsque ce service se termine. Dans la primitive de confirmation, il spécifie l'état courant du canal après achèvement du service. Sa valeur peut être Activer ou Désactiver.

4.2.2.4 Service CCA de Ph

4.2.2.4.1 Types de primitives et de paramètres

Le Tableau 5 indique les types de primitives et paramètres nécessaires au service CCA de Ph. Ce service est utilisé pour vérifier l'état du canal. Le service de demande n'est couronné de succès que si le canal est activé en mode réception.

Tableau 5 – Primitives et paramètres d'évaluation CCA de Ph

	Demande	
Nom de paramètre	Entrée	Sortie
Etat		M
NOTE La primitive de demande ne nécessite aucun paramètre.		

4.2.2.4.2 Paramètre – état

Ce paramètre montre le résultat de l'évaluation de canal libre. Les valeurs de ce paramètre sont:

– Canal au repos;
– Canal occupé;
– Emetteur-récepteur éteint et incapable d'accomplir l'évaluation.

4.2.2.5 Service "Délimiteur de début reçu par la Ph"

La seule primitive de ce service est l'indication et elle n'a pas de paramètre. Cette primitive est utilisée par la PhE à la fin de la réception du délimiteur de début en mode réception.

4.2.2.6 Service de données Ph

4.2.2.6.1 Types de primitives et de paramètres

Le Tableau 6 indique les types de primitives et les paramètres nécessaires au service de données Ph.

Tableau 6 – Primitives et paramètres de données Ph

Nom de paramètre	Demande	Indication	Confirmation
Données utilisateur de service Ph	M	C(=)	
Niveau de signal reçu		C	
Statut		M	M

4.2.2.6.2 Paramètres

4.2.2.6.2.1 Données utilisateur de service Ph

Ce paramètre permet l'émission de données entre les utilisateurs du PhS sans modification par le fournisseur du PhS. S'il y a une erreur de réception, ce paramètre est absent de la

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primitive d'indication. Autrement, sa valeur est identique à la valeur dans la primitive de demande.

4.2.2.6.2.2 Niveau de signal reçu

Ce paramètre indique le niveau estimé du signal reçu pour cette PhPDU. Il n'est présent qu'en l'absence d'erreur de réception.

4.2.2.6.2.3 Statut

Dans la primitive d'indication, ce paramètre indique soit le succès, soit l'une des causes d'erreur suivantes:

- Dépassement de capacité du tampon de réception,
- Paquet incomplet.

Dans la primitive de confirmation, ce paramètre indique soit le succès, soit l'une des causes d'erreur suivantes:

- Emetteur-récepteur éteint,
- Récepteur allumé,
- Emetteur occupé.

Si le récepteur est allumé, la PhE ne peut pas émettre.

4.2.2.7 Service établir PhM

4.2.2.7.1 Types de primitives et de paramètres

Le Tableau 7 indique la primitive et les paramètres de ce service.

Tableau 7 – Primitive et paramètres de Etablir PhM

	Demande	
Nom de paramètre	Entrée	Sortie
PhM-object-identifier	M	
Valeur prescrite	M	
Statut		M

4.2.2.7.2 Paramètres

4.2.2.7.2.1 PhM-object-identifier

Ce paramètre spécifie l'objet au sein de la PhE dont la valeur est à modifier. Le domaine de désignation de PhM-object-identifier est la vue locale.

4.2.2.7.2.2 Valeur prescrite

Ce paramètre spécifie la valeur désirée pour l'objet spécifié par le paramètre PhM-object-identifier associé. Son type est identique à celui de l'objet spécifié.

4.2.2.7.2.3 Statut

Ce paramètre permet à l'utilisateur du PhS de déterminer si le service demandé a été fourni avec succès ou a échoué.

La cause de l'échec peut également être fournie.

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4.2.2.8 Service obtenir PhM

4.2.2.8.1 Types de primitives et de paramètres

Le Tableau 8 indique la primitive et les paramètres de ce service.

Tableau 8 – Primitive et paramètres de Obtenir PhM

	Demande	
Nom de paramètre	Entrée	Sortie
PhM-object-identifier	M	
Statut		M
Valeur courante		C

4.2.2.8.2 Paramètres

4.2.2.8.2.1 PhM-object-identifier

Ce paramètre spécifie l'objet au sein de la PhE dont la valeur est demandée. Le domaine de désignation de PhM-object-identifier est la vue locale.

4.2.2.8.2.2 Statut

Ce paramètre permet à l'utilisateur du PhS de déterminer si le service demandé a été fourni avec succès ou a échoué.

La cause de l'échec peut également être fournie.

4.2.2.8.2.3 Valeur courante

Ce paramètre est présent lorsque le paramètre de statut indique que le service demandé a été accompli avec succès. Ce paramètre spécifie la valeur actuelle pour l'objet spécifié par le paramètre "Identifiant d'objet PhM" associé. Son type est identique à celui de l'objet spécifié.

4.3 Spécification du protocole de couche physique

Le protocole de couche physique est spécifié dans l'IEEE Std 802.15.4-2011. Le profil pour la présente norme est spécifié en 9.3.4.

5 Définition de service de couche liaison de données – Eléments de Type 20

5.1 Généralités

Le présent document définit le service de Couche Liaison de données sans fil de Type 20 en complément du service de Couche Liaison de données câblée de Type 20 spécifié dans l'IEC 61158-3-20.

5.2 Services de la couche liaison de données

5.2.1 Fonctionnalités des services de la couche liaison de données

5.2.1.1 Service de transfert de données

Les services Message prennent en charge le transfert de DL-service-data-unit (DLSDU) d'un utilisateur de DLS source vers un utilisateur de DLS de destination. La couche Liaison de données prend en charge la réémission automatique afin d'assurer un transfert de données exempt erreurs.

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5.2.1.2 Service Réception de données

Ce service prend en charge la réception seule de DL-service-data-unit (DLSDU) sans envoyer d'acquittement.

5.2.1.3 Service Evénement

Ces services indiquent les événements sur la liaison:

- réception d'une DLPDU issue d'une DLE indiquant qu'elle se déconnecte de la liaison et fourniture d'une indication de cet événement à l'utilisateur de DLS,
- détection de la défaillance du trajet vers une autre DLE et fourniture d'une indication de cet événement à l'utilisateur du DLS,
- réception d'une DLPDU qui invite une nouvelle DLE à se connecter à la liaison et fourniture d'une indication de cet événement à l'utilisateur de DLS, et
- réception d'une DLPDU issue d'une DLE absente de la Table des voisins de la DLE de réception et fourniture d'une indication de cet événement à l'utilisateur de DLS.

5.2.1.4 Service de Gestion locale de DL

Ce service prend en charge la configuration de la DL et l'accès aux statistiques de la DLL. Les fonctionnalités de gestion de la DL fournissent des moyens pour

- écrire des paramètres de configuration de DLE,
- lire des paramètres de configuration, des paramètres opérationnels et des statistiques de DLE,
- commander des actions majeures de la DLE, et
- recevoir une notification des événements significatifs de DLE.

Ces fonctionnalités constituent ensemble le service de gestion de DL (DLMS).

5.2.1.5 Fonction de sécurité

La DL assure une fonction de sécurité pour les communications entre les paires d'appareils communiquant sur une liaison. Un code est utilisé pour garantir que la DLPDU émane d'un appareil authentifié et approuvé.

Il n'y a pas de service utilisateur explicite pour la sécurité. Les paramètres de sécurité sont écrits en utilisant le service de gestion de DL.

5.2.2 QoS pour le service Messages

5.2.2.1 Priorité

Les primitives du service Messages spécifient la priorité de la DLSDU transférée. Les quatre priorités, de la plus haute à la plus basse, sont définies ci-dessous.

- Commande – il convient que l'utilisateur de DLS se serve de cette priorité pour envoyer une DLSDU d'informations de diagnostic, de configuration ou de commande relatives au réseau.
- Processus de données – il convient que l'utilisateur de DLS se serve de cette priorité pour envoyer une DLSDU contenant des mesures issues d'émetteurs de processus ou des valeurs de consigne à des appareils de commande ou n'importe quelles autres données relatives au processus ou des données statistiques du réseau.
- Normal – il convient que l'utilisateur de DLS se serve de cette priorité pour envoyer une DLSDU contenant n'importe quelles autres données qui ne remplissent pas les critères relatifs à la priorité "Commande", "Traitement des données" ou "Alarme".

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- Alarme – il convient que l'utilisateur de DLS se serve de cette priorité pour envoyer une DLSDU contenant seulement une alarme ou une DLSDU d'événement.

5.2.2.2 Expiration de délai

Chaque demande de message spécifie les bornes supérieures de la durée maximale permise pour l'achèvement de chaque instance correspondante d'une séquence de primitives de message.

5.2.3 Séquence de primitives

Les relations que les primitives de chaque type au niveau de l'interface utilisateur du DLS et d'une DLE ont avec les primitives au niveau de l'utilisateur du DLS et des autres DLE pour des cas exempts d'erreurs sont récapitulées dans les diagrammes de la Figure 6.

La séquence a) montre une simple transaction de monodiffusion sans erreurs. Dans cette séquence, la demande d'émission de DL au niveau de la DLE source insère le message dans la file d'attente d'émission de la DLE. Un peu plus tard, lorsque survient un intervalle de temps prenant en charge la communication programmée à la DLE de destination, la DLPDU transportant la DLSDU de message est émise. Lorsqu'une DLPDU de non-diffusion est reçue et validée, la DLE réceptrice émet un acquittement et génère une indication d'émission de DL à l'attention de son utilisateur. À la réception de l'acquittement, la DLE source génère une confirmation d'émission de DL à l'attention de l'utilisateur demandeur.

La séquence b) montre plusieurs transactions de monodiffusion sans erreurs. Dans cette séquence, la demande d'émission de DL au niveau de la DLE source insère le message dans la file d'attente d'émission de la DLE. Avant que la DLPDU transportant cette DLSDU de message ne soit émise, la DLE reçoit une autre demande d'émission de DL à envoyer à une DLE différente de la demande précédente. Un peu plus tard, lorsque survient un intervalle de temps prenant en charge la communication programmée à la DLE de destination, la DLPDU transportant la seconde DLSDU de message est émise. Lorsqu'une DLPDU de non-diffusion est reçue et validée, la DLE réceptrice émet un acquittement et génère une indication d'émission de DL à l'attention de son utilisateur. Par conséquent, la DLSDU peut ne pas être émise dans le même ordre dans lequel elle a été émise au niveau de la DLE source.

La séquence c) montre une simple transaction de multidiffusion sans erreurs. Dans cette séquence, la demande d'émission de DL au niveau de la DLE source insère le message dans la file d'attente d'émission de la DLE. Un peu plus tard, lorsque survient un intervalle de temps prenant en charge la communication programmée à la DLE de destination, la DLPDU transportant la DLSDU de message est émise. Lorsqu'une DLPDU destinée à plusieurs DLE est reçue et validée, la DLE réceptrice génère une indication d'émission de DL à l'attention de son utilisateur. À l'émission de la DLPDU, la DLE source génère une confirmation d'émission de DL à l'attention de l'utilisateur demandeur.

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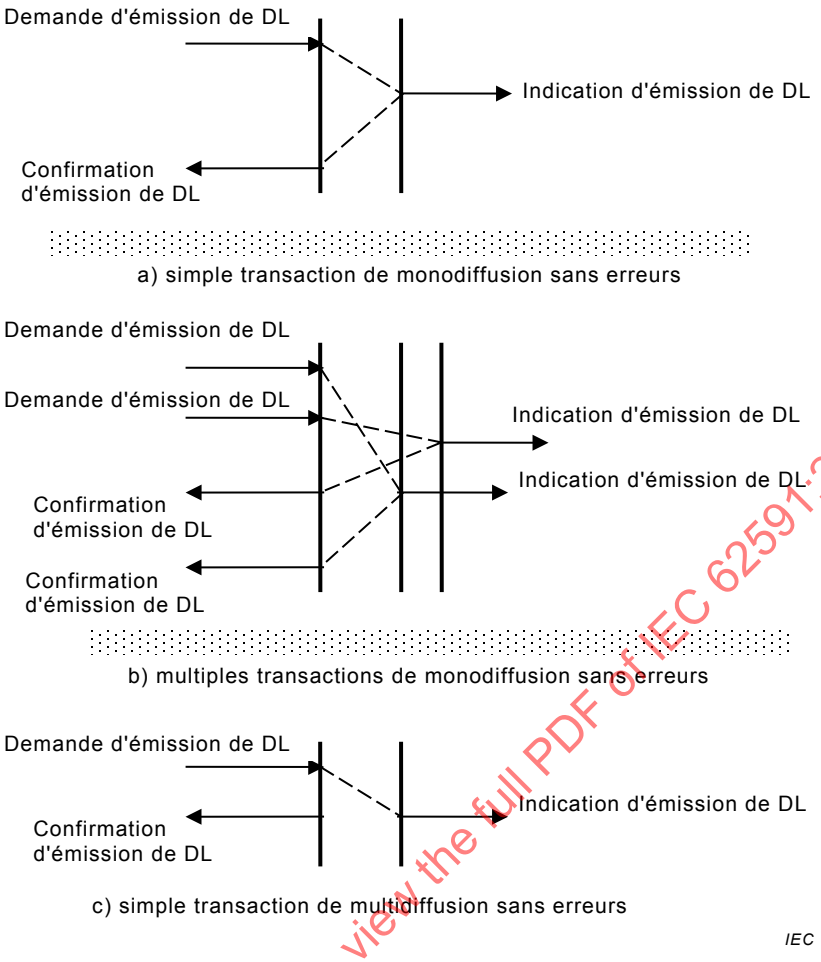

Figure 6 – Séquences de service message sans erreur

Les relations que les primitives de chaque type au niveau de l'interface utilisateur du DLS et d'une DLE ont avec des primitives au niveau de l'utilisateur du DLS et des autres DLE pour des cas d'erreurs sont récapitulées dans les diagrammes de la Figure 7.

La séquence a) montre la DLPDU perdue dans la transmission. La séquence b) montre que la DLE réceptrice a rejeté la DLPDU à cause d'un manque de ressources tampon et envoie un acquittement avec un code de réponse "Erreur". Comme illustré, la DLE source réémet le message tant qu'un acquittement avec un code de réponse "Succès" n'a pas été reçu ou bien tant qu'une limite sur le nombre minimal de nouvelles tentatives n'a pas été atteinte. Si le paquet séjourne dans la DLE source sans acquittement de la part de la DLE de destination pendant une durée supérieure à la valeur spécifiée pour l'expiration de délai, la DLE cesse ses tentatives.

La séquence c) montre que la DLE de destination a reçu la DLPDU soit avec un code d'intégrité de message non valide, soit avec une adresse de destination qui ne concorde pas. La DLE réceptrice rejette la DLPDU et n'envoie pas d'acquittement.

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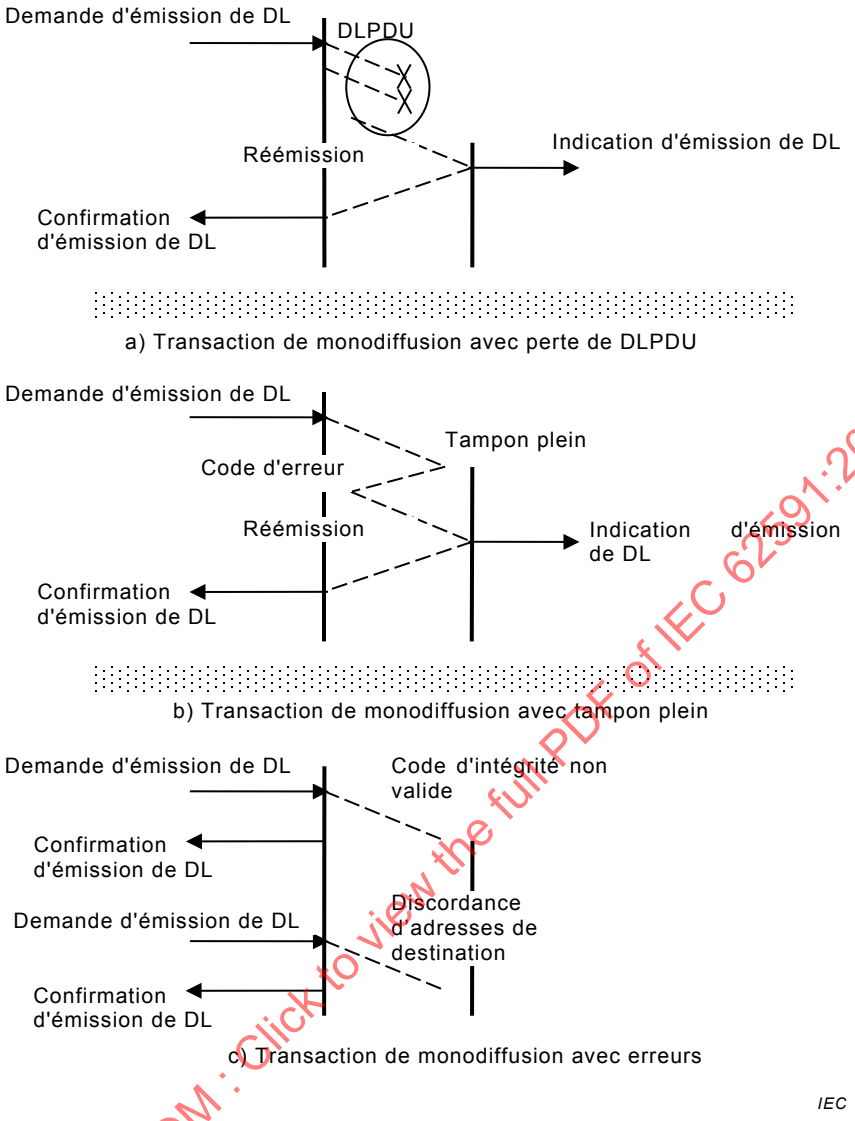

Figure 7 – Séquences de service Messages avec erreurs

La Figure 8 illustre la primitive "réception seule". Celle-ci est disponible dans une DLE qui prend en charge un mode de fonctionnement banalisé dans lequel des communications issues d'autres DLE sont captées.

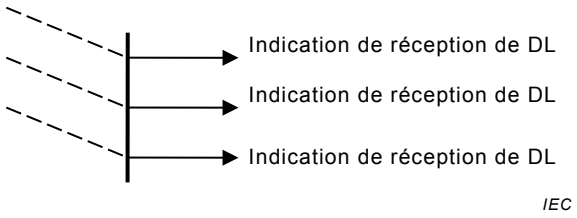

Figure 8 – Service Messages "réception seule"

5.2.4 Service d'émission de DL

5.2.4.1 Fonction

Il peut être utilisé pour émettre une DLSDU indépendante complète d'une DLE vers une autre DLE dans un seul accès au service et pour retourner le statut de cette livraison à l'utilisateur de DLS émetteur.

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5.2.4.2 Types de primitives et de paramètres

Le Tableau 9 indique les types de primitives et les paramètres nécessaires au service d'émission de DL.

Tableau 9 – Primitives et paramètres d'émission de DL

Nom de paramètre	Demande	Indication	Confirmation
Traitement	M		M(=)[a]
Diffusion	M	M	
Adresse source		M	
Adresse de destination			
Adresse courte	S		
Adresse longue	S		
Superframe_ID	C		
Graphe	C		
Priorité	M	M (=)	
Expiration de délai	M		
Données utilisateur DLS	M	M (=)	
Statut		M	M

[a] La valeur de ce paramètre est égale à la valeur dans la primitive de demande.

5.2.4.3 Paramètres

5.2.4.3.1 Traitement

Ce paramètre est pris en charge pour la commodité de l'utilisateur de DLS. Sa valeur dans la primitive de confirmation est identique à la valeur dans la primitive de demande correspondante.

5.2.4.3.2 Diffusion

Si la valeur de ce paramètre est VRAI, la DLSDU est diffusée dans la supertrame spécifiée dans la primitive de demande.

5.2.4.3.3 Adresse source

Ce paramètre identifie la source de la DLSDU acheminée par la primitive d'indication.

5.2.4.3.4 Adresse de destination

5.2.4.3.4.1 Adresse courte

Ce paramètre n'est présent que si Diffusion est FAUX. Il s'agit du surnom de la DLE de destination, utilisé pour le prochain saut.

5.2.4.3.4.2 Adresse longue

Ce paramètre n'est présent que si Diffusion est FAUX. Il s'agit de l'ID propre de la DLE de destination, utilisé pour le prochain saut.

5.2.4.3.5 Superframe_ID

Ce paramètre n'est présent que si Diffusion est VRAI. Il spécifie la supertrame dont les liaisons de diffusion doivent être utilisées pour émettre la DLSDU.

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5.2.4.3.6 Graphe

Ce paramètre n'est présent que si le routage par graphe doit être utilisé. Lorsqu'il est utilisé, le graphe indique les voisins qui peuvent servir de destination pour le prochain saut.

5.2.4.3.7 Priorité

Ce paramètre spécifie la priorité de l'émission. Sa valeur est un élément quelconque de l'ensemble: {commande, traitement des données, normal, alarme}.

5.2.4.3.8 Expiration de délai

Il s'agit de la durée maximale pour l'achèvement de chaque instance correspondante d'une séquence de primitives d'émission de DL.

5.2.4.3.9 Données utilisateur DLS

Ce paramètre permet l'émission de données entre les utilisateurs du DLS sans modification par le fournisseur du DLS.

5.2.4.3.10 Statut

Dans la primitive d'indication, ce paramètre indique la clé de liaison de données utilisée pour authentifier la DLPDU et si, oui ou non, la DLPDU était une diffusion.

Dans la primitive de confirmation, ce paramètre indique que le service a été fourni avec succès ou n'a pas abouti pour la raison spécifiée.

5.2.5 Service de réception de DL

5.2.5.1 Fonction

Il peut être utilisé par une DLE pour recevoir n'importe quelle DLPDU et fournir la DLSDU dans la DLPDU en question à l'utilisateur de DLS. Ce service est également appelé "mode de fonctionnement banalisé" et peut être utilisé pour le dépannage du réseau.

5.2.5.2 Type de primitive et paramètres

Le Tableau 10 indique le type de primitive et les paramètres nécessaires au service réception.

Tableau 10 – Primitive et paramètres de réception de DL

Nom de paramètre	Indication
RSL (niveau de signal reçu) de paquet	M
Données utilisateur DLS	M

5.2.5.3 Paramètres

5.2.5.3.1 RSL (niveau de signal reçu) de paquet

Ce paramètre est le niveau de signal reçu de la DLPDU qui vient d'être reçue.

5.2.5.3.2 Données utilisateur DLS

Ce paramètre achemine les données reçues par la DLE.

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5.2.6 Service de déconnexion de DL

5.2.6.1 Fonction

Ce service notifie qu'une autre DLE se déconnecte de la liaison. Une DLPDU a été reçue de cette DLE indiquant qu'elle se déconnecte de la liaison.

NOTE Les DLPDU Déconnecter ne sont attendues que d'un appareil voisin. Il est possible que l'appareil de réception ne connaisse pas tous ses voisins. Par conséquent, il reçoit toujours Déconnecter DLPDU et fournit une indication, même s'il provient d'un appareil qui n'est pas connu comme voisin.

5.2.6.2 Type de primitive et paramètres

5.2.6.2.1 Généralités

Le Tableau 11 indique le type de primitive et les paramètres nécessaires au service Déconnecter.

Tableau 11 – Primitive et paramètres de Déconnexion de DL

Nom de paramètre	Indication
Adresse source	M

5.2.6.2.2 Adresse source

Ce paramètre identifie l'adresse de la DLE qui vient de se déconnecter.

5.2.7 Service de défaillance de trajet DL

5.2.7.1 Fonction

Ce service notifie que le trajet menant à une DLE avec laquelle cette DLE est connectée a une défaillance. Les communications avec la DLE indiquée ont cessé intempestivement suite à une expiration de délai et la DLE apparaît indisponible.

5.2.7.2 Type de primitive et paramètres

5.2.7.2.1 Généralités

Le Tableau 12 indique le type de primitive et les paramètres nécessaires au service Défaillance de trajet.

Tableau 12 – Primitive et paramètres de Défaillance de trajet de DL

Nom de paramètre	Indication
Adresse source	M

5.2.7.2.2 Adresse source

Ce paramètre identifie l'adresse de la DLE à laquelle le trajet a juste failli.

5.2.8 Service d'annonce de DL

5.2.8.1 Fonction

Ce service notifie que la DLE a reçu une DLPDU d'annonce. Il convient que l'utilisateur du DLS utilise les informations fournies dans ce service avant de rejoindre le réseau.

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5.2.8.2 Type de primitive et paramètres

5.2.8.2.1 Généralités

Le Tableau 13 indique le type de primitive et les paramètres nécessaires au service d'annonce.

Tableau 13 – Primitive et paramètres d'Annonce de DL

Nom de paramètre	Indication
Données utilisateur DLS	M

5.2.8.2.2 Données utilisateur DLS

Ce paramètre achemine les données reçues par la DLE dans la DLPDU d'annonce.

5.2.9 Service de voisinage de DL

5.2.9.1 Fonction

Ce service notifie que la DLE a reçu une DLPDU d'une DLE qui n'est pas répertoriée dans sa Table des voisins (voir 6.4.3.4).

5.2.9.2 Type de primitive et paramètres

Le Tableau 14 indique le type de primitive et les paramètres nécessaires pour le service voisin.

Tableau 14 – Primitive et paramètres de Voisin de DL

Nom de paramètre	Indication
Adresse source	M
RSL (niveau de signal reçu) de paquet	M

5.2.9.3 Paramètres

5.2.9.3.1 Adresse source

Ce paramètre identifie l'adresse de la DLE qui n'est pas dans sa Table des voisins.

5.2.9.3.2 RSL (niveau de signal reçu) de paquet

Cette primitive indique le niveau de signal reçu de la DLPDU reçue.

5.2.10 Etablir DLM

5.2.10.1 Fonction

Cette primitive peut être utilisée pour établir (écrire) la valeur d'un paramètre de configuration de DLE.

5.2.10.2 Types de paramètres

Le Tableau 15 indique la primitive et les paramètres du service Etablir.

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Tableau 15 – Primitive et paramètres de Etablir DLM

	Demande	
Nom de paramètre	Entrée	Sortie
DLM-object-identifier	M	
Valeur prescrite	M	
Statut		M

5.2.10.3 Paramètres

5.2.10.3.1 DLM-object-identifier

Ce paramètre spécifie la primitive ou l'objet composite au sein de la DLE dont la valeur est à modifier. Le domaine de désignation de l'identifiant d'objet de gestion de DL (DLM) est la vue locale de DLM.

5.2.10.3.2 Valeur prescrite

Ce paramètre spécifie la valeur désirée pour l'objet DLM spécifié par l'identifiant d'objet de gestion de DL (DLM) associé. Son type est identique à celui de l'objet DLM spécifié.

5.2.10.3.3 Statut

Ce paramètre permet à l'utilisateur du Service DLM (DLMS) de déterminer si le DLMS demandé a été fourni avec succès ou a échoué.

La cause de l'échec peut également être fournie.

5.2.11 Obtenir DLM

5.2.11.1 Fonction

Cette primitive peut être utilisée pour récupérer (lire) la valeur d'un paramètre de configuration, d'un paramètre opérationnel ou les statistiques d'une DLE.

5.2.11.2 Types de paramètres

Le Tableau 16 indique la primitive et les paramètres du service Obtenir.

Tableau 16 – Primitive et paramètres de Obtenir DLM

	Demande	
Nom de paramètre	Entrée	Sortie
DLM-object-identifier	M	
Statut		M
Valeur courante		C

5.2.11.3 Paramètres

5.2.11.3.1 Identifiant d'objet DLM

Ce paramètre spécifie la primitive ou l'objet composite au sein de la DLE dont la valeur est demandée. Le domaine de désignation de l'identifiant d'objet de gestion de DL (DLM) est la vue locale DLM.

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5.2.11.3.2 Statut

Ce paramètre permet à l'utilisateur du DLMS de déterminer si le DLMS demandé a été fourni avec succès ou a échoué.

La cause de l'échec peut également être fournie.

5.2.11.3.3 Valeur courante

Ce paramètre est présent lorsque le paramètre de statut indique que le service demandé a été accompli avec succès. Il spécifie la valeur actuelle pour l'objet DLM spécifié par l'identifiant d'objet de gestion de DL (DLM) associé. Son type est identique à celui de l'objet DLM spécifié.

5.2.12 Action DLM

5.2.12.1 Fonction

Cette primitive peut être utilisée pour commander une action spécifiée de la DLE.

5.2.12.2 Types de paramètres

Le Tableau 17 indique les primitives et les paramètres du service Action.

Tableau 17 – Primitive et paramètres de DLM-Action

	Demande	Confirmation
Nom de paramètre	Entrée	Sortie
Action prescrite	M	
Qualificatifs d'action	C	
Statut		M
Informations supplémentaires		C

5.2.12.3 Paramètres

5.2.12.3.1 Action prescrite

Ce paramètre spécifie l'action souhaitée que la DLE a à entreprendre. Les valeurs possibles pour ce paramètre sont énumérées au Tableau 47.

5.2.12.3.2 Qualificatifs d'action

Ce paramètre définit des paramètres supplémentaires spécifiques à l'action, utilisés pour qualifier l'action commandée.

NOTE Certaines des actions exigent des paramètres complémentaires; par exemple SUPPRIMER SUPERTRAME nécessite l'identifiant Superframe_ID.

5.2.12.3.3 Statut

Ce paramètre permet à l'utilisateur du DLMS de déterminer si le DLMS demandé a été fourni avec succès ou a échoué.

La cause de l'échec peut également être fournie.

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5.2.12.3.4 Informations supplémentaires

Ce paramètre facultatif fournit des informations complémentaires spécifiques à l'action qui augmentent le statut retourné.

5.2.13 Evénement DLM

5.2.13.1 Fonction

Cette primitive est utilisée pour rapporter l'occurrence d'un événement DL susceptible d'être significatif pour la gestion de DL.

5.2.13.2 Types de paramètres

Pas de paramètres définis.

5.3 Services de couche réseau

5.3.1 Fonctionnalités des services de la couche réseau

5.3.1.1 Service de transfert de données

La couche réseau fournit un service pour émettre une unité de données de service de couche réseau (NL) (une NSDU) d'une entité NL (NLE) source vers une NLE de destination. Cela peut nécessiter d'acheminer une unité de données de protocole de NL (une NPDU) en passant par des NLE intermédiaires. L'itinéraire pour une NPDU est établi à l'aide de services de gestion de NL (NLMS).

5.3.1.2 Service de Gestion locale de NL

Ce service prend en charge la configuration de la NL et l'accès aux statistiques de la NL. Les fonctionnalités de gestion de la NL fournissent des moyens pour:

- écrire des paramètres de configuration de NLE,
- lire des paramètres de configuration, des paramètres opérationnels et des statistiques de NLE,
- commander des actions majeures de la NLE, et
- recevoir une notification des événements significatifs de NLE.

Ces fonctionnalités constituent ensemble le NLMS.

5.3.1.3 Fonction de sécurité

La NL assure une fonction de sécurité pour les communications de bout en bout entre paires d'appareils en communication. La NL est orientée session pour les besoins de la sécurité. Une session permet une communication privée et sécurisée entre une paire d'adresses réseau. Les types de clés de sécurité ci-après sont pris en charge.

- Rattachement

  Cette clé est utilisée lorsque l'appareil tente de rejoindre le réseau.

- Gestionnaire de réseau

  Cette clé sert à la communication entre un gestionnaire de réseau et un appareil de réseau.

- Passerelle

  Cette clé sert à la communication entre une passerelle et un appareil de réseau.

Il n'y a pas de service utilisateur explicite pour la sécurité. Les paramètres de sécurité sont écrits en utilisant le service de gestion de NL.

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5.3.2 QoS pour le service Messages

Les primitives du service de transfert de données spécifient la priorité de la NSDU transférée. Les quatre priorités sont, de la plus haute à la plus basse:

- Commande

  Il convient que l'utilisateur du NLS se serve de cette priorité pour envoyer des données d'informations de diagnostic, de configuration ou de commande concernant le réseau.

- Données de processus

  Il convient que l'utilisateur du NLS se serve de cette priorité pour envoyer des données contenant des mesures issues d'émetteurs de processus ou des valeurs de consigne à des appareils de commande ou n'importe quelles autres données relatives au processus ou des données statistiques du réseau.

- Normale

  Il convient que l'utilisateur du NLS se serve de cette priorité pour envoyer des données contenant n'importe quelles autres données qui ne remplissent pas les critères relatifs à la priorité "Commande", "Données de processus" ou "Alarme".

- Alarme

  Il convient que l'utilisateur du NLS se serve de cette priorité pour envoyer des données contenant seulement une alarme ou des informations d'événement.

5.3.3 Séquence de primitives

Les relations que les primitives aux points d'extrémité du service Messages de chaque type au niveau de l'interface de l'utilisateur du NLS et d'une NLE ont avec les primitives au niveau de l'utilisateur de NLS et des autres NLE sont récapitulées dans les diagrammes de la Figure 9. Une fois que l'entité DLE a fourni la confirmation d'une transmission, l'entité NLE génère une confirmation d'émission de NL à l'attention de son utilisateur demandeur. Il n'y a pas de confirmation de livraison de la part de la NLE distante.

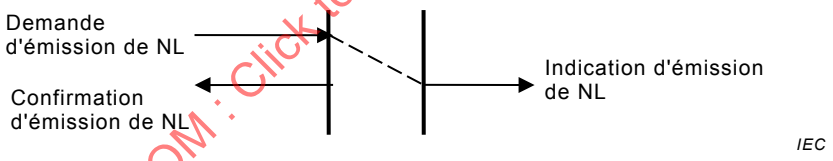

Figure 9 – Séquences de service de transfert de données NLL

5.3.4 Service d'émission de NL

5.3.4.1 Fonction

Il peut être utilisé pour émettre une NSDU indépendante autonome d'une NLE vers une autre NLE dans un seul accès au service et pour retourner le statut de cette livraison à l'utilisateur de NLS émetteur.

5.3.4.2 Types de primitives et de paramètres

Le Tableau 18 indique les types de primitives et les paramètres nécessaires au service d'émission.

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Tableau 18 – Primitives et paramètres d'émission de NL

Nom de paramètre	Demande	Indication	Confirmation
Traitement	M		M(=)[a]
Sequence_number		M	
Adresse source		M	
Adresse de destination			
Adresse courte	S		
Adresse longue	S		
Diffusion	S		
Priorité	M	M(=)	
Timetable_ID	C		
Transport_type	M	M(=)	
Données utilisateur NLS	M	M(=)	
Statut			M

[a] La valeur de ce paramètre est égale à la valeur dans la primitive de demande.

5.3.4.3 Paramètres

5.3.4.3.1 Traitement

Dans la demande, ce paramètre est pris en charge pour la commodité de l'utilisateur de NLS. Sa valeur dans la primitive de confirmation est identique à la valeur dans la primitive de demande correspondante.

5.3.4.3.2 Sequence_number

Ce numéro de séquence de paramètre est utilisé pour identifier de façon univoque la TPDU.

5.3.4.3.3 Adresse source

Ce paramètre identifie la source de la NSDU acheminée par la primitive d'indication.

5.3.4.3.4 Adresse de destination

5.3.4.3.4.1 Adresse courte

Il s'agit du surnom de la NLE de destination.

5.3.4.3.4.2 Adresse longue

Il s'agit de l'ID propre à la NLE de destination.

5.3.4.3.4.3 Diffusion

Toutes les NLE du réseau sont les destinations.

5.3.4.3.5 Priorité

Ce paramètre spécifie la priorité de l'émission. Sa valeur est un élément quelconque de l'ensemble: {commande, traitement des données, normal, alarme}.

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5.3.4.3.6 Timetable_ID

Ce paramètre spécifie l'indicateur horaire utilisé pour allouer la largeur de bande de communication réseau à cette primitive de service. Ce paramètre n'est présent que si l'adresse de destination n'est pas celle du gestionnaire de réseau et si cette demande est requise pour utiliser la largeur de bande allouée. S'il ne reste pas suffisamment de largeur de bande pour la demande d'émission de NL, une erreur doit être retournée et les données utilisateur NLS ne doivent pas être transmises. Le gestionnaire de réseau ne doit pas être limité par l'indicateur horaire.

5.3.4.3.7 Transport_type

Le paramètre Transport_type indique le type de service de transport utilisé (voir 5.4.4.3.2).

5.3.4.3.8 Données utilisateur NLS

Ce paramètre permet l'émission de données entre les utilisateurs du NLS sans modification par le fournisseur du NLS.

5.3.4.3.9 Adresse source

Ce paramètre identifie la source de la NSDU acheminée par la primitive d'indication.

5.3.4.3.10 Statut

Dans la primitive de confirmation, ce paramètre indique le succès, l'avertissement ou l'échec du service. Pour l'avertissement et l'échec, il indique aussi la cause de l'avertissement ou de l'erreur.

5.3.5 Etablir NLM

5.3.5.1 Fonction

Cette primitive peut être utilisée pour établir (écrire) la valeur d'un paramètre de configuration de NLE.

5.3.5.2 Types de paramètres

Le Tableau 19 indique la primitive et les paramètres du service Etablir.

Tableau 19 – Primitive et paramètres de Etablir NLM

	Demande	
Nom de paramètre	Entrée	Sortie
NLM-object-identifier	M	
Valeur prescrite	M	
Statut		M

5.3.5.3 Paramètres

5.3.5.3.1 NLM-object-identifier

Ce paramètre spécifie la primitive ou l'objet composite au sein de la NLE dont la valeur est à modifier. Le domaine de désignation du paramètre "identifiant d'objet NLM" est la vue locale NLM.

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5.3.5.3.2 Valeur prescrite

Ce paramètre spécifie la valeur désirée pour l'objet NLM spécifié par le paramètre "identifiant d'objet NLM" associé. Son type est identique à celui de l'objet NLM spécifié.

5.3.5.3.3 Statut

Ce paramètre permet à l'utilisateur du NLMS de déterminer si le NLMS demandé a été fourni avec succès ou a échoué.

La cause de l'échec peut également être fournie.

5.3.6 Obtenir NLM

5.3.6.1 Fonction

Cette primitive peut être utilisée pour récupérer (lire) la valeur d'un paramètre de configuration, d'un paramètre opérationnel ou les statistiques d'une NLE.

5.3.6.2 Types de paramètres

Le Tableau 20 indique la primitive et les paramètres du service Obtenir.

Tableau 20 – Primitive et paramètres de Obtenir NLM

	Demande	
Nom de paramètre	Entrée	Sortie
NLM-object-identifier	M	
Statut		M
Valeur courante		C

5.3.6.3 Paramètres

5.3.6.3.1 NLM-object-identifier

Ce paramètre spécifie la primitive ou l'objet composite au sein de la NLE dont la valeur est demandée. Le domaine de désignation du paramètre "identifiant d'objet NLM" est la vue locale NLM.

5.3.6.3.2 Statut

Ce paramètre permet à l'utilisateur du NLMS de déterminer si le NLMS demandé a été fourni avec succès ou a échoué.

La cause de l'échec peut également être fournie.

5.3.6.3.3 Valeur courante

Ce paramètre est présent lorsque le paramètre de statut indique que le service demandé a été accompli avec succès. Ce paramètre spécifie la valeur actuelle pour l'objet NLM spécifié par le paramètre "identifiant d'objet NLM" associé. Son type est identique à celui de l'objet NLM spécifié.

5.3.7 Action NLM

5.3.7.1 Fonction

Cette primitive peut être utilisée pour commander une action spécifiée de la NLE.

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5.3.7.2 Types de paramètres

Le Tableau 21 indique les primitives et les paramètres du service Action.

Tableau 21 – Primitive et paramètres d'Action NLM

	Demande	Confirmation
Nom de paramètre	Entrée	Sortie
Action prescrite	M	
Qualificatifs d'action	C	
Statut		M
Informations supplémentaires		C

5.3.7.3 Paramètres

5.3.7.3.1 Action prescrite

Ce paramètre spécifie l'action souhaitée que la NLE a à entreprendre. Les valeurs possibles pour ce paramètre sont énumérées au Tableau 59.

5.3.7.3.2 Qualificatifs d'action

Ce paramètre définit des paramètres supplémentaires spécifiques à l'action, utilisés pour qualifier l'action commandée. Certaines des actions exigent des paramètres complémentaires; par exemple "supprimer session" nécessite l'identifiant de session.

5.3.7.3.3 Statut

Ce paramètre permet à l'utilisateur du NLMS de déterminer si le NLMS demandé a été fourni avec succès ou a échoué.

La cause de l'échec peut également être fournie.

5.3.7.3.4 Informations supplémentaires

Ce paramètre facultatif fournit des informations complémentaires spécifiques à l'action qui augmentent le statut retourné.

5.4 Services de la couche transport

5.4.1 Fonctionnalités des services de la couche transport

5.4.1.1 Service de transfert de données

La couche transport (TL) prend en charge les services tant acquittés que non acquittés.

Le service non acquitté permet à des appareils d'envoyer des paquets sans exiger d'acquittement de la part de l'extrémité de réception. Les paquets peuvent être livrés à l'appareil de destination dans un ordre différent de celui dans lequel ils ont été initialement envoyés de l'appareil d'origine. Ce service est utile pour éditer des données de processus. Sachant que les données de processus sont propagées périodiquement, l'acquittement de bout en bout et les tentatives ont une utilité limitée étant donné qu'un nouveau point de données sera généré sur une base régulière.

Le service acquitté est utilisé pour construire un tube de transport synchrone à travers le réseau reliant deux appareils. Ce tube permet aux appareils d'envoyer des paquets et de confirmer leur livraison. L'utilisateur du service de TL (TLS) peut envoyer un paquet qui sera livré à l'utilisateur de TLS de réception sans perte, duplication ou ordre incorrect. Ce service

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convient à un trafic de demandes et de réponses ainsi qu'à des notifications d'événements. Lorsque le service acquitté est utilisé, la communication est synchrone. Une seule transaction en cours à la fois est autorisée à travers le réseau pour le tube de transport en question.

L'utilisation du service acquitté permet à la couche client de garantir que les répétitions de tentatives sont effectuées automatiquement, si la latence de communication devient excessive. Du point de vue statistique, la fiabilité de la communication pour un réseau maillé de Type 20 correctement constitué est supérieure à 3 σ (3 sigmas = 99,730 020 4 %) et normalement supérieure à 4 σ (99,993 7 %). Le principal avantage fourni par un service acquitté est que la couche client recevra un acquittement positif après l'arrivée à destination de l'unité de données de protocole de couche transport (TPDU). Cela permet un fonctionnement synchrone à travers le réseau et donne en même temps l'assurance à la couche client que la TPDU a été livrée et acquittée.

5.4.1.2 Service de Gestion locale de TL

Ce service prend en charge la configuration de la TL et l'accès aux statistiques de la TL. Les fonctionnalités de gestion de la TL fournissent des moyens pour

- écrire les paramètres de configuration de l'entité TL (TLE),
- lire les paramètres de configuration, les paramètres opérationnels et les statistiques de TLE.

Ces fonctionnalités constituent ensemble le service de gestion de NL (NLMS).

5.4.2 QoS pour le service Messages

5.4.2.1 Priorité

Les primitives du service de transfert de données spécifient la priorité des données transférées. Les quatre priorités sont, de la plus haute à la plus basse:

- Commande

  Il convient que l'utilisateur du TLS se serve de cette priorité pour envoyer des données d'informations de diagnostic, de configuration ou de commande concernant le réseau.

- Données de processus

  Il convient que l'utilisateur du TLS se serve de cette priorité pour envoyer des données contenant des mesures issues d'émetteurs de processus ou des valeurs de consigne à des appareils de commande ou n'importe quelles autres données relatives au processus ou des données statistiques du réseau.

- Normale

  Il convient que l'utilisateur du TLS se serve de cette priorité pour envoyer des données contenant n'importe quelles autres données qui ne remplissent pas les critères relatifs à la priorité "Commande", "Données de processus" ou "Alarme".

- Alarme

  Il convient que l'utilisateur de TLS se serve de cette priorité pour envoyer des données contenant seulement une alarme et des informations d'événement.

5.4.2.2 Nouvelle tentative

La gestion de TL spécifie les bornes supérieures de la durée maximale permise pour l'achèvement de chaque instance correspondante d'une séquence de primitives de transfert de données. Elle spécifie aussi le nombre maximal de tentatives pour envoyer une demande et recevoir une primitive de réponse.

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5.4.3 Séquence de primitives

Le Paragraphe 5.4.3 spécifie la relation des primitives au niveau des points d'extrémité du service de transfert de données.

Les relations que les primitives de chaque type au niveau de l'interface utilisateur du TLS et d'une TLE ont avec les primitives au niveau de l'utilisateur du TLS et des autres TLE pour des cas exempts d'erreurs sont récapitulées dans les diagrammes de la Figure 10.

La séquence a) montre un transfert de données unidirectionnel exempt d'erreurs sans acquittement de la part de la TLE de destination. Une fois que la NLE a fourni la confirmation d'une transmission, la TLE génère une confirmation de transfert de données de TL à l'attention de son utilisateur demandeur.

La séquence b) montre un échange de données acquitté bidirectionnel sans erreurs. Dans cette séquence, la demande d'échange de données de TL au niveau de la TLE source insère le message dans la file d'attente d'émission de la TLE. Lorsqu'une TPDU est reçue et validée, la TLE de destination génère une indication d'échange de données de TL. L'utilisateur de TLS à la destination en question est censé fournir des données de réponse. La TLE émet cette réponse vers la TLE source. À la réception de la réponse, la TLE source génère une confirmation d'échange de données de TL à l'attention de l'utilisateur.

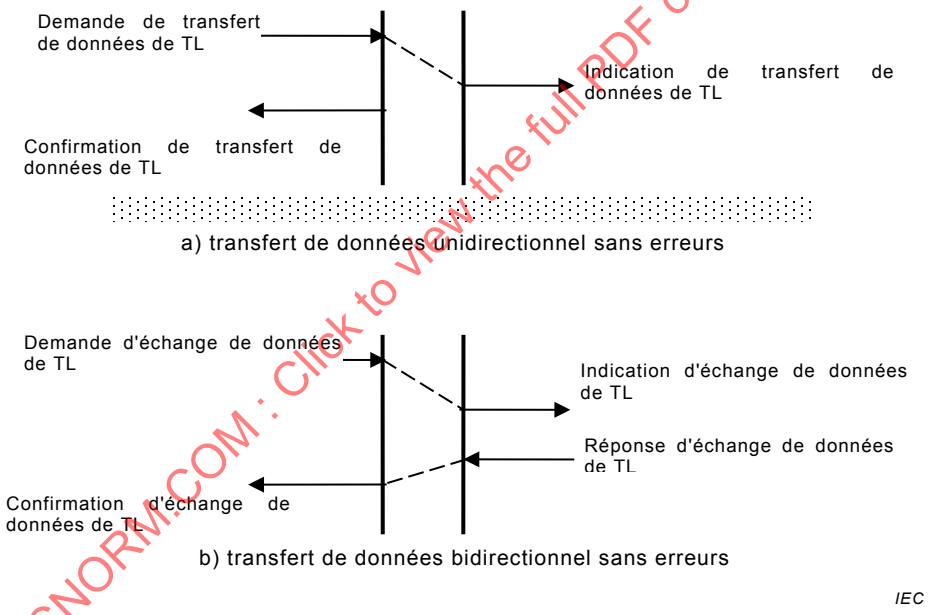

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Figure 10 – Séquences du service de transfert de données sans erreurs

Les relations que les primitives de chaque type au niveau de l'interface utilisateur du TLS et d'une TLE ont avec les primitives au niveau de l'utilisateur du TLS et des autres TLE pour des cas d'erreurs sont récapitulées dans le diagramme de la Figure 11. La séquence montre l'unité de données de protocole de couche transport (TPDU) perdue dans la transmission. Comme illustré, la TLE source réémet la TPDU tant qu'une TPDU de réponse n'a pas été reçue ou tant qu'une limite sur le nombre maximal de tentatives n'a pas été atteinte. Si le paquet séjourne dans la TLE source sans réponse de la part de la TLE de destination pendant une durée supérieure à la valeur spécifiée pour l'expiration de délai, la TLE cesse ses tentatives.

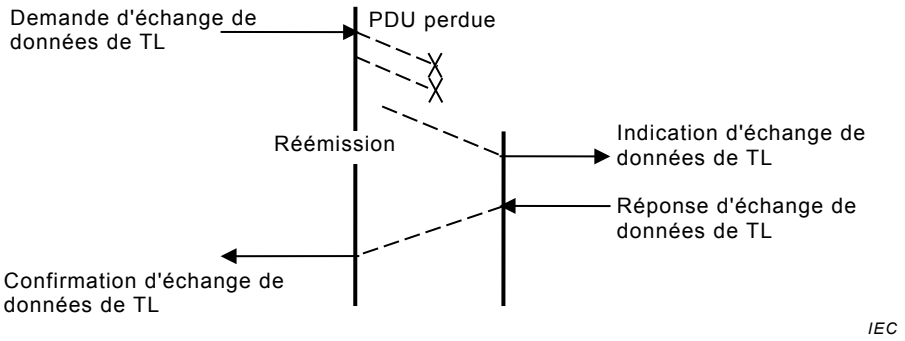

Figure 11 – Séquences du service de transfert de données avec erreurs

5.4.4 Service de transfert de données de TL

5.4.4.1 Fonction

Il peut être utilisé pour émettre un TL-service-data-unit (TSDU) de demande indépendante complète d'une TLE vers une autre TLE dans un seul accès au service sans confirmation de livraison.

5.4.4.2 Types de primitives et de paramètres

Le Tableau 22 indique les types de primitives et les paramètres nécessaires au service de transfert de données.

Tableau 22 – Primitives et paramètres de transfert de données de TL

Nom de paramètre	Demande	Indication	Confirmation
Traitement	M	M(=)[a]	M(=)[b]
Type de transport	M	M	
Adresse source		M	
Adresse de destination			
Adresse courte	S		
Adresse longue	S		
Diffusion	S		
Priorité	M	M(=)	
Timetable_ID	C		
Données utilisateur TLS	M	M(=)	
Statut			M

a Dans une indication ce paramètre est considéré comme le numéro de séquence.

b La valeur de ce paramètre est égale à la valeur dans la primitive de demande.

5.4.4.3 Paramètres

5.4.4.3.1 Traitement

Dans la demande, ce paramètre est pris en charge pour la commodité de l'utilisateur de DLS. Sa valeur dans la primitive de confirmation est identique à la valeur dans la primitive de demande correspondante. Dans la primitive d'indication, ce paramètre est utilisé pour fournir un numéro de séquence.

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5.4.4.3.2 Type de transport

Dans la primitive de demande, ce paramètre indique le type de service demandé. Il prend l'une des valeurs suivantes:

- Demande de transfert par blocs
- Réponse de transfert par blocs
- Diffusion de recherche
- Diffusion d'édition
- Diffusion de réponse
- Edition en monodiffusion

5.4.4.3.3 Adresse source

Ce paramètre identifie la source de la TSDU acheminée par la primitive d'indication.

5.4.4.3.4 Adresse de destination

5.4.4.3.4.1 Adresse courte

Il s'agit du surnom de la TLE de destination.

5.4.4.3.4.2 Adresse longue

Il s'agit de l'ID propre à la TLE de destination.

5.4.4.3.4.3 Diffusion

Toutes les TLE du réseau sont les destinations.

5.4.4.3.5 Priorité

Ce paramètre spécifie la priorité de l'émission. Sa valeur est un élément quelconque de l'ensemble: {commande, traitement des données, normal, alarme}.

5.4.4.3.6 Timetable_ID

Ce paramètre spécifie l'indicateur horaire utilisé pour allouer la largeur de bande de communication réseau à cette primitive de service. Ce paramètre n'est présent que si l'adresse de destination n'est pas celle du gestionnaire de réseau.

5.4.4.3.7 Données utilisateur TLS

Ce paramètre permet l'émission de données entre les utilisateurs du TLS sans modification par le fournisseur du TLS.

5.4.4.3.8 Adresse source

Ce paramètre identifie la source de la TSDU acheminée par la primitive d'indication.

5.4.4.3.9 Statut

Dans la primitive de confirmation, ce paramètre indique le succès, l'avertissement ou l'échec du service. Pour l'avertissement et l'échec, il indique aussi la cause de l'avertissement ou de l'erreur.

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5.4.5 Service d'échange de données de TL

5.4.5.1 Fonction

Il peut être utilisé pour émettre une TSDU de demande indépendante complète d'une TLE vers une autre TLE dans un seul accès au service, pour recevoir une TSDU de réponse de la part de la TLE de destination et pour retourner le statut de cet échange à l'utilisateur de TLS émetteur.

5.4.5.2 Types de primitives et de paramètres

Le Tableau 23 indique les types de primitives et les paramètres nécessaires au service d'échange de données de TL.

Tableau 23 – Primitives et paramètres d'échange de données de TL

Nom de paramètre	Demande	Indication	Réponse	Confirmation
Traitement	M	M(=)[a]	M(=)	M(=)[b]
Type de transport	M	M(=)		
Adresse source		M		
Adresse de destination				
Adresse courte	S			
Adresse longue	S			
Diffusion	S			
Priorité	M	M(=)		
Timetable_ID	C			
Données utilisateur TLS	M	M(=)	M	C(=)
Statut				M

[a] Dans une indication ce paramètre est considéré comme le numéro de séquence.

[b] Ce paramètre est égal à la valeur dans la primitive de demande.

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5.4.5.3 Paramètres

5.4.5.3.1 Traitement

Dans la demande, ce paramètre est pris en charge pour la commodité de l'utilisateur de DLS. Sa valeur dans la primitive de confirmation est identique à la valeur dans la primitive de demande correspondante. Dans la primitive d'indication, ce paramètre est utilisé pour associer la demande à la réponse.

5.4.5.3.2 Type de transport

Dans la primitive de demande, ce paramètre indique le type de service demandé par le maître. Il prend l'une des valeurs suivantes:

- Demande en monodiffusion
- Diffusion de demande

Dans la primitive de réponse, ce paramètre indique le type de service demandé par l'esclave. Sa valeur est – Réponse en monodiffusion.

5.4.5.3.3 Adresse source

Ce paramètre identifie la source de la TSDU acheminée par la primitive d'indication.

5.4.5.3.4 Adresse de destination

5.4.5.3.4.1 Adresse courte

Il s'agit du surnom de la TLE de destination.

5.4.5.3.4.2 Adresse longue

Il s'agit de l'ID propre à la TLE de destination.

5.4.5.3.4.3 Diffusion

Toutes les TLE du réseau sont les destinations.

5.4.5.3.5 Priorité

Ce paramètre spécifie la priorité de l'émission. Sa valeur est un élément quelconque de l'ensemble: {commande, traitement des données, normal, alarme}.

5.4.5.3.6 Timetable_ID

Ce paramètre spécifie l'indicateur horaire utilisé pour allouer la largeur de bande de communication réseau à cette primitive de service. Ce paramètre n'est présent que si l'adresse de destination n'est pas celle du gestionnaire de réseau.

L'attribution de largeur de bande pour la communication est demandée par l'initiateur de la transaction et la réponse n'est incluse dans l'attribution pour aucun indicateur horaire dans l'appareil. Par conséquent, Timetable_ID n'est pas inclus dans la primitive de réponse.

5.4.5.3.7 Données utilisateur TLS

Ce paramètre permet l'émission de données entre les utilisateurs du TLS sans modification par le fournisseur du TLS.

5.4.5.3.8 Adresse source

Ce paramètre identifie la source de la TSDU acheminée par la primitive d'indication.

5.4.5.3.9 Statut

Dans la primitive de confirmation, ce paramètre indique le succès, l'avertissement ou l'échec du service. Pour l'avertissement et l'échec, il indique aussi la cause de l'avertissement ou de l'erreur.

5.4.6 Etablir TLM

5.4.6.1 Fonction

Cette primitive peut être utilisée pour établir (écrire) la valeur d'un paramètre de configuration de TLE.

5.4.6.2 Types de paramètres

Le Tableau 24 indique la primitive et les paramètres du service Etablir.

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Tableau 24 – Primitive et paramètres de TLM-Set

	Demande	
Nom de paramètre	Entrée	Sortie
TLM-object-identifier	M	
Valeur prescrite	M	
Statut		M

5.4.6.3 Paramètres

5.4.6.3.1 TLM-object-identifier

Ce paramètre spécifie la primitive ou l'objet composite au sein de la TLE dont la valeur est à modifier. Le domaine de désignation du paramètre TLM-object-identifier est la vue locale TLM.

5.4.6.3.2 Valeur prescrite

Ce paramètre spécifie la valeur désirée pour l'objet TLM spécifié par le paramètre "Identifiant d'objet TLM" associé. Son type est identique à celui de l'objet TLM spécifié.

5.4.6.3.3 Statut

Ce paramètre permet à l'utilisateur du Service de gestion de TL (TLMS) de déterminer si le TLMS demandé a été fourni avec succès ou a échoué.

La cause de l'échec peut également être fournie.

5.4.7 Obtenir TLM

5.4.7.1 Fonction

Cette primitive peut être utilisée pour récupérer (lire) la valeur d'un paramètre de configuration, d'un paramètre opérationnel ou les statistiques d'une TLE.

5.4.7.2 Types de paramètres

Le Tableau 25 indique la primitive et les paramètres du service Obtenir.

Tableau 25 – Primitive et paramètres de TLM-Get

	Demande	
Nom de paramètre	Entrée	Sortie
TLM-object-identifier	M	
Statut		M
Valeur courante		C

5.4.7.3 Paramètres

5.4.7.3.1 TLM-object-identifier

Ce paramètre spécifie la primitive ou l'objet composite au sein de la TLE dont la valeur est demandée. Le domaine de désignation du paramètre TLM-object-identifier est la vue locale TLM.

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5.4.7.3.2 Statut

Ce paramètre permet à l'utilisateur du TLMS de déterminer si le TLMS demandé a été fourni avec succès ou a échoué.

La cause de l'échec peut également être fournie.

5.4.7.3.3 Valeur courante

Ce paramètre est présent lorsque le paramètre de statut indique que le service demandé a été accompli avec succès. Ce paramètre spécifie la valeur actuelle pour le TLM-object spécifié par le paramètre TLM-object-identifier associé. Son type est identique à celui du TLM-object spécifié.

6 Spécification du protocole de couche liaison de données – Eléments de Type 20

6.1 Généralités

Le présent document spécifie le protocole de la Couche Liaison de données sans fil de Type 20 en complément du protocole de Couche Liaison de données câblée de Type 20 spécifiée dans l'IEC 61158-4-20.

6.2 Vue d'ensemble

6.2.1 Fonctionnement de la couche liaison de données

6.2.1.1 Modèle de DLL à deux sous-couches

La DLL est modélisée comme étant

- une sous-couche supérieure de contrôle de liaison logique (LLC), et
- une sous-couche inférieure de contrôle d'accès au support (MAC).

Les fonctions DL-management interagissent avec toutes les sous-couches.

6.2.1.2 Contrôle de liaison logique

La sous-couche LLC fournit la fonctionnalité de niveau supérieur permettant de

- gérer toutes les interactions de DLE avec l'utilisateur de DLS, en convertissant toutes les primitives de demande et de réponse de l'utilisateur de DLS en la séquence nécessaire d'opérations de DLE ainsi qu'en générant, s'il y a lieu, des primitives d'indication et de confirmation d'utilisateur de DLS,
- préparer la DLPDU pour émission,
- analyser la DLPDU reçue,
- contrôler le flux de données,
- détecter les erreurs,
- assurer la maintenance de la Table des voisins, et
- assurer la sécurité de la couche Liaison de données.

6.2.1.3 Contrôle d'accès au support

La couche Liaison de données de Type 20 utilise Time Division Multiple Access (TDMA) et le saut de canal pour commander l'accès à la liaison. Cette technique de Contrôle d'accès au support (MAC) assure une communication déterministe sans collision entre deux appareils. La communication entre deux appareils a lieu pendant un intervalle de temps. Une supertrame

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TDMA consiste en une série d'intervalles de temps. La structure de base d'intervalles de temps TDMA et la supertrame sont illustrées à la Figure 12. Les tailles d'intervalles de temps et la longueur de supertrame en nombre d'intervalles de temps sont fixes et forment un cycle de liaison. Tous les appareils prennent en charge plusieurs supertrames, en commençant par la supertrame numéro zéro (0). Une supertrame au moins est toujours activée alors que des supertrames supplémentaires peuvent être activées ou désactivées. La longueur d'une supertrame ne peut être modifiée que pendant qu'elle est active. Les supertrames peuvent avoir des longueurs différentes les unes des autres. Les supertrames se répètent en continu avec une fréquence de répétition fixe.

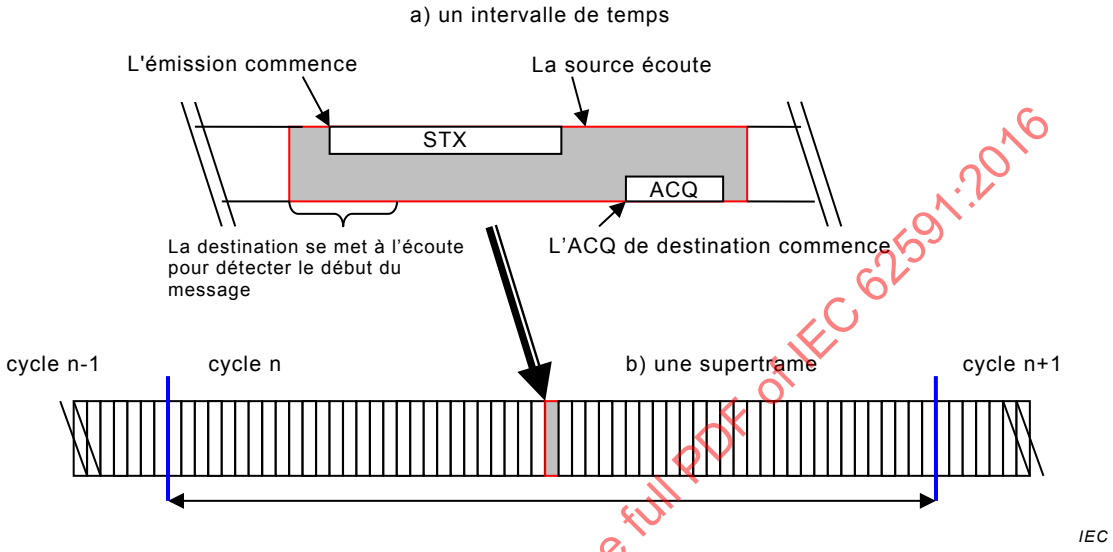

Figure 12 – Intervalle de temps TDMA et supertrame

Typiquement, deux appareils sont attribués à un même intervalle de temps. L'un est désigné comme étant la source et l'autre comme la destination. Une transaction de liaison dans un intervalle de temps prend en charge l'émission d'une DLPDU par un appareil d'origine et, le cas échéant, elle est immédiatement suivie de l'émission d'une DLPDU d'acquittement (ACQ) par l'appareil de destination. La DLPDU d'ACQ contient soit le code de réponse "Succès" indiquant que la DLPDU initiale a été reçue et gérée avec succès, soit un code de réponse d'erreur. Un code de réponse d'erreur indique que la DLPDU initiale a été reçue avec succès, mais que le traitement ultérieur a échoué, par exemple il n'y avait pas de tampons disponibles dans l'appareil de réception.

Un message de diffusion utilisant l'adresse de destination de la liaison de données comme adresse de diffusion n'est jamais acquitté. Dans ce cas, plusieurs récepteurs sont attribués au même intervalle de temps.

Pour des communications TDMA réussies et efficaces, il est impératif que les appareils connaissent l'instant auquel un intervalle de temps commence. Cela exige la synchronisation des horloges de tous les appareils du réseau. Pour assurer la synchronisation des horloges des appareils à l'échelle du réseau, les tolérances sur les mécanismes de maintien de l'heure et de synchronisation du temps sont spécifiées dans ce protocole.

Dans un intervalle de temps, l'émission de la DLPDU source débute à un décalage spécifié par rapport au début de l'intervalle de temps. Ce décalage permet à la source et à la destination de régler leur canal de fréquence et permet au récepteur de commencer l'écoute sur le canal spécifié. Sachant qu'il existe une tolérance sur les horloges, le récepteur commence à écouter avant l'instant idéal de début d'émission et continue l'écoute après l'instant idéal en question. Une fois l'émission terminée, le sens de la communication est inversé et l'appareil de destination indique, en émettant un ACQ, s'il a reçu la DLPDU de l'appareil d'origine avec succès ou avec une classe spécifique d'erreurs détectées. Si la

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destination n'a pas entendu d'émission ou s'il y a eu une erreur de réception qui n'est pas incluse dans cette classe d'erreurs, l'appareil de destination n'émet pas de DLPDU d'ACQ.

6.2.1.4 Saut de canal

Pour renforcer la fiabilité, le saut de canal est combiné au TDMA comme illustré à la Figure 13. Le saut de canal fournit la diversité de fréquence, ce qui peut éviter les systèmes perturbateurs et réduire les effets d'évanouissement par trajets multiples. Le TDMA permet une communication à saut de canal efficace, de faible puissance et fiable, car la synchronisation de l'intervalle de temps et du canal utilisée par les appareils en communication leur permet d'effectuer un rendez-vous en temps et en fréquence, ce qui favorise le succès des communications.

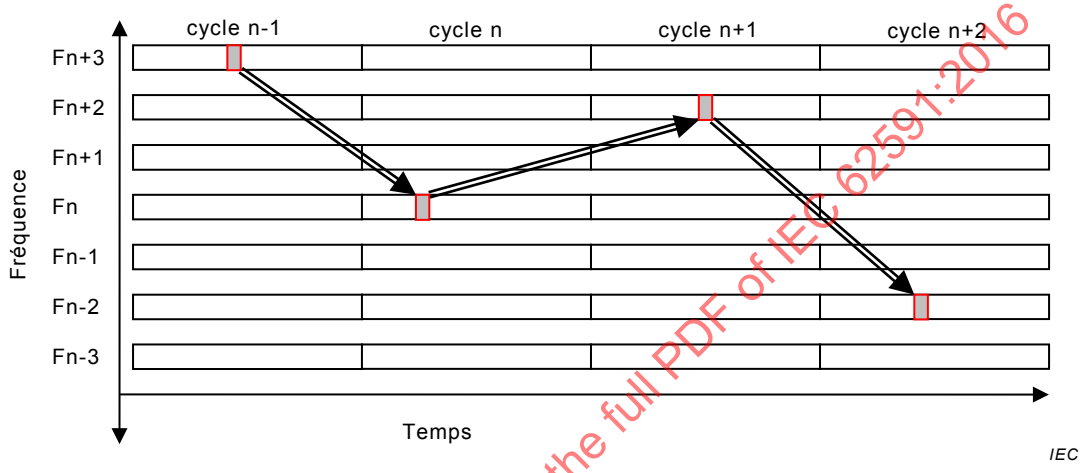

Figure 13 – Saut de canal

Des appareils en communication sont attribués à une supertrame, à un intervalle de temps dans la supertrame en question et à un décalage de canal. Ce trio forme une liaison de communications entre deux appareils en communication. Tous les appareils prennent en charge les liaisons multiples. Le nombre de liaisons possibles est, typiquement, égal au nombre de canaux utilisés par un réseau multiplié par le nombre d'intervalles de temps de la supertrame. Par exemple, avec 15 canaux et 9 000 intervalles de temps par supertrame, il y a 135 000 liaisons possibles.

Le saut de canal fournit la diversité de canaux et, de ce fait, chaque intervalle de temps est utilisé sur plusieurs canaux en même temps par des nœuds différents. Cela peut s'obtenir par la création de liaisons sur le même intervalle de temps, mais avec des décalages de canal différents. Chaque appareil conserve une liste de canaux en utilisation et la spécification (la fréquence par exemple) pour le canal en question. Tous les appareils dans un réseau ont des listes de canaux identiques qui sont déterminés par le gestionnaire de réseau. L'affectation des liaisons et des appareils dans une liaison incombe au gestionnaire de réseau.

La mise en liste noire d'un canal est une caractéristique de ce protocole qui permet à l'administrateur réseau de limiter le saut de canal par les appareils à des canaux sélectionnés dans la bande RF disponible. Par exemple, des administrateurs réseau peuvent placer en liste noire certains canaux afin de protéger un service sans fil qui utilise une partie fixe de la bande RF qui aurait pu être partagée par les appareils dans ce réseau. Dans la pratique, la communication dans la largeur de bande disponible par les appareils utilisant d'autres protocoles est très aléatoire et utilise une quantité infime de la largeur de bande disponible totale. Par conséquent, la liste noire procure rarement des avantages tangibles.

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6.2.1.5 Maintenance du réseau

Le temps et le canal sont les deux premières dimensions d'un réseau de Type 20. La troisième dimension est l'espace (la distance). Les appareils de réseau sont installés en divers emplacements dans une installation et un appareil donné dispose d'un ensemble d'autres appareils avec lesquels il peut communiquer directement. Cet ensemble d'appareils est défini comme étant le voisinage. Sachant que l'environnement RF est susceptible de changer, l'appareil conserve courante sa liste de voisins. Les activités de maintenance incluent de découvrir des voisins potentiels, de rassembler des statistiques relatives au canal de communication menant à chaque voisin et de maintenir la synchronisation du temps avec les voisins.

Deux DLPDU spéciales aident à dresser et maintenir une liste de voisins d'un appareil. Il s'agit de la DLPDU d'annonce et de la DLPDU d'entretien (au sens de "maintien en activité"). Ces DLPDU contiennent des informations suffisantes pour permettre de découvrir de nouveaux voisins ou pour permettre à un appareil nouvellement installé de demander son admission au réseau. S'il est accepté, le nouvel appareil peut devenir un voisin de l'appareil annonceur.

NOTE Le gestionnaire de réseau peut programmer l'émission de ces DLPDU.

Chaque communication réussie avec un voisin confirme la présence du voisin et permet d'évaluer la qualité de la liaison de communication. Les communications n'ayant lieu que lorsque l'appareil a une DLPDU pour le voisin, la liaison peut rester non utilisée pendant de longs intervalles. Les DLPDU d'entretien sont utilisées pour sonder les liaisons à l'état passif et pour maintenir la synchronisation du temps.

6.2.1.6 Mesure du temps

Sur le réseau, la synchronisation est essentielle pour les communications en TDMA. Quel que soit le choix de la source matérielle de temps de l'appareil (par exemple quartz, résonateurs céramiques, etc.), un certain décalage entre appareils (en raison de variations de température ou de tension ou du vieillissement par exemple) est inévitable. En conséquence, la couche Liaison de données de Type 20 dispose de plusieurs mécanismes pour synchroniser le temps à l'échelle du réseau.

Lorsqu'un appareil reçoit une DLPDU qui lui est destinée, son heure d'arrivée est notée. En utilisant cette information, la destination calcule la différence entre le temps réel d'arrivée et le temps prévu d'arrivée pour la DLPDU en question. Ce delta-t (Δt) est communiqué dans chaque DLPDU de réponse d'ACQ envoyée à l'appareil d'origine. Ainsi, chaque transaction acquittée mesure l'alignement du temps réseau entre les appareils.

La liste de voisins contient des voisins sélectionnés, spécifiés par le gestionnaire de réseau, qui sont utilisés comme sources de synchronisation du temps. Lorsqu'une DLPDU issue d'un voisin de synchronisation du temps est reçue, l'heure réseau de l'appareil récepteur est réajustée. La synchronisation du temps repose soit sur l'heure d'arrivée de la DLPDU, soit sur le delta-t dans la DLPDU d'ACQ, en fonction de l'appareil qui a lancé la transaction.

En outre, il convient que les concepteurs d'appareils comprennent les caractéristiques de dérive du temps de leurs produits. Lorsque la source de temps de l'appareil dérive, l'appareil émet une DLPDU d'entretien, au besoin, vers ses voisins de synchronisation du temps afin de maintenir la synchronisation du temps. Il convient que, par construction, un appareil ne nécessite pas de DLPDU d'entretien à une fréquence supérieure à une fois toutes les 30 s si la température varie de 2 °C/min ou moins. De surcroît, il convient que les conceptions d'appareils tolèrent une nouvelle tentative en cas de perte de paquet (à savoir une marge de sécurité de 10 s). Cela correspond approximativement à une précision d'horloge compensée de 10 parties par million ou meilleure.

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6.2.2 Fonctionnement de la couche réseau

6.2.2.1 Généralités

Le réseau de Type 20 est un système de communication maillé de capteurs et d'actionneurs qui simplifie l'installation du réseau et des appareils et permet à l'utilisateur final de personnaliser l'installation et sa topologie pour satisfaire à des exigences d'application spécifiques. Les éléments de base de ce réseau comprennent les appareils de terrain, la passerelle et le gestionnaire de réseau. Chaque réseau comporte au moins une passerelle. Alors que des gestionnaires de réseau redondants sont pris en charge, il n'y a qu'un seul gestionnaire de réseau actif par réseau. Les passerelles peuvent inclure un ou plusieurs points d'accès.

6.2.2.2 Réseau maillé

La Figure 14 illustre un exemple de réseau avec les appareils de terrain déployés en une topologie maillée. Cet exemple de réseau comporte une passerelle, un gestionnaire de réseau et treize appareils de terrain (étiquetés a à n). Toute la communication a lieu en déplaçant des paquets de la passerelle, en passant par les appareils intermédiaires, jusqu'à l'appareil de terrain de destination du paquet. Chaque déplacement d'un paquet d'un appareil vers un autre le long de l'itinéraire menant à la destination finale du paquet est appelé "saut".

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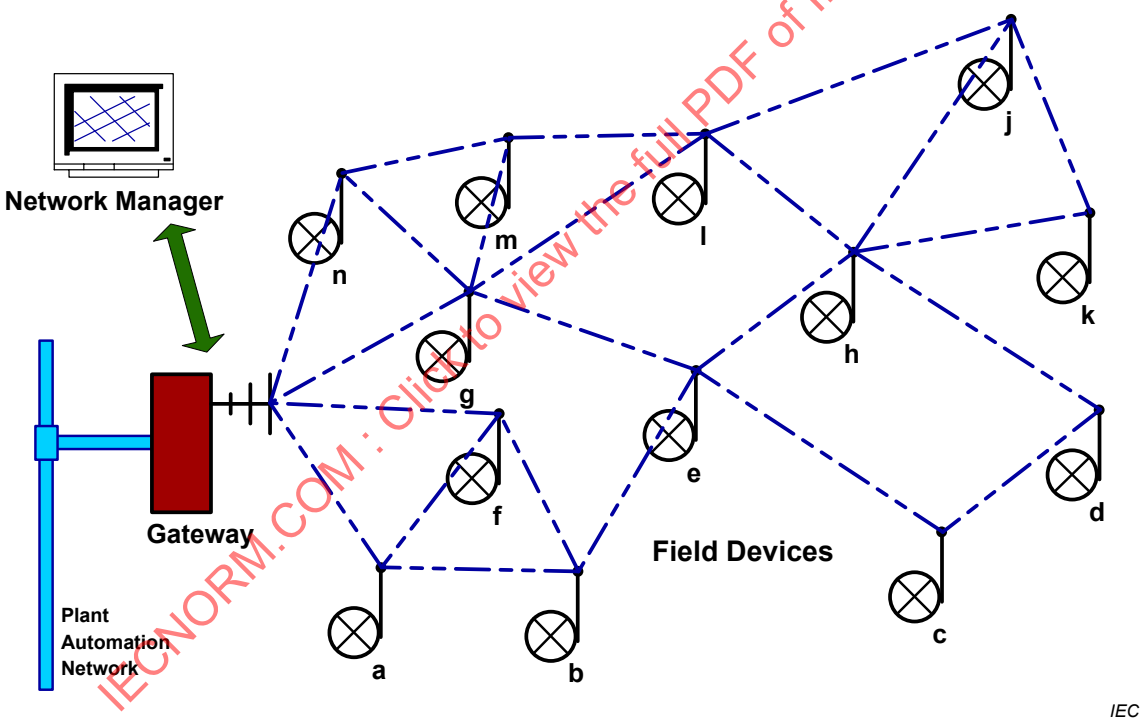

Anglais	Français
Network Manager	Gestionnaire de réseau
Gateway	Passerelle
Plant Automation Network	Réseau d'automatisation d'installation
Field Devices	Appareils de terrain

Figure 14 – Réseau sans fil

Tous les appareils sont capables d'être des sources et des puits pour les paquets et sont capables d'acheminer les paquets reçus en provenance d'autres appareils sur le réseau. Le routage des paquets de leur source initiale jusqu'à leur destination finale peut nécessiter plusieurs sauts. Cette opération incombe à la couche réseau.

Au sein de ce réseau, les nœuds 'a', 'f', 'g' et 'n' forment un saut à partir de la passerelle. Etant donné que ces appareils peuvent transmettre des paquets directement à la passerelle, la communication avec ces appareils a la latence la plus faible. Cependant, étant donné que ce réseau utilise une topologie maillée, les liaisons redondantes sont incluses afin d'améliorer la fiabilité du système en permettant l'acheminement des paquets en contournant les perturbations. Dans la Figure 14, le nœud 'a' peut communiquer directement avec la passerelle, mais peut aussi communiquer via le nœud 'f' avec la passerelle, si l'itinéraire direct devient bloqué.

Les nœuds 'c', 'd', 'j' et 'k' se situent à plusieurs sauts de la passerelle. Tous les appareils intermédiaires (les appareils de terrain 'g' et 'e' par exemple) sont capables de recevoir et transmettre les paquets en provenance et à destination de ces appareils. Etant donné que les paquets doivent faire plusieurs sauts depuis les nœuds 'c', 'd', 'j' et 'k' et vers ceux-ci, la latence de communication par rapport à ces appareils est supérieure à celle relative aux appareils qui se trouvent à une distance d'un saut. Cependant, la topologie maillée permet d'agrandir la taille physique du réseau et permet la communication autour d'obstacles. De surcroît, le nombre d'appareils pouvant être pris en charge dans un même réseau maillé peut être plus grand que celui du nombre d'appareils pouvant être pris en charge par un seul réseau en étoile.

Le protocole pour la topologie maillée peut aussi être utilisé dans une topologie en étoile, c'est-à-dire que tous les appareils sont à un saut seulement de la passerelle pour prendre en charge une application haute performance. Il peut aussi être utilisé dans une topologie maillée exagérément connectée à sauts multiples pour une application moins exigeante (par exemple surveillance) ou n'importe quelle topologie entre les deux. Ce protocole est suffisamment flexible pour que diverses applications (tant haute que basse performance) puissent fonctionner sur un même réseau.

Le réseau sans fil conserve une très haute fiabilité en utilisant plusieurs mécanismes comportant des trajets multiples menant aux appareils de réseau, des fréquences multiples et des répétitions de tentatives. Si une fiabilité améliorée est exigée, d'autres trajets peuvent être insérés en ajoutant des appareils de terrain supplémentaires. La passerelle utilise un point d'accès pour se connecter au réseau et peut avoir plusieurs points d'accès (voir Annexe D). Des points d'accès au réseau supplémentaires peuvent être utilisés pour augmenter le débit et réduire la latence.

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6.2.3 Procédures relatives aux appareils

Plusieurs procédures au niveau de l'appareil sont spécifiées en Annexe B.

6.3 Contrôle de liaison logique

6.3.1 Structure générale de DLPDU

6.3.1.1 Vue d'ensemble

La Figure 15 illustre la structure commune aux DLPDU. La DLE doit fournir les octets à la Couche physique dans la même séquence comme illustré dans cette figure. Sauf spécification contraire, l'octet de poids fort d'un champ à plusieurs octets doit être émis en premier.

Chaque DLPDU doit être constituée de champs dans une séquence telle que décrite ci-dessous:

a) Un seul octet mis à 0x41 (ce qui signifie que le mode de données est activé selon le Tableau 120 de l'IEEE Std 802.15.4-2011 et que la sécurité est activée selon le paragraphe 5.2.1.1.2 de l'IEEE Std 802.15.4-2011).

b) Un spécificateur d'adresse sur 1 octet.

c) Le numéro de séquence sur 1 octet.

d) Le Network_ID sur 2 octets.

e) Les adresses de destination et de source, chacune pouvant avoir une longueur de 2 ou 8 octets.

f) Un spécificateur d'adresse sur 1 octet.

g) Les données utiles de la DLL.

h) Un code d'intégrité de message (MIC) chiffré sur 4 octets.

i) Un CRC16 de l'UITT sur 2 octets.

0x41	Spécificateur d'adresse	Numéro de séquence	Network_ID	Adresse de destination	Adresse source	Spécificateur de DLPDU	Données utiles de la DLL	MIC	CRC

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Figure 15 – Structure d'unité DLPDU

6.3.1.2 Champs de la structure de DLPDU

6.3.1.2.1 Spécificateur d'adresse

Ce champ spécifie la longueur et le type des adresses de destination et de source comme illustré à la Figure 16. Le bit 6 spécifie le type d'adresse source; Le bit 2 spécifie le type d'adresse de destination. Si la valeur de l'un de ces deux bits est '1', l'adresse dans la DLPDU correspondant au bit en question est EUI-64, autrement il s'agit d'un surnom (voir 6.3.1.2.4). N'importe quelle combinaison de longueurs d'adresse peut être utilisée dans une DLPDU.

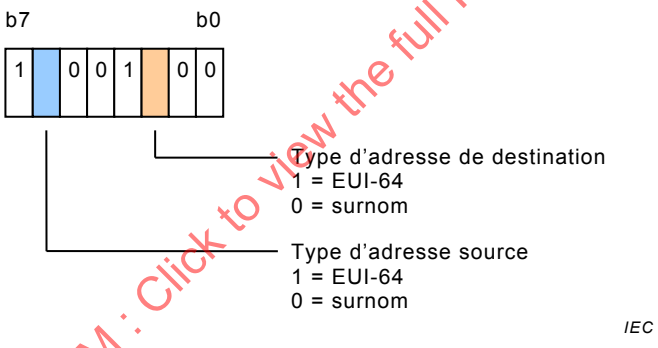

Figure 16 – Spécificateur d'adresse

Les autres bits de ce champ sont mis comme illustré à la Figure 16.

6.3.1.2.2 Numéro de séquence

Le numéro de séquence doit être égal à l'octet de poids faible du nombre d'intervalles de temps absolus (ASN).

6.3.1.2.3 Network_ID

Tous les réseaux sont identifiés à l'aide d'un nombre de 2 octets. Un appareil connecté à un réseau donné ne doit pas envoyer une PDU directement à un autre appareil connecté à un réseau différent.

La valeur à 2 octets est émise, l'octet de poids faible (LSB) le premier, dans toutes les DLPDU. Si le Network_ID ne concorde pas avec celui du réseau dont l'appareil est membre, le paquet doit être rejeté. Les plages des valeurs de Network_ID et leur application sont présentées au Tableau 26.

Sauf note spécifique contraire, l'octet de poids fort de la DLPDU doit être émis le premier. Le Network_ID doit être émis avec l'octet de poids faible en premier.

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Tableau 26 – Attribution de Network_ID

Plage des Network_ID	Application des Network_ID
00 000-32 767 (0x0000-0x7FFF)	Réseaux permanents définis par l'utilisateur (réseaux critiques)
32 768-36 863 (0x8000-0x8FFF)	Réseaux temporaires définis par l'utilisateur (démonstrations, salons commerciaux, essais de terrain, etc.)
36 864-57 343 (0x9000-0xDFFF)	Réservé
57 344-61 439 (0xE000-0xEFFF)	Réseaux de fabrication (non publics utilisés par les fabricants d'appareils)
61 440-65 535 (0xF000-0xFFFF)	Réservé

6.3.1.2.4 Adresse de destination et adresse source

La DLL prend en charge deux types d'adresses: un surnom de 2 octets et une adresse IEEE EUI-64 de 8 octets.

Le surnom de 2 octets est une adresse attribuée à un appareil de réseau spécifique (voir 3.2.74). Il est nécessaire qu'il soit unique seulement au sein du réseau auquel l'appareil est connecté. La valeur 0xFFFF est réservée comme adresse de diffusion.

L'EUI-64 doit être une concaténation de la valeur à 3 octets de l'identifiant propre à une organisation (OUI) telle que définie par l'IEEE 802 et d'un ID propre de 5 octets (voir 3.2.105) comme illustré à la Figure 17. L'ID propre doit être une concaténation du code de type "Appareil étendu" de 2 octets et de l'ID d'appareil de 3 octets.

Deux appareils quelconques conformes à la présente norme ne doivent pas avoir d'adresse EUI-64 identique.

NOTE La valeur de l'identifiant OUI est donnée par le Comité de l'Autorité d'enregistrement de l'IEEE – voir http://standards.ieee.org/regauth/tutorials.html.

Le code de Type d'appareil étendu doit être attribué de manière univoque à des appareils au sein d'un réseau et à des appareils dans la portée d'autres réseaux. Chaque appareil fabriqué avec le code de type d'appareil étendu identique doit recevoir un ID d'appareil unique parmi toutes les instances du type d'appareil en question.

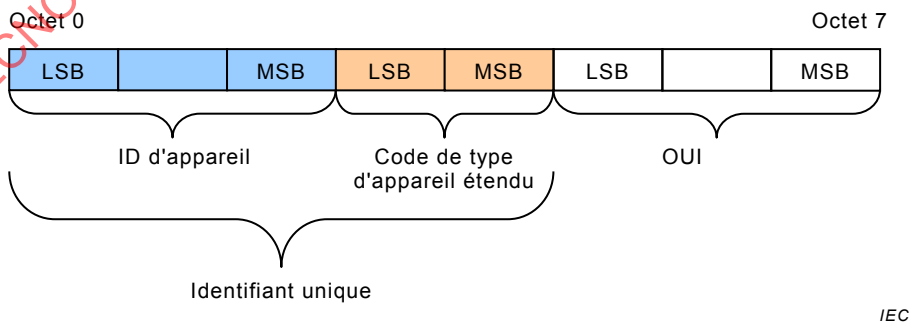

Figure 17 – Construction de l'adresse EUI64 de 8 octets

Le paragraphe 10.1 de l'IEEE STD 802.15.4-2011 exige que les champs à plusieurs octets soient émis avec l'octet de poids faible (LSB) en premier. Par conséquent, l'adresse EUI-64 dans la DLPDU doit être émise dans la séquence illustrée à la Figure 17 c'est-à-dire commençant par le LSB de l'ID d'appareil et se terminant par le MSB de l'OUI. Le surnom doit aussi être émis en commençant par le LSB.

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6.3.1.2.5 Spécificateur de DLPDU

Ce champ est illustré à la Figure 18. Les deux bits de poids fort sont réservés pour usage futur. La DLE doit mettre la valeur de ces bits à '00' avant émission. La DLE doit ignorer toute valeur de ces deux bits.

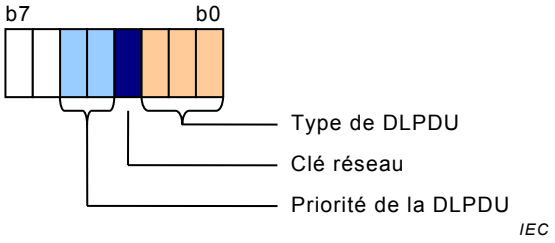

Figure 18 – Spécificateur de DLPDU

Les bits 5 et 4 indiquent la priorité de la DLSDU contenue dans la DLPDU. Son codage est:

00: Priorité Alarme (la plus basse)

01: priorité Normale

10: Priorité données de processus

11: Priorité Commande (la plus haute).

Le bit 3 indique le type de la clé réseau utilisée dans la DLPDU. Son codage est:

0: la clé notoire de cette spécification, utilisée seulement par l'appareil non authentifié;

1: la clé réseau confidentielle utilisée par l'appareil authentifié.

Elle indique la clé utilisée pour authentifier la DLPDU. Pour toutes les communications au sein du réseau entre appareils authentifiés, la DLE doit mettre ce bit à '1' et utiliser la clé réseau confidentielle pour générer la DLPDU MIC (voir 6.3.4.2). Ce bit doit être remis à '0' au cours du processus de rattachement alors que l'appareil est non authentifié. Les DLPDU transmises entre l'appareil non authentifié et ses voisins doivent utiliser la clé notoire (voir 6.3.4.2.3).

Les bits 2, 1 et 0 du spécificateur de DLPDU indiquent le type de la DLPDU. Son codage est:

000: ACQ;

001: Annonce;

010: Entretien;

011: Déconnexion;

111: Données.

Les DLPDU d'ACQ, Annonce, Entretien et Déconnexion doivent utiliser la commande de priorité (la plus élevée).

Les autres codes de ce champ sont réservés pour un usage futur.

6.3.1.2.6 Données utiles de la DLL

Les données utiles de la DLL dépendent du type de DLPDU. Les DLPDU de données contiennent une DLSDU. Les autres types de DLPDU ont des données de maintenance de DLE qui dépendent du type de DLPDU. Par exemple, une DLPDU d'ACQ a des données utiles qui sont constituées d'un ajustement du temps tel que mesuré par l'appareil de destination spécifié dans la DLPDU immédiatement antérieure.

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6.3.1.2.7 Code d'intégrité de message chiffré

Un code d'intégrité de message (MIC) chiffré est utilisé pour l'authentification de liaison de la DLPDU reçue. Les appareils récepteurs doivent répondre uniquement à une DLPDU de non-acquittement de monodiffusion qui a été authentifiée avec succès.

6.3.1.2.8 Contrôle de redondance cyclique

Le champ Contrôle de redondance cyclique (CRC) est basé sur un polynôme CRC de l'UIT-T à 16 bits, également appelé CRC16. Le CRC est calculé sur toute la trame en utilisant le polynôme générateur de degré 16 suivant:

$$G_{16}(x) = x^{16} + x^{12} + x^5 + 1$$

Pour plus d'informations, voir 5.2.1.9 de l'IEEE 802.15.4-2011. Il convient de calculer le CRC dans le matériel de l'appareil.

Au niveau des récepteurs, le train d'octets reçus est soumis à un calcul similaire. Lorsqu'un récepteur peut prédire les octets qui contiendront un CRC, il peut omettre ces octets du calcul et vérifier que le CRC reçu concorde avec ces octets. En variante, le récepteur peut calculer un CRC sur tous les octets du message et vérifier que le résultat concorde avec une valeur résiduelle prévue de zéro.

Le CRC est utilisé pour détecter des erreurs sur les bits et les appareils doivent répondre uniquement à une DLPDU de non-acquittement avec un CRC concordant avec celui calculé par l'appareil récepteur ou dont la valeur résiduelle après traitement de la DLPDU complète, y compris les octets de CRC reçus, concorde avec la valeur résiduelle prévue de zéro.

6.3.2 Structure, codage et éléments de procédure spécifiques à la DLPDU

6.3.2.1 Généralités

Il existe cinq types de DLPDU.

- DLPDU de type Données – contient la DLSDU en transit vers leur appareil de destination finale. La couche réseau est la source et le puits pour les DLPDU de type Données.
- DLPDU de type ACQ – est la réponse de niveau de liaison apportée immédiatement à la réception de la DLPDU d'émission de l'appareil d'origine.
- DLPDU de type Entretien – facilite la maintenance de la connexion entre appareils voisins.
- DLPDU de type Annonce – fournit les informations aux appareils voisins qui essaient de rejoindre le réseau.
- DLPDU de type Déconnexion – elles sont utilisées pour signaler aux appareils voisins que l'appareil quitte le réseau.
- Les appareils recevant une DLPDU d'un type autre que ceux énumérés ci-dessus doivent la rejeter et ne doivent pas acquitter la DLPDU reçue.
- Les DLPDU d'ACQ, d'annonce, d'entretien et de déconnexion sont générées et consommées par des DLE homologues. Ces DLPDU ne sont pas propagées vers la couche réseau ou à travers le réseau.

6.3.2.2 DLPDU de données

6.3.2.2.1 But d'une DLPU de données

La DLPDU de données est utilisée pour envoyer des données utilisateur de DLS d'une DLE source vers une DLE de destination. Elle est également utilisée par la couche réseau pour transmettre ses données utilisateur d'une DLE intermédiaire vers une autre DLE.

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6.3.2.2.2 Contenu des données utiles d'une DLPDU

Les données utiles de DLL dans cette DLPDU proviennent de la couche réseau de l'appareil d'origine de ce saut et sont transmises à la couche réseau de l'appareil de destination. Elle est ensuite transmise par la couche réseau homologue vers sa destination finale.

6.3.2.3 DLPDU d'ACQ

6.3.2.3.1 But d'une DLPU d'ACQ

Elle est utilisée pour envoyer une réponse immédiate à la DLPDU non-ACQ qui vient juste d'être reçue.

6.3.2.3.2 Contenu des données utiles d'une DLPDU d'ACQ

La structure des données utiles de DLL pour une DLPDU d'ACQ est présentée au Tableau 27.

Tableau 27 – Contenu des données utiles d'une DLPDU d'ACQ

Décalage par rapport au début des données utiles	Longueur en octets	Description
0	1	Code de réponse
1	2	Ajustement de temps en µs. La valeur de l'ajustement du temps est positive (négative) si la DLPDU a été reçue plus tôt (plus tard) que prévu.

Le code de réponse doit spécifier soit la réception réussie, soit l'erreur de réception de la DLPDU immédiatement antérieure comme présenté au Tableau 28.

Tableau 28 – Code de réponse ACQ

Code	Classe	Description
0	Succès	La DLPDU a été reçue sans erreur et a été acceptée par l'appareil de destination.
61	Erreur	Aucun tampon n'était disponible pour stocker la DLPDU ayant une priorité autre que 'Alarme'; La DLPDU a été rejetée.
62	Erreur	Aucun tampon n'était disponible pour stocker la DLPDU ayant une priorité 'Alarme'; La DLPDU a été rejetée.
63	Erreur	La priorité de la DLPU reçue était inférieure à Priority_threshold (seuil de priorité) (voir 6.5.2); La DLPDU a été rejetée.

L'ajustement du temps est la différence de l'heure prévue de réception du délimiteur de début complet qui encadre une DLPDU non-ACQ et l'heure de réception réelle du délimiteur de début complet, mesuré en µs. L'ajustement du temps est un entier de 2 octets en complément en deux.

6.3.2.3.3 Contenu du MIC d'ACQ

Le champ MIC de la DLPDU d'ACQ doit être calculé en utilisant la même clé que la clé dans la DLPDU qui vient d'être reçue. Voir 6.3.4.2 pour la génération du MIC.

6.3.2.3.4 Envoi de la DLPDU d'ACQ

La DLPDU d'ACQ doit être envoyée sur la liaison lorsque la DLE d'envoi a juste reçu une DLPDU quelconque, excepté une DLPDU d'ACQ, qu'il n'y a pas d'erreur de réception et que l'adresse de destination dans la DLPDU qui vient d'être reçue n'est pas une adresse de diffusion. La DLE doit vérifier la priorité de la DLPDU reçue et la disponibilité du tampon de stockage local et ensuite accepter ou rejeter la DLPDU reçue comme spécifié en 6.3.3.

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6.3.2.3.5 Réception de la DLPDU d'ACQ

La DLPDU reçue doit être traitée comme spécifié en 6.4.5.2.4.

6.3.2.4 DLPDU d'entretien

6.3.2.4.1 But de la DLPDU d'entretien

Les DLPDU d'entretien sont utilisées:

- pour la synchronisation du temps réseau. La synchronisation du temps est actualisée en fonction de la valeur d'ajustement du temps retournée dans la DLPDU d'ACQ;
- pour confirmer la connectivité avec un voisin;
- pour permettre à l'appareil d'être détecté par d'autres.

6.3.2.4.2 Contenu des données utiles d'une DLPDU d'entretien

Ce champ doit être nul.

6.3.2.4.3 Envoi de la DLPDU d'entretien

Cette DLPDU est envoyée comme spécifié en 6.4.3.4.

6.3.2.4.4 Réception de la DLPDU d'entretien

La DLPDU reçue doit être utilisée pour actualiser la Table des voisins comme spécifié en 6.4.3.4.

6.3.2.5 DLPDU d'annonce

6.3.2.5.1 But d'une DLPDU d'annonce

La DLPDU d'annonce est utilisée pour inviter de nouveaux appareils sur le réseau.

6.3.2.5.2 Contenu des adresses de destination

L'adresse de destination doit être l'adresse de diffusion. L'adresse de diffusion doit avoir une longueur de cinq octets et des zéros partout comme valeur.

6.3.2.5.3 Contenu des données utiles d'une DLPDU d'annonce

Les données utiles de la DLL incluent des informations de réseau. La structure des données utiles de DLL pour une DLPDU d'annonce est présentée au Tableau 29.

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Tableau 29 – Contenu des données utiles d'une DLPDU d'annonce

Décalage par rapport au début des données utiles	Longueur en octets	Description
0	5	Nombre d'intervalles de temps absolus – le nombre d'intervalles de temps depuis le début du réseau jusqu'à l'intervalle de temps utilisé pour l'émission de cette DLPDU.
5	1	Contrôle de rattachement
6	1	La taille d'une matrice de carte de canaux en nombre de bits. La taille maximale de la matrice de carte de canaux est de 256 bits.
7	Variable	Matrice de carte de canaux – il s'agit d'une matrice de bits commençant avec le bit de poids faible (bit 0 de l'octet 0) et ajoutant des octets autant que nécessaire jusqu'à ce que tous les bits soient comptabilisés. Chaque bit correspond à un canal. Si le bit est mis à '1', le canal correspondant est en utilisation.
n+1	2	Graph_ID
n+3	1	Nombre de supertrames

Le champ "contrôle de rattachement" spécifie le niveau de sécurité et la Join_priority (priorité de rattachement) comme illustré ci-dessous:

Bits 7 à 4: Niveau de sécurité pris en charge par le réseau,

Bits 3 à 0: Join_priority – entier non signé indiquant la capacité de l'appareil annonceur à prendre en charge un autre appareil enfant. Plus la valeur est faible et plus l'appareil annonceur se prête au rattachement.

Le contenu du Tableau 30, du Tableau 31 et du Tableau 32 est répété pour chaque supertrame.

Tableau 30 – Début de la supertrame

Décalage par rapport au début des données utiles	Longueur en octets	Description
Variable	1	Superframe_ID
Variable	2	Taille de supertrame, à savoir le nombre d'intervalles de temps dans cette supertrame.

Tableau 31 – Champ qui suit la taille de la dernière supertrame

Décalage par rapport au début des données utiles	Longueur en octets	Description
Variable	1	Nombre de liaisons

Tableau 32 – Répété pour chaque liaison

Décalage par rapport au début des données utiles	Longueur en octets	Description
Variable	2	Intervalle de temps de rattachement – l'intervalle de temps spécifique au sein de la supertrame pour cette liaison
Variable	1	Décalage de canaux d'intervalles de rattachement

Le champ Décalage de canaux d'intervalles de rattachement spécifie:

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Bit 7:	Réservé à un usage futur; la DLE d'envoi doit le mettre à '0';
Bit 6:	Si la liaison sert à l'émission de DLPDU par l'appareil de rattachement, la DLE d'envoi doit le mettre à '1';
Bits 5 à 0:	Décalage de canal: le décalage de canal de fréquence pour cet intervalle de temps. Cette valeur est utilisée pour calculer la fréquence de la liaison/le numéro de canal.

La taille de la matrice de carte de canaux dépend de la couche physique sous-jacente. La couche physique de 2 450 MHz de l'IEEE 802.15.4-2011 prévoit 16 canaux. Le champ "matrice de carte de canaux" a une longueur de deux octets. L'octet de poids faible contient les canaux 11 à 18 et l'octet de poids fort contient les canaux 19-25 comme présenté au Tableau 33. Le canal 26 n'est pas utilisé et donc le bit 15 est toujours '0'.

Tableau 33 – Affectations des canaux et de la fréquence

Indice	Numéro de canal
0	11
1	12
2	13
3	14
4	15
5	16
6	17
7	18
8	19
9	20
10	21
11	22
12	23
13	24
14	25
15	26

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Le nombre d'intervalles de temps absolus et la carte des canaux permettent d'identifier le décalage de canal actuel lors de l'émission d'un paquet pour demander au gestionnaire de réseau l'admission au réseau.

6.3.2.5.4 Contenu du MIC d'annonce

Le champ MIC de la DLPDU d'annonce doit être calculé en utilisant la clé notoire. Voir 6.3.4.2 pour la génération du MIC.

6.3.2.5.5 Envoi de la DLPDU d'annonce

Un paquet d'annonce peut être envoyé sur n'importe quelle liaison d'émission disponible pour l'émission par l'appareil annonceur. Sur l'appareil de rattachement, lorsque la gestion de DL demande que la DLE rejoigne un réseau, la DLE est à l'écoute pour détecter les DLPDU d'annonce envoyées par d'autres DLE. Elle utilise ensuite les informations contenues dans les DLPDU reçues pour se synchroniser au réseau et lancer le processus de rattachement en envoyant sa DLPDU Demande de rattachement. L'appareil de rattachement est limité à ces liaisons jusqu'à ce qu'il soit authentifié par le gestionnaire de réseau et ait reçu sa clé réseau. En limitant la communication aux seules liaisons de rattachement, le gestionnaire de réseau peut mettre l'appareil en quarantaine jusqu'à ce que l'appareil soit prêt à participer totalement au réseau.

Toutes les autres DLPDU ont une plus haute priorité que la DLPDU d'annonce.

6.3.2.5.6 Réception de la DLPDU d'annonce

La DLE qui n'a pas rejoint le réseau doit recevoir toutes les DLPDU d'annonce. Elle doit apprendre les paramètres réseau inclus comme données utiles de DLL de la DLPDU d'annonce. La réception de cette DLPDU doit générer la primitive DL-Advertise indication à l'attention de l'utilisateur de DLM.

6.3.2.6 DLPDU de Déconnexion

6.3.2.6.1 But d'une DLPDU de Déconnexion

La DLPDU de Déconnexion est utilisée par un appareil qui quitte le réseau. Elle est envoyée à chaque voisin connu de l'appareil.

6.3.2.6.2 Contenu des adresses de destination

L'adresse de destination doit être l'adresse du voisin.

6.3.2.6.3 Contenu des données utiles d'une DLPDU de Déconnexion

Ce champ doit être vide, ce qui signifie qu'aucun octet ne doit être utilisé dans les données utiles.

6.3.2.6.4 Contenu du MIC de Déconnexion

Le champ MIC de la DLPDU d'ACQ doit être calculé en utilisant la clé réseau. Voir 6.3.4.2 pour la génération du MIC.

6.3.2.6.5 Envoi de la DLPDU de Déconnexion

Lorsque la gestion de DL demande que la DLE quitte le réseau, elle doit envoyer la DLPDU de Déconnexion à la première occasion.

6.3.2.6.6 Réception de la DLPDU de Déconnexion

La DLE de réception doit retirer la DLE d'envoi de sa liste de voisins et doit supprimer toutes les liaisons assurant la connexion à la DLE d'envoi. La réception de cette DLPDU doit générer la primitive d'indication de Déconnexion de DL à l'attention de l'utilisateur de DLM.

6.3.3 Priorité de DLPDU et contrôle de débit

La priorité de DLPDU est utilisée à des fins de régulation de débit, pour limiter l'encombrement du réseau et assurer que le gestionnaire de réseau garde le contrôle du réseau pendant un dysfonctionnement de processus ou lorsqu'un événement RF défavorable se produit. Par exemple, le gestionnaire de réseau peut élever le Priority_threshold pour diminuer le débit de paquets à travers l'appareil en changeant la valeur de Priority_threshold (voir 6.5.2).

La DLE est tenue d'avoir au moins un tampon de stockage réservé pour recevoir une DLPDU de priorité "Alarme" et au moins un tampon de stockage réservé pour recevoir une DLPDU de priorité "Commande". En outre, ces tampons réservés ne doivent pas être utilisés pour stocker la DLPDU reçue ayant une autre priorité. La DLE de réception doit vérifier la priorité de la DLPDU reçue, le Priority_threshold courant et la disponibilité du tampon de stockage local pour déterminer si la DLPDU est acceptée ou rejetée comme suit.

Si la destination finale de la DLPDU qui vient d'être reçue n'est pas la DLE elle-même et que le niveau de priorité de la DLPDU reçue est inférieur au Priority_threshold, la DLE doit rejeter la DLPDU reçue et le code de réponse dans la DLPDU d'ACQ doit être mis à 63.

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NOTE 1 Pour gérer le flux des DLPDU sur le réseau, le gestionnaire de réseau peut élever ou baisser le niveau de priorité des DLPDU qu'une DLE est autorisée à accepter.

Sinon, si le niveau de priorité est "Alarme", alors

1) si un et un seul tampon dédié au stockage de ce niveau de priorité n'est pas disponible, la DLE doit rejeter la DLPDU reçue et le code de réponse dans la DLPDU d'ACQ doit être mis à 62;

NOTE 2 Un seul tampon pour la priorité "Alarme" est autorisé à réduire le flot d'alarmes. Les alarmes ne sont pas perdues, car elles sont horodatées et la PDU contenant les informations y relatives est envoyée de nouveau après une expiration de délai.

2) Sinon, la DLE doit accepter la DLPDU reçue et le code de réponse dans la DLPDU d'ACQ doit être mis à "Succès".

Sinon, si le niveau de priorité n'est pas "Alarme" et

1) si un tampon dédié au stockage du niveau de priorité de la DLPU reçue n'est pas disponible, la DLE doit rejeter la DLPDU reçue et le code de réponse dans la DLPDU d'ACQ doit être mis à 61;
2) Sinon, la DLE doit accepter la DLPDU reçue et le code de réponse dans la DLPDU d'ACQ doit être mis à "Succès".
3) Si la DLPDU reçue est du type Entretien ou Annonce ou Déconnexion, la DLE doit toujours l'accepter et le code de réponse dans la DLPDU d'ACQ doit être mis à "Succès".

Si un tampon de stockage est disponible, la DLE accepte toujours la DLPDU de priorité "Commande", car elle a la priorité la plus élevée. Il convient que la DLE alloue suffisamment de tampons de manière à pouvoir recevoir pratiquement toutes les DLPDU de priorité "Commande" reçues.

En résumé, les DLPDU de gestion de réseau se propagent toujours à travers le réseau, permettant au gestionnaire de réseau de maintenir le réseau opérationnel. Le flux d'alarmes à travers le réseau est limité, ce qui assure que des flots d'alarmes ne perturbent pas le fonctionnement du réseau. Les alarmes étant toujours datées, aucune information relative aux séquences de défaillances n'est perdue.

Tous les autres trafics du réseau s'écoulent à travers le réseau dans la mesure permise par l'espace tampon et la capacité du réseau. Au sein du trafic réseau, les données de processus ont la priorité la plus élevée. Le fonctionnement et le contrôle du processus ont une priorité plus faible pour prévenir l'interruption des communications du réseau.

6.3.4 Détection d'erreurs et sécurité

6.3.4.1 Généralités

Pour réaliser la détection d'erreurs, la présente norme inclut une séquence de contrôle des trames à la fin de chaque DLPDU. Le contrôle (CRC) est utilisé pour détecter les erreurs des communications. Le CRC est calculé sur toute la DLPDU en utilisant l'algorithme de l'UIT-T de 16 bits.

Pour la sécurité, chaque DLPDU inclut un MIC dans chaque DLPDU.

6.3.4.2 Calcul de MIC

6.3.4.2.1 Généralités

Un MIC chiffré est utilisé pour garantir que la DLPDU émane d'un appareil authentifié et approuvé. La DLPDU elle-même n'est pas chiffrée; en revanche, son contenu est authentifié à l'aide du MIC de quatre octets. Le MIC est généré et confirmé en mode CCM* (compteur combiné avec CBC-MAC [de l'anglais Cipher Block Chaining-Message Authentication Code – Code d'authentification de messages avec enchaînement de blocs de chiffrement] (corrigé)) conjointement au chiffrement par blocs de 128 bits AES (de l'anglais Advanced Encryption

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Standard – Norme de cryptage avancé) pour assurer l'authentification comme spécifié dans la Publication 800-38C du NIST (National Institute of Standards and Technology). Ce chiffre exige quatre chaînes d'octets comme paramètres:

- 'a', les données complémentaires devant être authentifiées, mais pas chiffrées;
- 'm', le message devant être chiffré;
- 'N', qui est le nonce de 13 octets; et
- 'K', qui est la clé AES de 128 bits.

Les parties d'une DLPDU, de l'octet 0x41 jusqu'à la fin des données utiles, correspondent à la chaîne d'octets 'a'. La DLPDU n'étant pas chiffrée, la chaîne d'octets 'm' est vide.

6.3.4.2.2 Nonce de la DLL

Le 'N' doit avoir une longueur de 13 octets exactement et il est la concaténation de l'ASN et de l'adresse source dans la DLPDU.

L'ASN contient toujours le numéro de l'intervalle de temps courant. L'ASN, d'une longueur de 5 octets, est copié dans les octets N[0] à N[4], où N[0] est l'octet de poids fort MSB de l'ASN.

Si la DLPDU a l'adresse EUI-64, elle est copiée (MSB à LSB) dans les octets N[5] à N[12]. En d'autres termes, l'OUI est copié dans les octets N[5] à N[7]. Le code de type d'appareil étendu et l'ID d'appareil sont respectivement copiés (MSB à LSB) dans les octets N[8] à N[9] et N[10] à N[12].

Si la DLPDU a le surnom de 2 octets, elle est copiée (MSB à LSB) dans les octets N[11] à N[12]. Les octets N[5] à N[10] sont mis à 0x00.

6.3.4.2.3 Clé de DLL

La clé doit avoir une longueur de 128 bits (16 octets) comme exigé par le Mode CCM. Elle est copiée dans la chaîne d'octets 'K' dans l'octet de poids fort en premier. Les octets K[0] et K[15] sont respectivement l'octet de poids fort et l'octet de poids faible de la clé.

Il y a deux clés de DLL:

- la clé notoire, qui est utilisée dans la DLPDU d'annonce; et
- la clé réseau, qui est utilisée pour toutes les autres DLPDU.

La clé notoire doit être identique pour tous les appareils et a une valeur hexadécimale de 7777 772E 6861 7274 636F 6D6D 2E6F 7267. Elle est utilisée pour les DLPDU transmises entre l'appareil de rattachement et les appareils faisant déjà partie du réseau.

NOTE La clé notoire est choisie au hasard.

Cette clé réseau est fournie par le gestionnaire de réseau à un appareil, lorsque celui-ci rejoint le réseau. L'appareil ne doit pas changer la valeur de cette clé.

Le gestionnaire de réseau peut changer la clé réseau à tout moment.

6.3.4.3 Détection d'erreurs

Lorsque la DLE reçoit une DLPDU, elle vérifie le CRC dans la DLPDU reçue. Si le CRC dans la DLPDU ne concorde pas avec le CRC attendu, la DLE doit rejeter la DLPDU reçue et ne doit pas envoyer de DLPDU d'ACQ en réponse.

Si le CRC dans la DLPDU reçue est correct, la DLE doit calculer le MIC attendu. Elle doit ensuite le comparer au MIC dans la DLPDU reçue. Si ces deux éléments ne sont pas

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identiques, la DLE doit rejeter la DLPDU reçue et ne doit pas envoyer de DLPDU d'ACQ en réponse.

6.4 Contrôle d'accès au support

6.4.1 Fonction

La sous-couche Contrôle d'accès au support (MAC) fournit la communication de base d'une DLE à une autre. Le moment d'une telle communication est régulé par la synchronisation des intervalles de temps à travers le réseau. Pour ce faire, la DLE comprend:

- Une Table des voisins, des supertrames, des liaisons et des graphes qui configurent la communication entre l'appareil et ses voisins (voir 6.4.3). Ces tables sont élaborées par le gestionnaire de réseau. De plus, la Table des voisins est actualisée par la DLE, lorsqu'elle découvre l'ajout d'un nouveau voisin au réseau ou la déconnexion d'un voisin existant du réseau.
- Un programmateur de liaison (voir 6.4.4), qui évalue les tables d'appareils et choisit le prochain intervalle de temps devant être pris en charge en étant à l'écoute pour détecter une DLPDU ou en envoyant une DLPDU. En général, le programmateur de liaison parcourt les tables pour identifier le prochain intervalle de temps dans lequel envoyer une DLPDU et le prochain intervalle de temps dans lequel être à l'écoute. L'intervalle de temps programmé est le suivant de ces deux intervalles de temps qui se produit.
- Des diagrammes d'états qui contrôlent la propagation des DLPDU à travers la sous-couche MAC. Le fonctionnement de MAC (voir 6.4.5) consiste en des intervalles de durée d'entretien et de maintenance programmée. Le fonctionnement de MAC est guidé par des événements et répond à des invocations de primitive de service et au début d'un intervalle de temps nécessitant une prise en charge.

La sous-couche MAC envoie la DLPDU placée en file d'attente dans les tampons de l'appareil et reçoit la DLPDU envoyée par une DLE voisine. Ces deux opérations sont exécutées un intervalle de temps à la fois. La réussite de la communication dépend de la synchronisation de l'heure des intervalles de temps entre voisins et du minutage conforme de la transaction dans l'intervalle de temps.

6.4.2 Synchronisation des intervalles de temps

6.4.2.1 Généralités

La Figure 19 représente un intervalle de temps et donne une vue générale des temporisations d'une transaction simple conforme à la Figure 22b de l'IEEE 802.15.4e:2012. Le diagramme (a) montre le fonctionnement au niveau du voisin source et le diagramme (b) montre le fonctionnement au niveau du voisin de destination. Les détails des paramètres d'heure d'un intervalle de temps sont définis au Tableau 34, qui présente également les valeurs requises pour la couche physique prise en charge par la présente norme et spécifiées dans la couche physique de 2 450 MHz du tableau 52e de l'IEEE 802.15.4e:2012. Toutes les transactions sont tenues de se conformer à ces paramètres temporels.

L'heure de début d'intervalle de temps au niveau de la source et celle au niveau de la destination peuvent différer en raison de la grandeur différente de la dérive d'horloge. Ce diagramme montre que l'intervalle de temps débute plus tard au niveau de l'appareil de destination.

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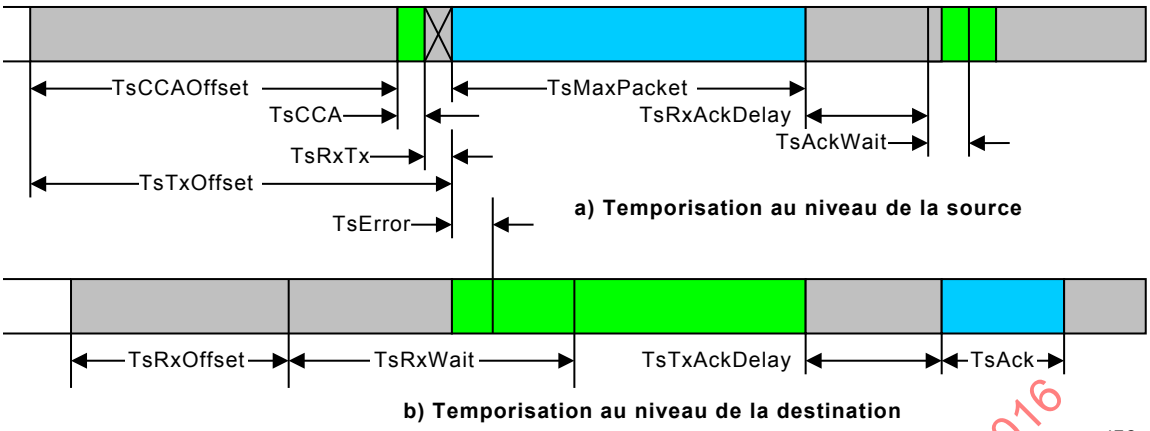

Figure 19 – Détails de la synchronisation d'un intervalle de temps

Tableau 34 – Définitions et valeurs de synchronisation d'un intervalle de temps

Symbole	Définition	Valeur requise
TsTxOffset	Du début de l'intervalle jusqu'au début de l'émission de préambule	2 120 µs
TsRxOffset	Du début de l'intervalle de temps jusqu'à l'instant où l'émetteur-récepteur doit être à l'écoute	1 120 µs
TsRxWait	Temps minimal d'attente du début du message; il est corrélé à la grandeur de la dérive entre les voisins qui peut être tolérée pour maintenir les communications	2 200 µs ±100 µs
TsMaxPacket	Durée que peut prendre l'émission du paquet le plus long possible qui inclut le préambule, le délimiteur, la longueur et la DLPDU de PhL	4 256 µs
TsTxAckDelay	De la fin du message jusqu'au début de l'ACQ; l'appareil de destination doit valider le STX et générer un ACQ, si requis, au cours de cet intervalle	1 000 µs ±100 µs
TsRxAckDelay	De la fin de PhPDU d'émission jusqu'à l'instant où l'émetteur-récepteur doit être à l'écoute pour détecter l'ACQ	800 µs ±100 µs
TsAckWait	Temps minimal d'attente du début d'un ACQ;	560 µs
TsAck	Temps pour émettre un ACQ (25 octets[a])	800 µs
TsCCAOffset	Du début d'intervalle de temps jusqu'au début de CCA	1 800 µs ±100 µs
TsCCA	Temps pour effectuer la CCA (8 symboles)	128 µs
TsRxTx	Durée la plus longue pour commuter de la réception à l'émission ou vice versa (12 symboles)	192 µs
TsError	Il s'agit de la différence entre l'heure de début réel du message et l'heure de début idéal du message telle que perçue par l'appareil de réception. En d'autres termes, il s'agit de la manière dont l'appareil de réception perçoit la désynchronisation de l'appareil émetteur.	

[a] ACK est plus long lorsque des adresses longues (8 octets) sont utilisées.

Un intervalle de temps doit être de 10 ms.

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Si un appareil a un paquet prêt pour l'émission et qu'il est programmé pour l'émission dans un intervalle de temps, l'intervalle de temps en question commence en accordant une durée pour préparer la PhPDU en vue de l'émission. La source doit effectuer l'évaluation de canal libre (CCA) et émettre le paquet. Si la DLPDU reçue exige un acquittement, la DLE de destination doit émettre la PhPDU contenant la DLPDU d'ACQ.

Si un appareil est programmé pour la réception dans un intervalle de temps, l'appareil en question doit entrer en mode réception. L'appareil doit commencer à écouter le support après un retard de TsRxOffset par rapport au début de l'intervalle de temps. La fenêtre de réception spécifiée par TsRxWait permet la dérive de l'heure de l'appareil, tout en permettant encore

aux appareils de communiquer et de resynchroniser leurs temporisateurs d'intervalles de temps.

Si l'appareil de destination détecte une PhPDU, il doit saisir la fin de la réception de l'heure de début du délimiteur de couche physique. Il doit calculer TsError comme étant la différence entre l'heure prévue de début et l'heure réelle de début du délimiteur de couche physique.

Du temps est alloué vers la fin de l'intervalle de temps pour traiter le paquet reçu et se préparer pour le prochain intervalle de temps (par exemple évaluer et classer par ordre de priorité les paquets mis maintenant en file d'attente dans chaque appareil). Si l'un des voisins était la source de temps pour l'autre, l'heure de fin de l'intervalle de temps doit être alignée après une communication réussie.

6.4.2.2 Emission d'un paquet

L'appareil d'origine doit attendre pendant une durée TsCCAOffset après le début d'un intervalle de temps et ensuite il doit effectuer une CCA pendant la durée TsCCA. Si le canal est occupé, la tentative de transaction est reprogrammée pour un intervalle de temps ultérieur. Sinon, si le canal est libre, l'appareil doit faire commuter l'émetteur-récepteur de la réception à l'émission. Ensuite, l'appareil doit commencer son émission de telle manière que le début de message (SOM) ait lieu exactement à une durée TsTxOffset par rapport au début de l'intervalle de temps.

6.4.2.3 Réception d'un paquet

L'appareil de destination doit entrer en mode réception au début de l'intervalle de temps. Il doit commencer à écouter le support après un retard de TsRxOffset par rapport au début de l'intervalle de temps. L'appareil de destination doit continuer à rechercher le SOM. Si le SOM n'est pas détecté au bout de la durée (TsRxOffset + TsRxWait) à partir du début de l'intervalle de temps, il doit cesser d'être à l'écoute. Sinon, si le SOM est détecté, il doit recevoir et valider le paquet reçu.

6.4.2.4 Transaction acquittée

La plupart des communications consistent en ce que l'appareil d'origine propage un message en émettant un paquet et l'appareil de destination acquitte la réception du paquet en question. Pour une communication acquittée, les adresses de la source et de la destination dans la DLPDU doivent contenir l'adresse d'appareil individuel.

Si le paquet reçu est valide, l'appareil de destination doit examiner l'adresse de destination dans la DLPDU. Si l'adresse de destination n'est pas une adresse de diffusion et qu'il n'y a pas d'erreur de réception, l'appareil doit commuter de la réception à l'émission et doit émettre la PhPDU contenant la DLPDU d'ACQ et, de ce fait, le SOM de cette PhPDU se produit exactement au moment TsTxAckDelay après la fin du paquet émis de l'appareil d'origine.

Entre-temps, l'appareil d'origine doit commuter de l'émission vers la réception. Après une durée TsRxAckDelay à partir de la fin de l'émission, l'appareil d'origine doit écouter le support. Il doit rechercher le SOM pendant la durée TsAckWait.

6.4.2.5 Diffusion transaction

Les émissions diffusées sont également prises en charge. L'adresse source de la DLPDU est une adresse d'appareil individuelle et l'adresse de destination est une adresse de diffusion. Les messages de diffusion ne sont pas acquittés par l'appareil de réception. L'adresse de diffusion doit avoir une longueur de cinq octets et des zéros partout comme valeur.

Si le paquet reçu est valide, l'appareil de destination doit examiner l'adresse de destination dans la DLPDU. Si l'adresse de destination est une adresse de diffusion, l'appareil de réception ne doit pas émettre de réponse.

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6.4.3 Tables et tampons de communication

6.4.3.1 Généralités

Tous les appareils doivent disposer d'une série de tables qui contrôlent les communications réalisées par l'appareil et recueillent les statistiques correspondantes. De plus, l'appareil doit placer en tampon les paquets reçus, les traiter et les transmettre, le cas échéant.

Les tables contrôlant les activités de communication sont:

- la Table des supertrames, qui stocke les attributs d'une supertrame;
- la Table des liaisons, qui est utilisée pour stocker les attributs d'une liaison;
- la Table des voisins, qui contient la liste de tous les autres appareils avec lesquels l'appareil peut communiquer directement;
- la Table des graphes, qui emmagasine les destinations des prochains sauts légitimes pour propager le paquet vers sa destination.

Certaines des informations contenues dans ces tables sont partagées entre la NLE et la DLE. La relation entre ces tables est illustrée à la Figure 20. Au sein de l'appareil, la Table des voisins est centrale. Elle contient une liste de tous les appareils qui ont été identifiés par l'appareil.

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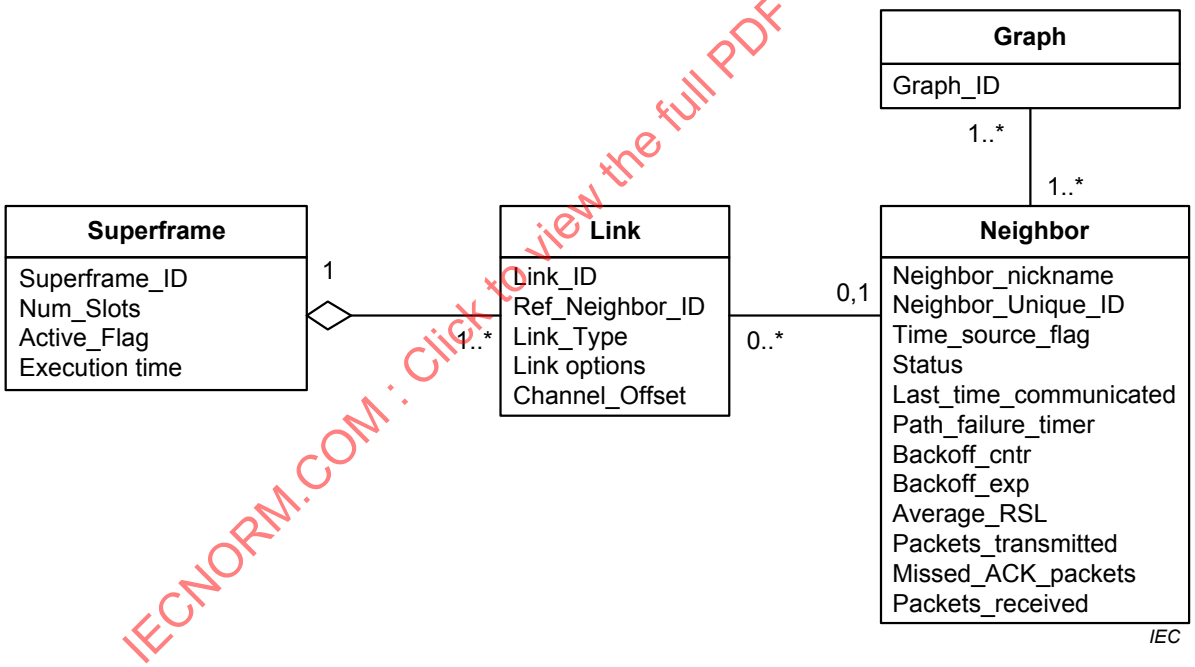

Anglais	Français
Superframe	Supertrame
Execution time	Temps d'exécution
Link	Liaison
Link options	Options de liaison
Graph	Graphe
Status	Statut
Neighbor	Voisin

Figure 20 – Tables des DLE et relations

Une supertrame contient 1 ou plusieurs liaisons. Une liaison est associée à 0 (liaison de diffusion) ou 1 voisin (appareil de réseau spécifique). Un voisin peut être associé à plusieurs

liaisons. Les voisins peuvent aussi être associés avec 0 ou plusieurs graphes et les graphes peuvent être associés à 1 ou plusieurs voisins.

Outre ces tables, des tampons sont utilisés pour stocker les paquets. Le Tableau 35 présente le nombre minimal d'entrées de table et l'espace tampon minimal que chaque appareil de réseau doit prendre en charge.

Tableau 35 – Exigences minimales de tables de DLE et d'espace tampon

Nom de la Table	Nombre minimal d'entrées requis
Supertrame	16
Link	64
Voisin	32
Graphe	32
Nombre total de connexions graphe-voisin	128
Tampons de paquets	16

Certains des attributs des tables décrites dans la présente norme peuvent être calculés ou dérivés d'autres d'informations et il n'est pas nécessaire de les stocker séparément.

NOTE Bien que la mise en œuvre spécifique du stockage de données et de la configuration soit laissée au choix des concepteurs de l'appareil, une description générale des champs contenus dans les structures de données est importante pour le fonctionnement global.

Chaque supertrame a une ou plusieurs liaisons. Les liaisons spécifient l'intervalle de temps et les informations associées indispensables pour transmettre ou accepter un paquet.

Chaque liaison définit une occasion de communication. Une liaison peut appartenir à une et une seule supertrame. Les liaisons spécifient un voisin qui est le partenaire dans toute communication utilisant la liaison. Une liaison est orientée vers un voisin ou bien elle est une liaison de diffusion. Pour une liaison, les paquets sont propagés soit vers le voisin, soit à partir de celui-ci. Les liaisons de diffusion propagent toujours les paquets à partir de l'appareil.

Un graphe peut spécifier plusieurs voisins, dont n'importe lequel peut être utilisé pour le prochain saut par les paquets empruntant l'itinéraire désigné par le Graph_ID. Pour transmettre un paquet en utilisant le routage par graphe, l'appareil peut le propager vers n'importe lequel des voisins associés au Graph_ID du paquet en question. Pour en savoir plus, voir 6.4.3.5.

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6.4.3.2 Table des supertrames

Les attributs de supertrame sont présentés au Tableau 36. Une supertrame est constituée d'un nombre fixe d'intervalles de temps, et ne comporte initialement aucune liaison. Les supertrames sont créées et maintenues par le gestionnaire de réseau. Une fois qu'une supertrame est créée, le gestionnaire de réseau peut ajouter, supprimer ou modifier des liaisons au sein de la supertrame, identifiant ainsi les opportunités de communication entre appareils. Une fois configurée avec des liaisons, la supertrame peut être activée pour permettre au programmateur de liaison de commencer à identifier les intervalles de temps d'émission et de réception. Au moment du rattachement, la supertrame annoncée est immédiatement activée. Lorsqu'une supertrame est créée au moyen du service Ecrire supertrame, les fanions de mode supertrame déterminent l'état (actif ou inactif) de la supertrame.

Tableau 36 – Attributs de supertrame

Nom d'attribut	Plage de valeurs	Définition
Superframe_ID	0 à 255	Identifiant propre à la supertrame, fourni par le gestionnaire de réseau
Num_Slots	0 à 65 535	Nombre d'intervalles de temps dans cette supertrame, c'est-à-dire la taille de la supertrame
Active_Flag	VRAI, FAUX	Fanion indiquant si la supertrame est actuellement activée
Liaisons [1.]	Link_ID	Liste des liaisons dans cette supertrame

6.4.3.3 Table des liaisons

6.4.3.3.1 Généralités

Les attributs d'une liaison sont présentés au Tableau 37. La liaison inclut une référence à un voisin qui est autorisé à communiquer avec l'appareil. Cette référence peut être faite à un seul voisin ou il peut s'agir d'un groupe non spécifié de voisins (pour une liaison de diffusion). Le gestionnaire de réseau peut spécifier plusieurs liaisons dans le même intervalle de temps. Le nombre d'intervalles de temps dans la supertrame, le sens de la communication, les caractéristiques de la liaison (partagée ou dédiée) et le canal de communication initiale sont spécifiés. La liaison est identifiée de façon univoque par la combinaison des paramètres-clés suivants:

Superframe_ID, nombre d'intervalles de temps et adresse de voisin.

Lorsque le gestionnaire de réseau supprime toutes les liaisons dans l'appareil, ledit appareil doit rejoindre le réseau.

Tableau 37 – Attributs d'une liaison

Nom d'attribut	Plage de valeurs	Définition
Link_ID	Voir Note	Identifiant de la liaison
Ref_Neighbor_ID	Voir Note	Référence à une entrée de la Table des voisins
Link_type	NORMAL, DIFFUSION, RATTACHEMENT, DÉCOUVERTE	Indique le type de liaison.
Tx_Link	VRAI, FAUX	Si vrai, indique que la liaison doit être utilisée pour l'émission
Rx_Link	VRAI, FAUX	Si vrai, indique que la liaison doit être utilisée pour la réception
Shared_Link	VRAI, FAUX	Si vrai, indique que la liaison est partagée par plusieurs appareils
Slot	0 à 65 535	Nombre d'intervalles de temps dans la supertrame attribué à cette liaison
Channel_Offset	11 – 25	Décalage initial du canal de saut de fréquence (voir Tableau 33)
NOTE La plage de valeurs n'est pas spécifiée par la présente norme; Elle dépend de la mise en œuvre.		

NOTE Le gestionnaire de réseau ne supprime ni ne suspend de liaison de type RATTACHEMENT pendant une demande de rattachement en cours.

Les liaisons sont allouées à une supertrame par le gestionnaire de réseau. Lorsque le gestionnaire de réseau désigne une liaison comme étant partagée, l'accès à de multiples expéditeurs fondé sur la gestion des conflits est réalisé dans la liaison correspondante. Pour

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ces liaisons, les messages qui ne sont pas acquittés conduisent à l'application d'un algorithme de repli aléatoire (voir 6.4.4.4).

6.4.3.3.2 Calcul de canal de liaison

La liaison spécifie également le Channel_Offset et, donc, implicitement l'ordre dans lequel les canaux sont sautés. Pendant le reste du temps, cette opération indexe la Table des canaux pour obtenir le canal réellement utilisé pour la communication dans l'intervalle de temps actif. Le contenu et la longueur de la Table des canaux dépendent de la couche physique sous-jacente. Dans la couche physique préférentielle spécifiée dans l'IEEE 802.15.4-2011 (2 450 MHz), le nombre de canaux disponibles est de 16.

NOTE La présente norme n'utilise que les 15 premières sur les 16 canaux disponibles.

La DLE doit contenir une variable ChannelMap (Carte de canaux) de 64 bits qui suit les canaux actifs de l'appareil. Chaque bit (bit 0 à bit 63) vrai identifie un canal actif. ChannelMap est initialisé à vrai partout (à savoir, tous les canaux sont actifs par défaut). Seuls les bits correspondant à des canaux disponibles pour la couche physique sont significatifs et considérés dans les calculs éventuels.

La DLE doit avoir une variable ActiveChannelArray (Matrice des canaux actifs) pour stocker le jeu ordonné de numéros de bits actifs dans ChannelMap. Le numéro de bit du canal actif le moins significatif doit être stocké à l'indice zéro de la matrice. Le numéro de bit correspond à l'indice dans la Table des canaux physiques pour la couche physique utilisée.

La DLE doit calculer la valeur de la variable ActiveChannel (Canal actif) en divisant la somme du Channel_Offset et du nombre d'intervalles de temps absolus par le nombre de canaux actuellement actifs.

ActiveChannel = (Channel_Offset + nombre d'intervalles de temps absolus) % nombre de canaux actifs.

Elle doit utiliser la valeur ActiveChannel comme indice dans l'ActiveChannelArray. La valeur stockée à cet indice doit être utilisée comme étant le canal à utiliser pour la liaison dans le nombre d'intervalles de temps absolus en question.

Canal = ActiveChannelArray [ActiveChannel].

La matrice ActiveChannelArray doit être une liste ordonnée allant de l'indice de canal actif le plus petit (ActiveChannelArray [0]) jusqu'au plus grand.

6.4.3.4 Table des voisins

L'appareil doit maintenir une liste des voisins dont il a connaissance. Ce sont les appareils connexes qui partagent une liaison avec cet appareil ou des voisins dont les communications ont fait l'objet d'une écoute indiscrète. Dans cette liste, tous les voisins liés doivent apparaître dans la liste avant (c'est-à-dire au début de la liste) les voisins non reliés.

Comme illustré à la Figure 20, la Table des voisins est primordiale pour le pilotage des communications de l'appareil:

- Chaque liaison a une référence à un voisin ou bien elle est une liaison de diffusion.
- Les graphes peuvent avoir des références à plusieurs voisins. Lorsqu'un graphe est utilisé pour le routage, les voisins pour le graphe en question sont tous des récipiendaires valides du paquet propagé.

La Table des voisins recueille une diversité d'attributs et de statistiques concernant le voisin comme présenté au Tableau 38, y compris:

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- les informations de base sur l'identité du voisin
- les performances et statistiques antérieures et
- les attributs d'intervalles de temps partagés.

Les informations de base concernant l'identité comprennent l'ID propre au voisin, l'adresse de surnom de 2 octets et si l'appareil est une source de temps ou non. Pour prendre en charge l'accès fondé sur la gestion des conflits, la Table des voisins contient également les paramètres nécessaires à la prise en charge de l'algorithme de repli (voir 6.4.4.4).

Tableau 38 – Attributs de voisin et variables

Nom d'attribut	Plage de valeurs	Définition
Neighbor_Unique_ID	voir 6.3.1.2.4	ID propre à l'appareil voisin (à savoir, l'adresse longue)
Neighbor_nickname	voir 6.3.1.2.4	L'adresse courte du voisin comme définie en 3.2.74
Join_priority	0 à 15	Join_priority à laquelle le voisin s'annonce
Time_source_flag	vrai, faux	Fanion indiquant s'il convient que l'appareil prenne la synchronisation de temps de son voisin
Statut	Champ binaire	Informations de statut relatives à ce voisin (par exemple, une défaillance de trajet) comme spécifié au Tableau F.34
Backoff_exp	0 à 7	Exposant de repli dans l'algorithme d'évitement de collision dans le cas des liaisons partagées[b]
Backoff_cntr (compteur de repli)	0 à 511	Compteur de repli dans l'algorithme d'évitement de collision dans le cas des liaisons partagées[b]
Last_time_communicated (temps de dernière communication)	0 à 2^{32}-1 en unités de ms	Temps de la dernière communication avec ce voisin
Path_failure_timer (temporisateur de défaillance de trajet)	0 à 2^{32}-1	Temporisateur cyclique en ms pour détecter la défaillance du trajet menant au voisin
Average_RSL (niveau moyen de signal reçu)	128 à 127	Niveau moyen de signal reçu en dBm pour les paquets reçus provenant de ce voisin
Packets_transmitted (paquets émis)	0 à 65 535[a]	Nombre de paquets de non-diffusion émis vers ce voisin
Missed_ACK_packets (paquets ACQ manqués)	0 à 65 535[a]	Nombre de paquets pour lesquels un ACQ escompté n'a pas été reçu de ce voisin
Packets_received (paquets reçus)	0 à 65 535[a]	Nombre de paquets de non-diffusion corrects reçus provenant de ce voisin
Broadcasts_received (diffusions reçues)	0 à 65 535[a]	Nombre de paquets de diffusion corrects reçus provenant de ce voisin
[a] La valeur des compteurs de paquets repasse de 65 535 à 0.		
[b] Voir 6.4.4.4 pour l'algorithme.		

La capacité de l'appareil à communiquer avec un voisin est une métrique clé pour former et nettoyer le réseau maillé. Les statistiques sont maintenues pour chaque voisin. Elles incluent Average_RSL; les statistiques sur les paquets émis et reçus ainsi que l'horodatage de la dernière communication avec le voisin. Pour les voisins reliés, Average_RSL se calcule en utilisant un filtre à réponse impulsionnelle infinie avec l'équation suivante:

Average_RSL = Average_RSL – (Average_RSL / RSL_damp) + (MeasuredRSL / RSL_damp)

où

MeasuredRSL est le niveau de signal reçu du paquet courant;

RSL_damp est le facteur d'amortissement.

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RSL_damp doit être une puissance de 2 et sa valeur par défaut est 4. Pour les voisins découverts (c'est-à-dire, les voisins avec lesquels l'appareil ne communique pas) la valeur de niveau de signal reçu la plus élevée est renvoyée.

Si une liaison vers un voisin existe, Last_time_communicated est utilisé pour déclencher l'émission d'une DLPDU d'entretien. Une DLPDU d'entretien doit être émise vers ce voisin chaque fois que la valeur de Last_time_communicated plus Keep_alive_time (durée d'entretien) (voir Tableau 46) est supérieure au temps courant. La DLPDU d'entretien doit être répétée jusqu'à réception d'une nouvelle DLPDU provenant du voisin en question.

Path_failure_timer doit aussi être maintenu pour chaque voisin. Chaque fois qu'une DLPDU est reçue du voisin, le temporisateur doit être initialisé à Path_fail_time (voir Tableau 46). Lorsque ce temporisateur atteint zéro, l'indication d'événement DLM avec l'événement PATH_FAILURE doit être invoquée. Lorsque cela se produit, le temporisateur doit être réinitialisé à Path_fail_time et être redémarré. L'appareil doit continuer de tenter d'utiliser le trajet défaillant jusqu'à ce que les voisins ou les liaisons soient supprimés du tableau.

Chaque paquet reçu est utilisé pour actualiser les attributs de voisin correspondants ou il crée une nouvelle Table des voisins. Si un appareil partage des liaisons avec un voisin, le voisin en question doit être maintenu dans la table. Lorsque la Table des voisins est pleine et qu'un nouveau voisin est détecté, le voisin ayant la valeur de Last_time_communicated la plus ancienne doit être supprimé et le nouveau voisin doit être ajouté à la table.

6.4.3.5 Table des graphes

Le graphe fournit les informations relatives au routage pour guider la livraison d'un paquet jusqu'à sa destination finale. Un graphe est une liste orientée de trajets qui relient deux appareils sur le réseau. Les graphes utilisés sont tant amont (à destination de la passerelle) qu'aval. Le gestionnaire de réseau est chargé de configurer correctement chaque graphe. Le Tableau 39 présente les attributs d'un graphe. Les graphes ont un identifiant, une liste de voisins ainsi qu'une adresse longue et une adresse courte. Lorsque la valeur de Graph_ID est inférieure à 0x0100, cela indique un Superframe_ID et lorsqu'elle est égale à 0xFFFF, cela indique que le graphe n'est pas valide.

Tableau 39 – Attributs d'un graphe

Nom d'attribut	Plage de valeurs	Définition
Graph_ID	256 à 65 534	Identifiant propre au graphe tel que défini en 3.2.49
RefNeighbor [ ]	Neighbor_Unique_ID ou Neighbor_nickname	Liste des références aux voisins qui sont le prochain saut en direction de la destination.

Au niveau de l'appareil d'origine pour un paquet, les couches supérieures identifient la destination finale du paquet et le graphe devant être utilisé pour acheminer le paquet.

NOTE L'appareil utilise les informations relatives aux itinéraires pour choisir le Graph_ID.

RefNeighbor identifie les appareils qui sont des destinations de liaisons de données admissibles pour le prochain saut du paquet vers sa destination finale. Sachant qu'un graphe a la possibilité de spécifier plusieurs prochains sauts, le routage par graphe intègre la redondance et la fiabilité. Les références individuelles de voisins sont également appelées "connexions".

Les adresses de destination sont exigées par tous les appareils alimentant des données vers une destination finale spécifique. Cependant, les adresses sont facultatives, car des appareils intermédiaires peuvent tout simplement transmettre le paquet sur son itinéraire et ne pas alimenter de données vers la même adresse finale.

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6.4.3.6 Liste de tampons de paquets

6.4.3.6.1 Généralités

Tous les appareils doivent maintenir une liste de tampons de paquets. Ces tampons sont utilisés pour recevoir, traiter et émettre des paquets. L'enregistrement associé à un paquet est présenté au Tableau 40. Packet_ID est utilisé pour référencer le paquet et il est créé lorsque le paquet est ajouté via la primitive du service de demande d'émission de DL.

Tableau 40 – Enregistrement de paquets

Elément d'enregistrement	Définition
Packet_ID	Identifiant propre au paquet
Payload (charge utile)	Les données utiles de la DLL, c'est-à-dire la NPDU
Priorité	Priorité d'émission du paquet
Destination	Graphe, informations de routage par source ou de proxy ou destination de diffusion
PacketBirthASN	PacketBirthASN est attribué lorsque la NPDU est créée pour la première fois. Cette valeur est utilisée conjointement avec la valeur courante d'ASN pour déterminer l'âge du paquet
Packet_time_stamp	L'heure ASN à laquelle un paquet a été ajouté à la liste d'émission

Packet_time_stamp doit être fixé lorsque le paquet est ajouté à la liste d'émission. Cet horodatage doit être utilisé pour sélectionner le paquet à émettre lorsque l'un ou l'autre de deux paquets d'égale priorité peut être propagé dans le même intervalle de temps absolu. Dans ce cas, le paquet le plus ancien doit être envoyé le premier. De même, dans les scénarios les plus défavorables, au bout d'un long moment, par comparaison à MaxPacketAge (âge maximal du paquet), Packet_time_stamp est utilisé pour évacuer automatiquement un très vieux paquet. L'enregistrement contient la priorité du paquet et la spécification de la destination du paquet.

6.4.3.6.2 Priorités des paquets

Sachant que l'appareil doit pouvoir stocker plusieurs paquets, en attendant leur propagation, il est possible que plusieurs paquets soient candidats à l'émission dans le même intervalle de temps. Lorsque cela se produit, la priorité et l'âge du paquet doivent être utilisés pour choisir le paquet à émettre dans l'intervalle de temps en question. Lorsqu'il y a plusieurs paquets pouvant être émis dans l'intervalle de temps, la priorité la plus élevée doit être choisie pour l'émission (voir 6.3.3). Si plusieurs paquets sont attachés à la priorité la plus élevée, le paquet le plus ancien doit être émis le premier.

6.4.3.6.3 Destinations

La destination d'une DLPDU peut être spécifiée comme étant de l'un de types suivants:

- Itinéraire par graphe – la couche réseau spécifie un Graph_ID comme destination. La DLE peut envoyer le paquet à n'importe lesquels des appareils associés au graphe en question.
- Itinéraire par source – la couche réseau spécifie une adresse d'appareil spécifique comme destination. La DLE doit émettre le paquet sur une liaison vers le voisin en question. Si l'appareil n'a pas de liaison vers le voisin en question, le gestionnaire de réseau doit être avisé qu'une erreur d'itinéraire par source s'est produite.
- Diffusion – l'adresse de destination est diffusée. La DLE doit transmettre en utilisant une liaison de diffusion à partir de la supertrame désignée.
- Itinéraire de proxy – la couche réseau indique que l'adresse de destination est celle d'un appareil candidat au rattachement. La DLE doit émettre le paquet en utilisant une liaison de rattachement.

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Le type de destination détermine le Link_type qui peut être utilisé et in fine l'intervalle de temps dans lequel la DLPDU peut être émise.

6.4.4 Programmation de liaison

6.4.4.1 Généralités

Tous les appareils doivent maintenir un programme de liaisons qui identifie le prochain intervalle de temps qui doit être pris en charge. Toutes les communications sont programmées pour avoir lieu au sein d'une supertrame au cours d'intervalles de temps spécifiques dans la supertrame en question. La prise en charge d'un intervalle de temps consiste soit à être à l'écoute pour détecter un nouveau paquet, soit à émettre un paquet. Lorsqu'un intervalle de temps a un paquet attendant d'être émis et il a aussi une liaison de réception, l'émission du paquet doit avoir la priorité sur la tentative d'écoute pour détecter un nouveau paquet.

La préparation du programme d'une liaison consiste à:

- évaluer les paquets en instance d'émission et déterminer le premier ASN qui peut être utilisé pour émettre un paquet; et
- déterminer le premier ASN qui peut être utilisé dans la tentative de réception d'un nouveau paquet.

Les événements externes à la DLE et les événements internes peuvent avoir une incidence sur le programme de la liaison. Par conséquent, la DLE doit réévaluer le programme chaque fois qu'un tel événement se produit. Un exemple d'événement interne est la défaillance d'une transaction d'émission de haute priorité. Un exemple d'événement externe est la désactivation d'une supertrame par le gestionnaire de réseau.

6.4.4.2 Prise en charge d'une liaison d'émission

La Figure 21 résume les relations qui ont une incidence sur le calcul du prochain intervalle de temps d'émission devant être pris en charge. Les paquets reçus de la NLE sont programmés pour un intervalle de temps basé sur le graphe, l'adresse de destination et le fait que l'appareil agisse ou non comme proxy pour un appareil rejoignant le réseau. Chaque paquet a une destination et une priorité. Comme spécifié en 6.4.3.6.3, il existe plusieurs types de destinations, chacune de celles-ci ayant une incidence sur la sélection de l'intervalle de temps. Pour chaque type de destination, le jeu de liaisons d'émission doit être déterminé.

- Pour une destination avec graphe d'itinéraire, le jeu de liaisons doit être constitué de toutes les liaisons d'émission pour tous les voisins figurant dans le graphe.
- Pour une adresse de destination de diffusion, le jeu de liaisons doit être constitué de toutes les liaisons de diffusion pour la supertrame désignée.
- Pour l'adresse de destination d'un voisin pris séparément, le jeu de liaisons doit être constitué de toutes les liaisons d'émission menant au voisin en question.
- Pour une adresse de destination de proxy, le jeu de liaisons doit être constitué de toutes les liaisons d'émission de type Rattachement.

Une fois que le jeu de liaisons appropriées pour émettre le paquet est déterminé, le jeu d'intervalles de temps à venir doit être déterminé. L'intersection des intervalles de temps à venir et des liaisons avec un paquet en instance détermine le prochain intervalle de temps devant être programmé pour propager le paquet en instance.

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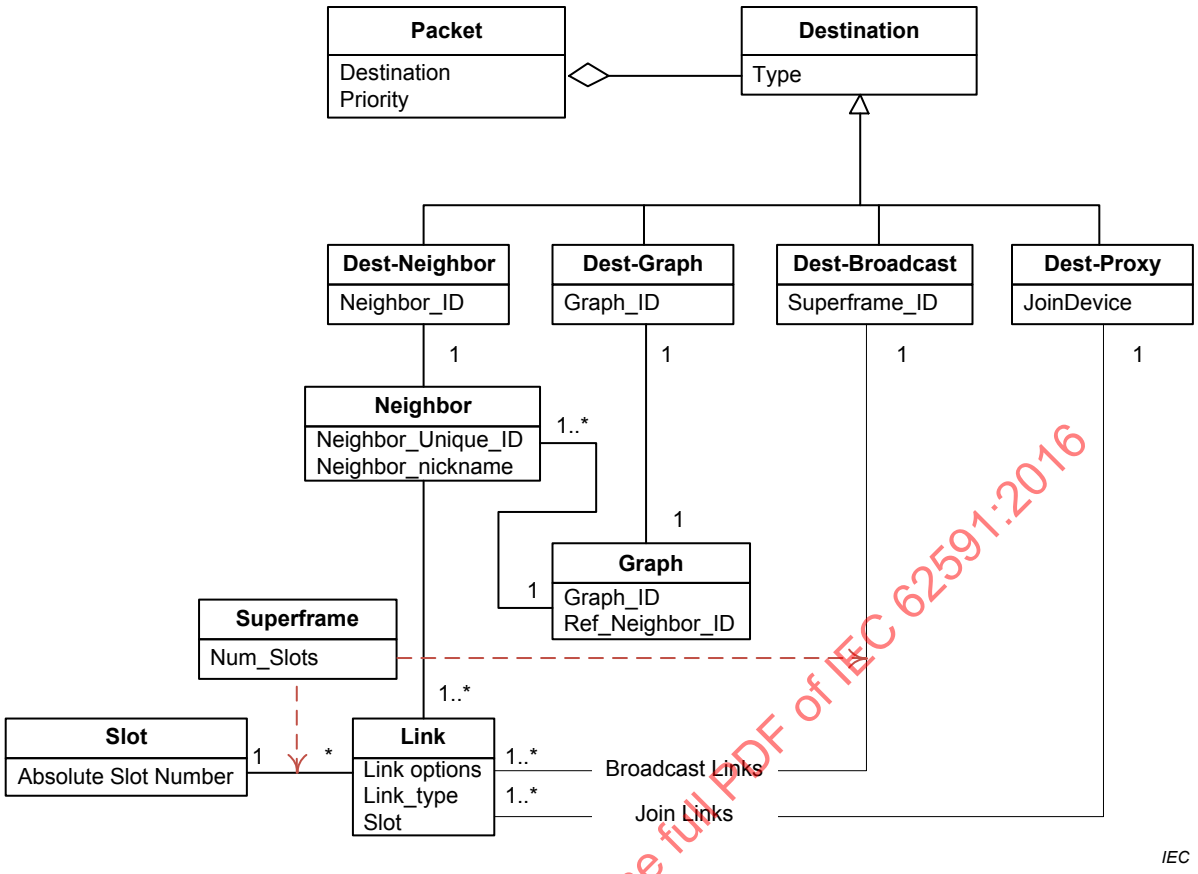

Anglais	Français
Packet	Paquet
Destination priority	Priorité de destination
Destination	Destination
Type	Type
Dest-Neighbor	Destination de type voisin
Dest-Graph	Destination de type graphe
Dest-Broadcast	Destination de type diffusion
Dest-Proxy	Destination de type proxy
Neighbor	Voisin
Graph	Graphe
Superframe	Supertrame
Slot	Intervalle de temps
Absolute Slot Number	Nombre d'intervalles de temps absolus
Link	Liaison
Link options	Options de liaison
Broadcast Links	Liaisons de diffusion
Join Links	Liaisons de rattachement

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Figure 21 – Relations utilisées pour la programmation de liaisons

La figure illustre les règles statiques utilisées au niveau de la DLL pour déterminer la liaison qui sera utilisée pour l'émission. Un nouvel objet "Intervalle de temps lié à la durée d'utilisation" est introduit pour modéliser le fait qu'une liaison pleinement spécifiée sera associée à une durée d'utilisation.

Un paquet contient une destination. La destination peut être spécialisée encore plus par le type de destination – un voisin spécifique, un graphe, une diffusion ou un proxy. Si l'adresse proxy est utilisée, la liaison doit être une liaison de rattachement. Si l'adresse est une adresse de diffusion, une liaison de diffusion doit être utilisée. Si l'adresse est un voisin spécifique, une liaison spécifique associée à un voisin doit être utilisée. Si la destination est un graphe, n'importe quel voisin dans le graphe peut être utilisé.

L'ASN doit être utilisé pour suivre à la trace l'occurrence de chaque intervalle de temps. Une liste ordonnée de liaisons qui vont apparaître bientôt au sein d'une supertrame doit être identifiée en utilisant l'équation suivante:

Intervalle de temps de supertrame = ASN % (Num_Slots de la supertrame).

Les liaisons peuvent être partagées (voir 6.4.4.4), être utilisées pour annoncer (voir 6.4.4.5) la présence de l'appareil à de nouveaux appareils tentant de rejoindre le réseau ou être utilisées pour découvrir des voisins (voir 6.4.4.6)

L'algorithme de repli dans des intervalles de temps partagés doit être utilisé pour déterminer le moment où une émission dans un intervalle de temps partagé est autorisée. Les paquets d'annonce (voir 6.4.4.5) sont émis périodiquement comme spécifié par le gestionnaire de réseau.

Les liaisons qui ne peuvent pas être utilisées pour propager un paquet en instance sont ignorées. À partir du jeu de liaisons résultant, la première liaison potentielle et son intervalle de temps associé peuvent être identifiés. Lorsqu'il y a plusieurs paquets qui peuvent être propagés dans l'intervalle de temps en question, les règles spécifiées ci-dessous doivent être utilisées. Les règles suivantes doivent être appliquées de a) à f) jusqu'à ce qu'un paquet unique ait été identifié:

- Trouver les paquets ayant la priorité la plus haute;
- Choisir le paquet le plus ancien en s'appuyant sur Packet_time_stamp;
- Trouver le paquet destiné aux voisins avec lesquels il n'y a eu aucune communication depuis le plus long temps;
- Si Keep_alive_time a expiré avec un voisin, préparer une DLPDU d'entretien pour émission vers les voisins avec lesquels il n'y a eu aucune communication depuis le plus long temps;
- Si une durée d'annonce s'est écoulée, préparer la DLPDU d'annonce pour l'émission;
- S'il y a une liaison de découverte dans cet intervalle de temps et si Discovery_time (temps de découverte) est écoulé, il est généré un paquet Keep_alive_time.

6.4.4.3 Prise en charge d'une liaison de réception

Pour chaque supertrame active, toutes les liaisons de réception doivent être programmées. Le jeu de liaisons de réception à venir peut être calculé de la même manière que les liaisons d'émission (voir 6.4.4.2). S'il n'est pas nécessaire de propager un paquet, toutes les liaisons de réception doivent être prises en charge. Une fois que la liste ordonnée des liaisons est créée, l'intervalle de temps le plus précoce est sélectionné et la liaison au sein de l'intervalle de temps en question ayant le numéro d'identifiant de supertrame le plus faible doit être le candidat à la prise en charge. S'il n'a pas d'autres liaisons de réception à prendre en charge, l'appareil doit prendre en charge la liaison de réception de découverte. Dans tous les cas, cette liaison de réception sera prise en charge s'il n'y a pas de paquets en instance d'émission sur cet intervalle de temps ou avant celui-ci.

6.4.4.4 Intervalles de temps partagés

Des intervalles de temps partagés sont attribués à plusieurs appareils sources. Un ou plusieurs de ces appareils peuvent tenter d'acheminer un paquet dans l'intervalle de temps et le canal en question. Par conséquent, des collisions peuvent se produire au sein d'un

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intervalle de temps partagé. Si une collision se produit, l'appareil de destination ne pourra pas recevoir avec succès d'émissions d'une source quelconque et ne produira un acquittement pour aucune d'entre elles. Afin de réduire la probabilité de collisions répétées, les appareils sources doivent utiliser un délai de repli aléatoire lorsque leur émission dans un intervalle de temps partagé n'est pas acquittée (à savoir, aucun ACQ n'est reçu par l'appareil d'origine).

Un appareil doit maintenir deux variables pour chaque voisin: l'exposant de repli (Backoff_exp) et le compteur de repli (Backoff_cntr). Chacune de ces deux variables doit être initialisée à 0. Lorsqu'une transaction dans un intervalle de temps partagé échoue, la période de repli aléatoire doit être calculée en fonction du Backoff_exp. Pour chaque tentative non réussie effectuée par l'appareil d'origine dans un intervalle de temps partagé, le Backoff_exp doit être incrémenté et un ensemble séquentiel de nombres est calculé. La valeur de Backoff_exp ne doit pas dépasser celle de Max_backoff_exp (valeur max. de l'exposant de repli). Le jeu de nombres est constitué des nombres entiers {0, 1,... L} où L = ((2 à la puissance Backoff_exp) – 1).

Le Tableau 41 présente les ensembles de repli pour les valeurs de Backoff_exp allant de un (1) à sept (7).

Tableau 41 – Exemple de jeux de sélection Backoff_cntr

Backoff_exp	Ensemble des valeurs possibles pour Backoff_cntr
1	{0, 1}
2	{0, 1, 2, 3}
3	{0, 1, 2, 3, 4, 5, 6, 7}
4	{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15}
5	{0, 1, 2, 3, 4, 5, …, 28, 29, 30, 31}
6	{0, 1, 2, 3, 4, 5, …, 60, 61, 62, 63}
7	{0, 1, 2, 3, 4, 5, …, 124, 125, 126, 127}

Une valeur aléatoire pour Backoff_cntr doit être sélectionnée dans cet ensemble calculé en fonction du Backoff_exp. Pour chaque liaison partagée ultérieure menant au voisin en question, le Backoff_cntr doit être décrémenté. Lorsque le Backoff_cntr correspondant est zéro, seul l'appareil d'origine doit tenter une émission dans l'intervalle de temps partagé en question.

Comme il est également possible qu'une interférence soit la cause d'une perte de paquet, l'exposant et le compteur de repli doivent être maintenus séparément pour chaque voisin. Si la communication avec le voisin en question s'inscrit sur une liaison dédiée, l'appareil doit supposer une dégradation de canal, au lieu d'une collision comme cause de la défaillance dans l'intervalle de temps partagé. De plus, Backoff_exp et Backoff_cntr doivent être remis tous les deux à zéro.

Les messages de diffusion ne doivent pas être émis dans des intervalles de temps partagés.

6.4.4.5 Annonce

Les nœuds qui font déjà partie du réseau peuvent être configurés par le gestionnaire de réseau pour l'annonce au réseau et la facilitation du rattachement de nouveaux appareils. L'attribut Advertise_time (voir 6.5.2) fixe l'intervalle auquel les paquets d'annonce sont générés. Chaque fois que l'intervalle Advertise_time s'écoule, un paquet d'annonce doit être émis sur la première liaison d'émission non partagée disponible. Lorsque Advertise_time est mis à zéro, un paquet d'annonce doit être généré chaque fois qu'une liaison d'émission non partagée est disponible.

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Un paquet d'annonce peut être envoyé sur une ligne d'émission non partagée qui n'est pas en cours d'utilisation. Tous les autres trafics ont une plus haute priorité que l'annonce.

6.4.4.6 Découverte de voisins

Les appareils doivent être en permanence à l'écoute pour des communications provenant du voisin existant et pour des communications provenant de nouveaux voisins. Une surveillance continue des voisins et la découverte de nouveaux voisins sont importantes pour la maintenance du réseau maillé et l'amélioration de la fiabilité des communications.

A la réception d'une DLPDU quelconque, provenant d'un nouveau voisin, l'appareil doit invoquer l'indication d'événement de DLM avec l'adresse du voisin en question et le niveau de signal reçu pour la DLPDU en question. Périodiquement, la NLE communique la liste de nouveaux voisins au gestionnaire de réseau. L'appareil peut recevoir une DLPDU, adressée à l'appareil, provenant d'un nouvel appareil tentant de rejoindre le réseau. Lorsque cela se produit, l'appareil doit ajouter l'appareil à la Table des voisins. L'appareil doit alors dupliquer les liaisons de rattachement et insérer l'appareil candidat au rattachement comme le voisin de la liaison. Ces voisins sont périssables et peuvent être détruits en fonction de Last_time_communicated pour dégager de la place pour les nouveaux voisins (voir 6.4.3.4). Lorsqu'un voisin est supprimé, les liaisons de rattachement créées automatiquement et reliant l'appareil à l'appareil candidat au rattachement doivent être supprimées.

Pour contribuer à la découverte de nouveaux voisins, l'appareil se met à l'écoute toutes les fois où cela est possible sur des liaisons de découverte. Les liaisons de découverte sont partagées par tous les appareils sur le réseau. Outre l'écoute, un appareil doit aussi émettre de façon aléatoire une DLPDU d'entretien dans une liaison de découverte d'émission. Cela donne à d'autres appareils à l'écoute sur la liaison de découverte l'occasion de découvrir l'appareil.

La fréquence la plus lente à laquelle l'appareil émet sur la liaison de découverte est limitée par Discovery_time (voir 6.5.2). Pour programmer l'émission de découverte, l'appareil doit sélectionner une durée aléatoire entre 0 et Discovery_time et l'utiliser pour initialiser le temporisateur de découverte. Lorsque le temporisateur en question expire, l'appareil doit mettre le fanion TimeToDiscover à VRAI et programmer la prochaine émission de découverte chronométrée de façon aléatoire. Si la valeur de Discovery_time est '-1' (c'est-à-dire 0xFFFFFFFF), la DLE ne doit pas desservir la liaison de découverte.

Une fois que le fanion TimeToDiscover est mis, la programmation de liaisons émettra un paquet d'Entretien à la première liaison d'émission de découverte disponible. Le paquet d'entretien doit être adressé au voisin relié ayant la valeur la plus ancienne de Last_time_communicated.

6.4.5 Fonctionnement de MAC

6.4.5.1 Généralités

Le présent Paragraphe 6.4.5 décompose la sous-couche MAC en trois composants primaires comme illustré en à la Figure 22. Les composants sont:

- La machine TDMA qui spécifie le fonctionnement global de la sous-couche MAC,
- L'émetteur qui envoie une DLPDU – à savoir la machine XMIT, et
- Le récepteur qui est à l'écoute d'une liaison et reçoit une DLPDU – à savoir la machine RECV.

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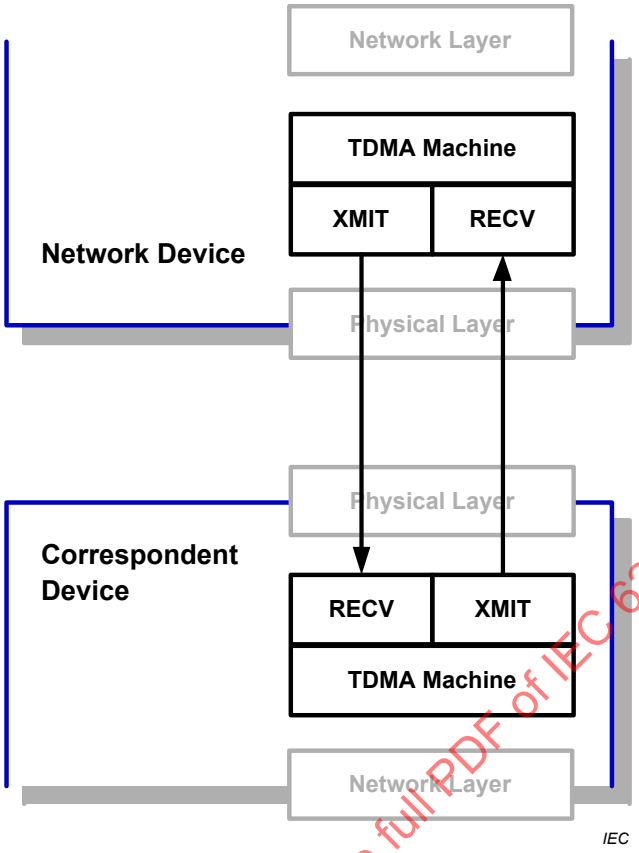

Anglais	Français
Network device	Appareil de réseau
Network layer	Couche réseau
TDMA Machine	Machine TDMA
Physical layer	Couche physique
Correspondent device	Appareil de correspondant

Figure 22 – Composants MAC

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6.4.5.2 Machine TDMA

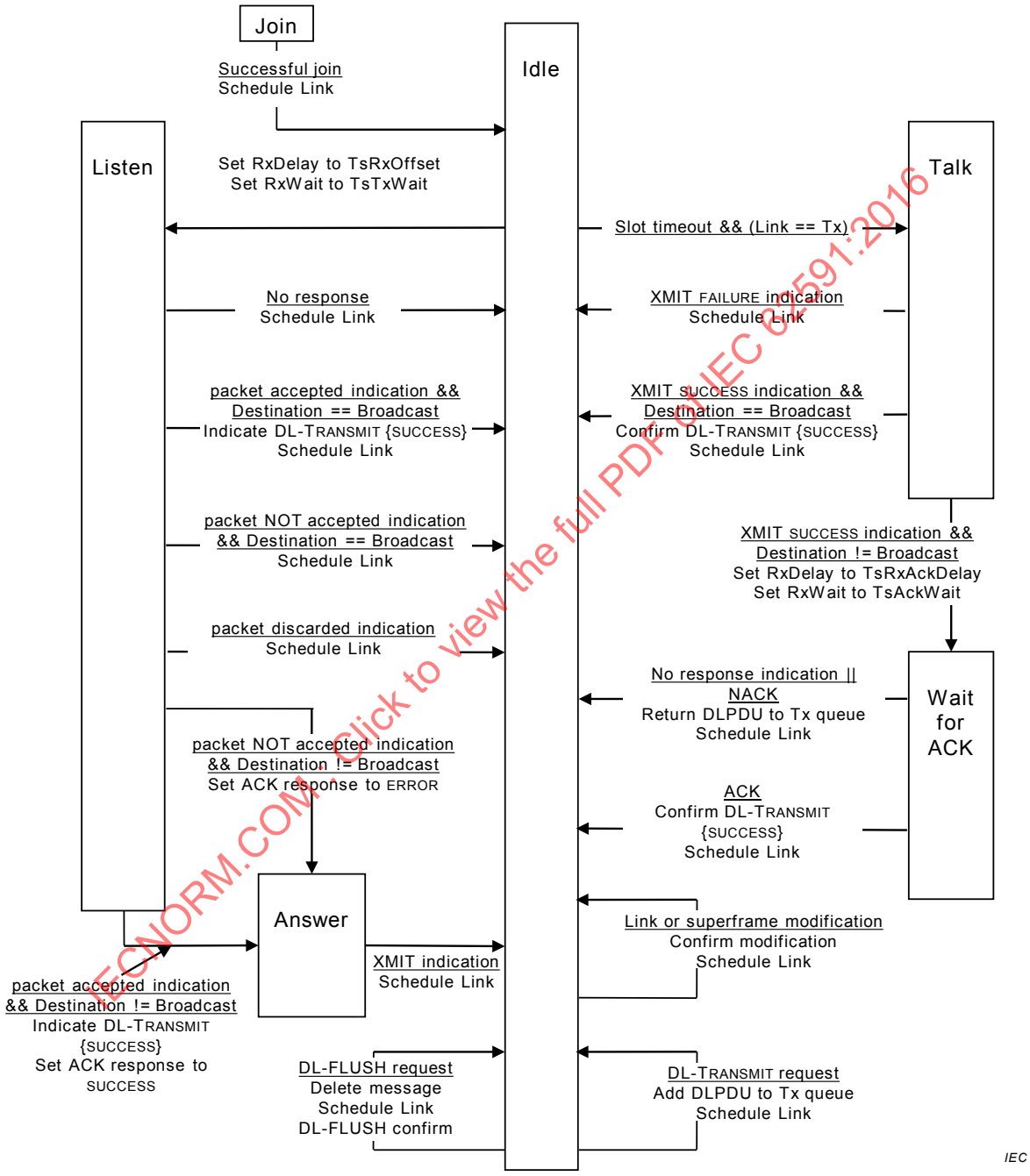
6.4.5.2.1 Généralités

Le fonctionnement de la machine TDMA est illustré à la Figure 23. Les transitions d'états sont présentées au Tableau 42. Le fonctionnement de la machine TDMA commence à l'état "Repos" lorsque l'appareil rejoint un réseau, il est configuré avec une liste de supertrames, de graphes de liaisons et commence à recevoir des DLPDU provenant d'autres appareils ou une demande d'émission provenant de la NLE. Le fonctionnement normal peut être divisé en quatre responsabilités:

- gérer le programme;
- émettre des DLPDU vers d'autres appareils;
- recevoir des DLPDU provenant d'autres appareils; et
- maintenir la synchronisation du temps.

La gestion de programme inclut la création et la maintenance de supertrames, de liaisons et statistiques relatives aux voisins. À mesure que les DLPDU sont acquises et propagées, les programmes doivent être actualisés. La programmation de liaisons consiste à évaluer les supertrames actives, les liaisons, les DLPDU en attente d'émission et à identifier le prochain intervalle de temps qui nécessite une prise en charge.

Le programme détermine la répartition des DLPDU. Toutes les liaisons de réception doivent être prises en charge en tentant une réception de DLPDU. Sachant que les liaisons doivent être allouées pour prendre en charge des répétitions de tentatives possibles, il y a souvent plus de liaisons de réception que de liaisons d'émission. Sachant qu'une émission est souvent réussie, plusieurs des liaisons de réception seront inutilisées, ne contenant pas d'émission correspondante. La plupart des DLPDU reçues contiennent des DLPDU destinées à la NLE.



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Anglais	Français
Listen	Ecouter
Packet accepted indication	Indication paquet accepté
&& Destination ! = Broadcast	&& Destination ! = Diffusion
Indicate DL TRANSMIT (SUCCESS)	Indiquer EMISSION DE DL (SUCCES)
Set ACK response to SUCCESS	Mettre la réponse ACQ à SUCCES

Anglais	Français
Join	Rattachement
Successful join	Rattachement réussi
Schedule link	Programmer la liaison
Set RxDelay to TsRxOffset	Mettre RxDelay à TsRxOffset
Set RxWait to Ts TxWait	Mettre RxWait à TsTxWait
No response	Aucune réponse
Packet accepted indication &&	Indication paquet accepté &&
Destination = = Broadcast	Destination = = Diffusion
Indicate DL transmit (SUCCESS)	Indiquer Emission de DL (SUCCES)
Packet NOT accepted indication	Indication paquet NON accepté
&& Destination = = Broadcast	&& Destination = = Diffusion
Packet NOT accepted indication	Indication paquet NON accepté
Packet discarded indication	Indication paquet rejeté
Set ACK response to ERROR	Mettre la réponse ACQ à ERROR
Answer	Répondre
XMIT indication	Indication de TRANSMISSION
DL-FLUSH request	Demande de PURGE DE COUCHE DL
Delete message	Supprimer message
DL-FLUSH confirm	Confirmation de PURGE DE COUCHE DL
Idle	Repos
Talk	Parler
Slot timeout && (Link = = Tx)	Expiration de délai de l'intervalle de temps && (Liaison == Tx)
XMIT FAILURE indication	Indication de DEFAILLANCE de TRANSMISSION
XMIT SUCCESS indication &&	Indication de SUCCES de TRANSMISSION &&
Destination = = Broadcast	Destination = = Diffusion
Confirm DL Transmit (SUCCESS)	Confirmer Emission de DL (SUCCES)
XMIT success indication &&	Indication de succès de TRANSMISSION &&
Destination ! = Broadcast	Destination ! = Diffusion
Set RxDelay to TsRxAckDelay	Mettre RxDelay à TsRxAckDelay
Set RxWait to TsAckWait	Mettre RxWait à TsAckWait
No response indication II	Indication Pas de Réponse ||
NACK	NACQ
Returm DLPDU to Tx queue	Retourner DLPDU à la file d'attente d'émission
Wait for ACK	Attendre ACQ
ACK	ACQ
Confirm DL Transmit	Confirmer Emission de DL
(SUCCESS)	(SUCCES)
Link or superframe modification	Modification de liaison ou supertrame
Confirm modification	Confirmer modification
DL-Transmit request	Demande d'émission de DL
Add DLPDU to Tx queue	Ajouter DLPDU à la file d'attente d'émission

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Figure 23 – Diagramme d'états TDMA

Tableau 42 – Diagramme d'états TDMA

Etat courant	Evénement ou condition => action	Etat suivant
Repos	Expiration de délai de l'intervalle de temps&& (Liaison == Tx)	Parler
Repos	Expiration de délai de l'intervalle de temps && (Liaison != Tx) && (Liaison == Rx) => Mettre RxDelay à TsRxOffset; Mettre RxWait à TsTxWait	Ecouter
Repos	Modification de liaison ou supertrame => Confirmer modification; Programmer la liaison	Repos
Repos	Demande d'émission de DL => Ajouter DLPDU à la file d'attente d'émission; Programmer la liaison	Repos
Parler	Indication d'échec d'émission => Programmer la liaison	Repos
Parler	Indication de succès d'émission && Destination == Diffusion => Indiquer Emission de DL {succès}; Programmer la liaison	Repos
Parler	Indication de succès d'émission && Destination != Diffusion => Indiquer Emission de DL {succès}; Programmer la liaison	Attendre ACQ
Attendre ACQ	Indication Pas de réponse || NACK => Renvoyer DLPDU à la file d'attente Tx; Programmer la liaison	Repos
Attendre ACQ	ACQ => Confirmation d'émission de DL {succès}; Programmer la liaison	Repos
Ecouter	Pas de réponse => Programmer la liaison	Repos
Ecouter	Indication paquet accepté && Destination == Diffusion => Indiquer Emission de DL {succès}; Programmer la liaison	Repos
Ecouter	Indication paquet non accepté && Destination == Diffusion => Programmer la liaison	Repos
Ecouter	Indication paquet rejeté => Programmer la liaison	Repos
Ecouter	Indication paquet NON accepté && Destination != Diffusion => Mettre réponse d'ACQ sur erreur	Répondre
Ecouter	Indication paquet accepté && Destination == Diffusion => Indiquer Emission de DL {succès}; Mettre réponse d'ACQ sur succès	Répondre
Répondre	Indication XMIT = Programmer la liaison	Repos

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6.4.5.2.2 Etat de repos

Les événements suivants peuvent survenir pendant l'état "Repos":

a) Expiration de délai de l'intervalle de temps: l'activité la plus fréquente accomplie par la machine TDMA est la prise en charge d'un événement Expiration de délai d'intervalle de temps. Cet événement indique qu'un intervalle de temps nécessite une prise en charge.

   1) Si l'intervalle de temps a expiré pour une liaison d'émission et qu'il y a une DLPDU en attente d'émission, la machine TDMA doit passer à l'état "parler".

   2) Sinon, s'il s'agit d'une liaison de réception, la machine TDMA doit passer à l'état "Ecouter".

b) Modification apportée à la liste de supertrames ou de liaisons de l'appareil: elle a une incidence sur la programmation des liaisons. Ces modifications résultent généralement d'une révision des définitions des liaisons et peuvent entraîner un nombre différent de tentatives d'émissions et de réceptions par seconde.

c) Demande d'émission de DL: cette commande doit ajouter une DLPDU à la file d'attente d'émission (Tx) de l'appareil et cela peut avoir une incidence sur la programmation des liaisons.

6.4.5.2.3 Etat "Parler"

Dans cet état, la DLE doit tenter d'émettre la DLPDU vers son/ses voisin(s). Le fonctionnement de cet état est spécifié en 6.4.5.3. La tentative débouchera soit sur un succès, soit sur un résultat négatif.

- La propagation réussie d'une DLPDU avec une adresse de destination qui est l'adresse de diffusion a lieu dès que la DLPDU est émise. Le tampon des DLPDU doit être libéré à l'achèvement de l'émission de la DLPDU et le programme de liaisons doit être évalué.
- La propagation réussie d'une DLPDU avec une adresse de destination qui n'est pas l'adresse de diffusion a lieu lorsqu'un ACQ réussi validé est reçu. Cela indique que la propagation de DLPDU a été achevée avec succès et le tampon des DLPDU doit être libéré.
- Si l'ACQ contient un code de réponse d'erreur, le voisin de destination a refusé la DLPDU. Lorsque cela se produit, la DLPDU doit être retenue et sa propagation de nouveau tentée.
- Si aucun ACQ n'est reçu, la DLPDU doit être reprogrammée et l'émission de nouveau tentée. Si le délai de la DLPDU expire, la DLPDU en file d'attente est retournée à la NLE pour prise de décision et un possible re-routage.
- Si l'émission échoue dans la machine XMIT, la transaction doit être abandonnée et le programme de liaisons doit être évalué.

À la suite d'une émission réussie et si la destination de la DLPDU n'est pas de diffusion, la machine TDMA doit passer à l'état "Attendre ACQ" décrit en 6.4.5.3. À l'entrée dans cet état, le temporisateur RxDelay doit être mis à TsRxAckDelay et le temporisateur RxWait (fenêtre de réception) doit être mis à TsAckWait.

6.4.5.2.4 Etat "Attendre ACQ»

La machine TDMA reste dans cet état jusqu'à ce que la machine RECV soit terminée. Si la machine RECV indique "Pas de réponse, la transaction échoue. S'il s'agissait d'une liaison partagée, Backoff_exp et Backoff_cntr doivent être réévalués pour produire une période de repli aléatoire avant la prochaine tentative d'émission dans un intervalle de temps partagé (voir 6.4.4.4). S'il ne s'agissait pas d'une liaison partagée, Backoff_exp et Backoff_cntr doivent être remis à zéro. Alors, après l'évaluation du programme de liaisons, la machine TDMA doit passer à l'état "Repos".

Si un ACQ contenant un code de réponse "Succès" est reçu, la communication a réussi. Cependant, si un code de réponse d'erreur a été reçu, le voisin n'a pas accepté la DLPDU. Dans un cas comme dans l'autre, la synchronisation du temps réseau peut être évaluée en utilisant le champ "Réglage du temps" dans la réponse du voisin. Si le voisin est une source de temps pour l'appareil, celui-ci doit resynchroniser son temps réseau en utilisant le champ "Réglage du temps". Si le voisin n'est pas une source de temps, aucune correction de temps ne doit être effectuée.

La réception d'un ACQ indique que l'appareil voisin a reçu le message avec succès et l'a accepté. Le tampon des DLPDU contenant la DLPDU émise doit être libéré. La machine TDMA doit passer à "Repos" et évaluer le programme de liaisons.

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6.4.5.2.5 Etat «Ecouter»

Dans cet état, la DLE doit tenter de recevoir la DLPDU. Le fonctionnement de cet état est spécifié en 6.4.5.4. La réception d'une DLPDU donne lieu à trois résultats possibles:

- la destination finale de la DLPDU est la DLE elle-même et la DLPDU doit être retenue pour traitement par la DLE;
- la destination finale de la DLPDU n'est pas la DLE elle-même et la DLPDU doit être transmise par la DLE vers la destination finale du message;
- la DLPDU n'est pas adressée à l'appareil et la DLPDU doit être rejetée.

Dans tous les cas, lorsqu'une DLPDU est reçue, l'entrée correspondante de la Table des voisins doit être actualisée ou, s'il y a lieu, l'entrée de la table doit être créée.

Le cycle de réception des DLPDU consiste en une tentative de réception d'une DLPDU, suivie par la validation de toute DPDU reçue et, si l'adresse de destination de la DLPDU n'est pas de diffusion, en l'émission d'une réponse à une DLPDU reçue valide.

Lors d'une tentative de réception d'une DLPDU, le temporisateur RxDelay doit être mis à TsRxOffset et le temporisateur RxWait (fenêtre de réception) à TsTxWait. Le temps TsTxWait fixe la durée de la fenêtre de réception et représente la plus grande dérive temporelle entre appareils voisins autorisée par la présente norme.

Si aucune DLPDU n'est reçue dans l'état "Ecouter", la machine TDMA doit réévaluer le programme de liaisons et retourner à l'état "Repos". Si une DLPDU est reçue, la synchronisation du temps réseau doit être évaluée. TsError doit être calculé en prenant la différence entre l'heure réelle de début et l'heure de début prévue de la DLPDU reçue. Si le voisin envoyant la DLPDU est l'une des sources de temps de la DLE, l'appareil doit utiliser le TsError mesuré pour resynchroniser son temps réseau. Si le voisin n'est pas une source de temps, aucune correction de temps ne doit être effectuée.

Alors qu'il est à l'état "Ecouter" et à la réception réussie d'une DLPDU, l'appareil doit déterminer s'il accepte la DLPDU ou la rejette. L'appareil accepte ou rejette la DLPDU en fonction de la priorité de la DLPDU, du Priority_threshold courant (voir 6.3.3) et du nombre de tampons de DLPDU actuellement occupés dans l'appareil. Si la DLPDU est acceptée par l'appareil, elle est soit consommée par la DLE elle-même, soit transmise à la NLE en utilisant l'indication d'émission de DL et la DLE doit actualiser le programme de liaisons.

Une fois que la couche Liaison de données a déterminé la décision relative à la DLPDU (accepter ou rejeter la DLPDU), la machine TDMA doit quitter l'état "Ecouter" comme suit:

- Si l'adresse de destination de la DLPDU est l'adresse de diffusion, la machine TDMA doit passer à l'état "Repos".
- Si l'adresse de destination n'est pas l'adresse de diffusion et que la DLPDU a été acceptée, la DLE doit émettre une DLPDU d'ACQ, avec une valeur de code de réponse égale à "Succès", vers l'expéditeur de la DLPDU qui vient d'être reçue. La machine TDMA doit passer à l'état "Répondre".
- Si l'adresse de destination n'est pas l'adresse de diffusion et que la DLPDU n'a pas été acceptée, la DLE doit émettre une DLPDU d'ACQ, avec une valeur de code de réponse égale à un code d'erreur, vers l'expéditeur de la DLPDU qui vient d'être reçue. La machine TDMA doit passer à l'état "Répondre".

6.4.5.2.6 Etat "Répondre"

La DLE doit copier le TsError mesuré dans le champ "Réglage du temps" de la DLPDU d'ACQ. La machine TDMA fonctionne comme une machine d'émission d'ACQ décrite en 6.4.5.5.

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Après l'achèvement de l'émission de l'ACQ, la machine TDMA doit évaluer le programme de liaisons et passer à l'état "Repos".

6.4.5.3 Machine XMIT

6.4.5.3.1 Généralités

La Figure 24 illustre le diagramme d'états utilisés pour émettre une DLPDU par l'intermédiaire d'un intervalle de temps dédié ou partagé. Les transitions d'états sont présentées au Tableau 43. Cette machine est démarrée pour émettre une DLPDU.

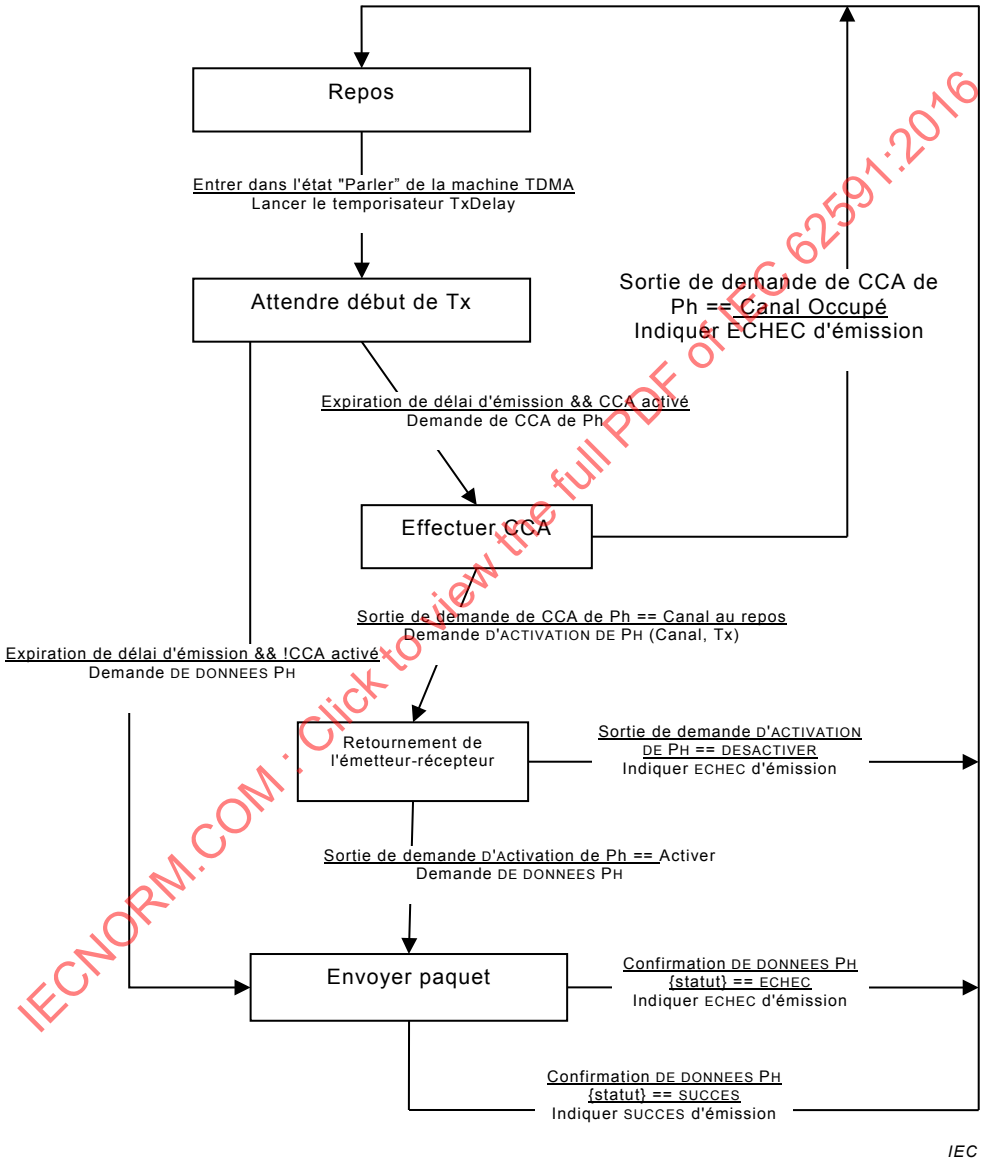

Figure 24 – Diagramme d'états XMIT

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Tableau 43 – Transitions d'états de XMIT

Etat courant	Evénement ou condition => action	Etat suivant
Repos	Entrer dans l'état "Parler" de la machine TDMA => Lancer le temporisateur TxDelay	Attendre début de Tx
Attendre début de Tx	Expiration de délai d'émission && !CCA activé => Demande de données PH	Envoyer paquet
Attendre début de Tx	Expiration de délai d'émission && !CCA activé => Demande de CAA de PH	Effectuer CCA
Effectuer CCA	Sortie de demande de CCA de Ph == Canal au repos => Demande de CCA de Ph (numéro de canal, émission)	Retournement de l'émetteur-récepteur
Effectuer CCA	Sortie de demande de CCA de Ph == canal occupé => Indication d'échec d'émission	Repos
Retournement de l'émetteur-récepteur	Sortie de demande d'activation de Ph == activer Demande de données PH {DLPDU}	Envoyer paquet
Retournement de l'émetteur-récepteur	Sortie de demande d'activation de Ph == désactiver Indication d'échec d'émission	Repos
Envoyer paquet	Confirmation de données Ph {status} == succès => Indication de succès d'émission	Repos
Envoyer paquet	Confirmation de données Ph {status} == échec => Indication d'échec d'émission	Repos

6.4.5.3.2 Etat de repos

Lorsque la machine XMIT a démarré, la DLE doit lancer le temporisateur TxDelay. TxDelay doit être fixé de façon à ce que l'émission débute au centre de la fenêtre de réception du voisin. L'appareil peut utiliser le temps TxDelay pour construire la DLPDU, faire fonctionner son moteur de chiffrement AES de 128 bits et générer le MIC pour la DLPDU.

La machine doit passer à l'état "Attendre début de Tx".

6.4.5.3.3 Etat "Attendre début de Tx"

Dans l'état "Attendre début de Tx", la DLE doit sélectionner le canal pour l'émission (voir 6.4.3.3.2). Lorsque le temporisateur TxDelay expire, la machine XMIT change l'état. Deux séquences d'émission sont possibles.

a) Si CCAEnabled est faux, la DLE doit émettre une Demande de données Ph pour émettre la DLPDU et faire passer l'état à "Envoyer paquet".

b) Si CCAEnabled est VRAI, la DLE doit émettre la demande Ph- CCA et faire passer l'état à "Exécuter CCA".

6.4.5.3.4 Etat "Lancer CCA"

La DLE doit attendre que la PhE ait achevé l'évaluation de canal libre.

a) Si la DLE reçoit une demande de CCA produite avec le statut "Canal au repos" provenant de la PhE, alors

   1) la machine XMIT doit passer à l'état "Retournement d'émetteur-récepteur";

   2) la PhE doit être initialisée en utilisant la Demande d'activation de Ph pour mettre l'émetteur-récepteur en mode émission.

b) Sinon, si la DLE reçoit demande de CCA produite avec le statut "Canal occupé", le moteur XMIT doit s'arrêter, indiquer que la tentative d'émission a échoué et ne doit pas émettre la DLPDU.

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6.4.5.3.5 Etat "Retourner émetteur-récepteur"

Lorsque la DLE reçoit une sortie de demande d'activation de Ph produite avec le statut "Activer" provenant de la PhE, la machine XMIT doit passer à l'état "Envoyer paquet". Sinon, si le statut retourné est "Désactiver", le moteur XMIT doit s'arrêter, indiquer que la tentative d'émission a échoué et ne doit pas émettre la DLPDU.

6.4.5.3.6 Etat "Envoyer paquet"

La DLE doit démarrer l'émission de paquets en utilisant le service de Demande de données Ph de la PhE. Lorsque la DLE reçoit la Confirmation de données Ph provenant de la PhE, la machine XMIT doit s'arrêter et indiquer que l'émission a soit réussi, soit échoué, en fonction du statut retourné dans la primitive de Confirmation de données Ph.

6.4.5.4 Machine RECV

6.4.5.4.1 Généralités

La Figure 25 illustre la machine utilisée pour recevoir une DLPDU. Cette machine est démarrée pour recevoir une DLPDU émise par l'un des voisins de l'appareil ou immédiatement après l'émission d'une DLPDU pour recevoir une DLPDU d'ACQ. Les transitions d'états sont présentées au Tableau 44.

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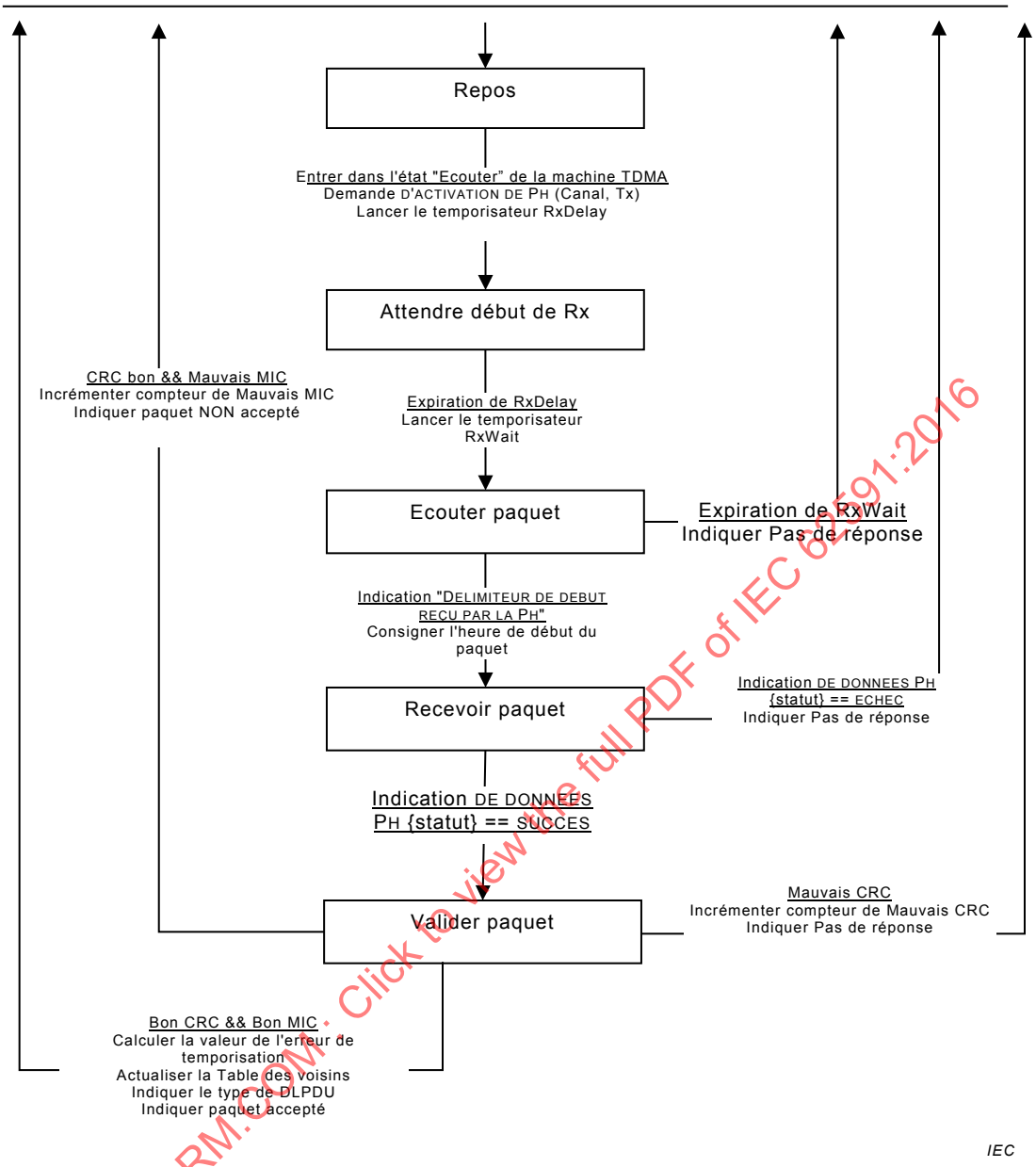

Figure 25 – Diagramme d'états RECV

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Tableau 44 – Diagramme d'états RECV

Etat courant	Evénement ou condition => action	Etat suivant
Repos	Entrer dans l'état "Ecouter" de la machine TDMA => Demande d'activation de Ph {numéro de canal, réception} Lancer le temporisateur RxDelay	Attendre début de Rx
Attendre début de Rx	Expiration de RxDelay => Lancer le temporisateur RxWait	Ecouter paquet
Ecouter paquet	Expiration de RxWait => Indiquer Pas de réponse	Repos
Ecouter paquet	Indication "Délimiteur de début reçu par la Ph" => Consigner l'heure de début du paquet	Recevoir paquet
Recevoir paquet	Consigner l'heure de début du paquet {status} == échec => Indiquer Pas de réponse	Repos
Recevoir paquet	Indication de données Ph {statut} == succès	Valider paquet
Valider paquet	Bon CRC => Incrémenter compteur de Mauvais CRC; Indiquer paquet rejeté	Repos
Valider paquet	Bon CRC && Mauvais MIC => Incrémenter compteur de Mauvais MIC; Indiquer paquet NON accepté	Repos
Valider paquet	Bon CRC && Bon MIC => Calculer la valeur de l'erreur de temporisation; Actualiser la Table des voisins; Indiquer le type de DLPDU; Indiquer paquet accepté	Repos

6.4.5.4.2 Etat de repos

Lorsque la machine RECV a démarré:

a) la DLE doit sélectionner un canal en fonction du décalage de canal de départ de la liaison et du nombre courant d'intervalles de temps absolus;

b) la DLE doit mettre l'émetteur-récepteur en mode réception en utilisant le service "Demande d'activation de Ph" de la PhE;

c) la DLE doit lancer le temporisateur RxDelay; et

d) la machine RECV doit passer à l'état "Attendre début de Rx".

Au cours de RxDelay, l'émetteur-récepteur s'établit et se synchronise au canal correct.

6.4.5.4.3 Etat "Attendre début de Rx"

Lorsque le temporisateur RxDelay expire, la machine RECV doit passer à l'état "Ecouter paquet" et lancer le temporisateur RxWait.

6.4.5.4.4 Etat "Ecouter paquet"

L'émetteur-récepteur reçoit l'instruction de commencer à se mettre à l'écoute du canal en utilisant le service d'indication "Délimiteur de début reçu par la Ph" de la PhE. La machine RECV demeure à l'état "Ecouter paquet" jusqu'à ce que 1) le début d'une DLPDU comme indiqué par la réception de la fin d'un délimiteur de début de PhPDU soit détecté, ou bien jusqu'à ce que 2) le temporisateur RxWait expire. Si le temporisateur RxWait expire, la tentative de réception échoue, le moteur RECV doit s'arrêter en indiquant "Pas de réponse" et la DLE doit actualiser les statistiques de la communication.

Si le délimiteur de début prévu est détecté, son heure d'arrivée doit être enregistrée et le moteur RECV doit passer à l'état "Recevoir paquet" pour se saisir de la DLPDU.

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6.4.5.4.5 Etat "Recevoir paquet"

Lorsque la machine RECV reçoit la primitive du service d'indication "Indication de données Ph" provenant de la PhE, elle doit effectuer une évaluation initiale de la DLPDU reçue. Si les adresses de DLPDU ne sont pas celles prévues pour la liaison, la machine RECV doit s'arrêter en indiquant "Pas de réponse" et la DLE doit actualiser les statistiques de communication. Sinon, la machine RECV doit passer à l'état "Valider paquet".

6.4.5.4.6 Etat "Valider paquet"

En l'absence d'erreurs dans la DLPDU reçue, une validation supplémentaire doit être effectuée. Si le CRC est incorrect, la PhPDU était corrompue avant ou pendant la réception; la machine RECV doit s'arrêter en indiquant "Paquet rejeté" et la DLE doit actualiser les statistiques de la communication.

Si le CRC reçu est correct, le MIC chiffré reçu doit être calculé et vérifié. Si le MIC reçu n'est pas tel que prévu, cela indique une possible attaque. Par conséquent, la réception est considérée comme étant un échec et la DLE doit actualiser la sécurité et les statistiques de la communication. La machine RECV doit s'arrêter en indiquant "paquet NON accepté".

Si le CRC et le MIC sont tous les deux corrects, la réception est considérée réussie et la machine RECV doit s'arrêter en indiquant le type de la DLPDU reçue.

6.4.5.5 Machine d'émission d'ACQ

Cette machine est démarrée pour acquitter la réception d'une DLPDU. La DLE doit copier la TsError mesurée dans le champ "Réglage du temps" de la DLPDU d'ACQ en question. La machine TDMA doit utiliser le diagramme d'états illustré à la Figure 26 pour émettre la DLPDU. Les transitions d'états sont présentées au Tableau 45.

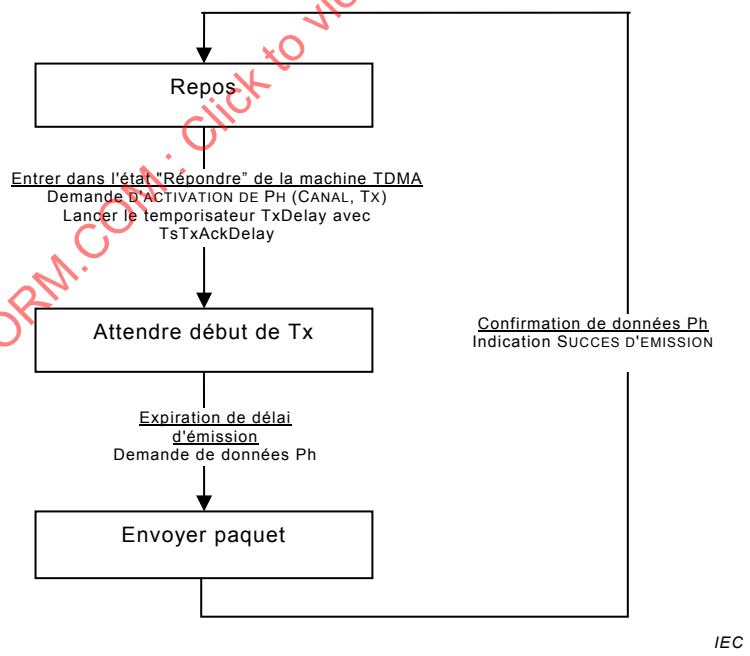

Figure 26 – Diagramme d'états pour l'émission des ACQ

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Tableau 45 – Diagramme d'états pour l'émission des ACQ

Etat courant	Evénement ou condition => action	Etat suivant
Repos	Entrer dans l'état "Répondre" de la machine TDMA => Demande d'activation de Ph {numéro de canal, émission}; Lancer le temporisateur TxDelay avec TsTxAckDelay;	Attendre début de Tx
Attendre début de Tx	Expiration de TxDelay => Demande de données Ph {DLPDU d'ACQ}	Envoyer paquet
Envoyer paquet	Confirmation de données Ph => Indication Succès d'émission	Repos

6.5 Informations de gestion de DL

6.5.1 Généralités

Plusieurs attributs de DL doivent être préconfigurés avant qu'une DLE ne puisse fonctionner correctement. Ces attributs sont définis en 6.5.2. Les actions de la DLE qui peuvent être demandées par le biais de la gestion de la DL sont également récapitulées en 6.5.3.

6.5.2 Attributs de DL

Le Tableau 36 définit les attributs des supertrames.

Le Tableau 37 définit les attributs des liaisons.

Le Tableau 39 définit les attributs des graphes.

Clé réseau utilisée pour le calcul du MIC, voir 6.3.4.2.3.

D'autres attributs sont définis au Tableau 46.

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Tableau 46 – Attributs de la DL

Nom d'attribut	Plage de valeurs	Définition
Keep_alive_time	0 à 2^{32}-1 en unités de ms	Intervalle pendant lequel un nœud doit communiquer avec succès avec chaque voisin relié
Path_fail_time	0 à 2^{32}-1 en unités de ms	Intervalle d'une communication ayant échoué avec un voisin donné, indiquant une défaillance de trajet
Advertise_time	0 à 2^{32}-1 en unités de ms	Intervalle auquel les DLPDU d'annonce sont émises
Discovery_time	0 à 2^{32}-1 en unités de ms	Intervalle maximal entre deux émissions consécutives de DLPDU d'annonce sur la liaison de découverte.
Priority_threshold	Alarme | Normale | Données de Processus | Commande	Spécifie la DLPDU ayant la priorité la plus faible devant être acceptée en provenance d'un autre appareil
Join_priority	0 à 15	Priorité utilisée dans la DLPDU d'annonce envoyée par la DLE; un nombre inférieur indique un meilleur choix pour le rattachement
Promiscuous_mode (mode banalisé)	vrai faux	Indique si, oui ou non, la DLE est en mode "recevoir tout", à savoir la DLE accepte toutes les DLPDU reçues de la PhE
Max_backoff_exp	{4, 5, 6, 7}	La valeur maximale qui peut être supposée pour l'exposant de repli utilisé dans des intervalles de temps partagés, la valeur par défaut est 4
Active_search_shed_time (temps de renforcement de recherche active)	0 à 2^{32}-1 en unités de ms	Durée maximale de séjour en mode de recherche active au cours du rattachement (la valeur par défaut est de 4 000 secondes). Une fois cette durée écoulée, l'appareil passe en mode de recherche passive.
Passive_cycle_time (temps de cycle passif)	0 à 2^{32}-1 en unités de ms	En mode de recherche passive, la période au cours de laquelle l'appareil commute entre sommeil et écoute (la valeur par défaut est de 600 secondes). L'intervalle de sommeil est égal au PassiveCycleTime (temps de cycle passif) moins le PassiveWakeTime (temps d'éveil passif).
Passive_wake_time (temps d'éveil passif)	0 à 2^{32}-1 en unités de ms	En mode de recherche passive, la durée d'éveil en écoute du réseau (la valeur par défaut est de 6,5 s)

6.5.3 Actions de la DLM

Les actions de DLE que la gestion de la DL peut demander sont définies au Tableau 47.

Tableau 47 – Actions de DL

Nom	Description
REINITIALISER	Initialiser la DLE
DECONNECTER	Déconnecter la DLE du réseau et cesser toutes les communications
RATTACHER DE NOUVEAU	Déconnecter la DLE du réseau, purger toutes les demandes en attente de la part de l'utilisateur de DLS, vider tous les tampons et files d'attente et vider toutes les tables, se rattacher de nouveau au réseau.
SUPPRIMER SUPERTRAME	Supprimer une supertrame existante et toutes les éventuelles liaisons associées
SUPPRIMER LIAISON	Supprimer une liaison existante, en actualisant éventuellement les Tables des voisins et les Tables des connexions associées à la liaison en question
SUPPRIMER GRAPHE	Supprimer une connexion de graphe existante

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6.6 Couche réseau

6.6.1 Modèle de NL à deux niveaux

6.6.1.1 Généralités

La couche réseau est modélisée comme

- une fonction de sécurité de niveau supérieur, et
- une fonction de routage de niveau inférieur.

Par ailleurs, la fonction de gestion de NL utilise les deux niveaux.

6.6.1.2 Fonction de sécurité

Un code d'intégrité de message (MIC) chiffré est utilisé pour l'authentification de la NPDU, le chiffrement et le déchiffrement des données utiles de la NL. Les clés sont distribuées par le gestionnaire de réseau.

6.6.1.3 Fonction de routage

6.6.1.3.1 Généralités

La couche réseau fournit des services de routage. Elle gère des sessions pour des communications de bout en bout avec les appareils de correspondants. Elle reçoit la NPDU provenant de la DLE. Si la destination de la NPDU est l'utilisateur local du NLS, elle transfère les données utilisateur vers leur utilisateur. Sinon, elle transmet la NPDU destinée à d'autres appareils en utilisant la DLE. Elle traite également la demande d'émission de NL et prépare la NPDU en vue de l'émission.

La couche réseau de la présente norme achemine une NPDU en utilisant l'une de deux méthodes.

- Graphe

  La topologie de réseau peut être représentée comme étant l'ensemble de tous les appareils et de toutes les liaisons orientées existant entre eux. Un graphe est un sous-ensemble des liaisons orientées et des appareils qui fournissent des itinéraires de communication redondants entre une source et un appareil de destination. L'itinéraire effectivement pris dépend des conditions courantes du réseau lorsque la NPDU est acheminée de la source vers la destination. La NPDU contient le Graph_ID, mais ne spécifie pas l'itinéraire complet. Par conséquent, chaque DLE intermédiaire dans l'itinéraire doit être configurée avec un fragment du graphe total avant d'utiliser l'itinéraire par graphe en question. Les itinéraires du graphe sont redondants et hautement fiables. Il convient d'utiliser cette méthode de routage pour des communications de routine normales, tant en amont qu'en aval de la passerelle.

- Source

  Il s'agit d'un itinéraire orienté simple (appareils et liaisons) entre un appareil d'origine et un appareil de destination. L'itinéraire complet est contenu de manière statique dans la NPDU elle-même. Les DLE intermédiaires n'ont pas besoin de connaître l'itinéraire à l'avance. À mesure que la NPDU est acheminée, chaque DLE intermédiaire propage la NPDU vers la DLE suivante en utilisant l'itinéraire par source contenu dans la NPDU. Les itinéraires par source ne sont pas redondants et peuvent défaillir à tout moment. Des conditions courantes du réseau pourraient casser l'itinéraire spécifié dans la NPDU et occasionner une perte de NPDU. Il convient d'utiliser cette méthode de routage uniquement pour soumettre des itinéraires à l'essai, dépanner des trajets du réseau ou pour des communications ad hoc telles que le routage de réponses de rattachement.

Tous les appareils sont tenus de prendre en charge tant le routage par source que le routage par graphe.

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6.6.1.3.2 Routage par graphe

Le graphe est un ensemble de trajets orientés qui relient des points d'extrémité du réseau. Les trajets spécifiques associés à chaque graphe sont configurés explicitement par le gestionnaire de réseau dans tous les appareils du réseau. Une simple instance de réseau peut avoir plusieurs graphes, dont certains peuvent se chevaucher. Chaque appareil de réseau peut avoir plusieurs graphes passant par lui, voire vers les mêmes voisins. Les graphes sont unidirectionnels.

Chaque graphe dans un réseau a un Graph_ID propre. Lors de l'utilisation du routage par graphe, la NLE place la valeur du Graph_ID dans l'en-tête de la NPDU. La NLE recevant la NPDU la transmet le long de l'ensemble de trajets appartenant au graphe en question vers la destination.

Il convient que chaque Graph_ID dans l'appareil ait plusieurs voisins associés. Dans un réseau correctement configuré, tous les appareils ont au moins deux appareils voisins dans le graphe auxquels la NLE peut envoyer la NPDU. Cela assure la redondance dans l'itinéraire et améliore la fiabilité. Une NLE examine le Graph_ID dans la NPDU reçue et transmet la NPDU à n'importe lequel des voisins énumérés dans le graphe en question.

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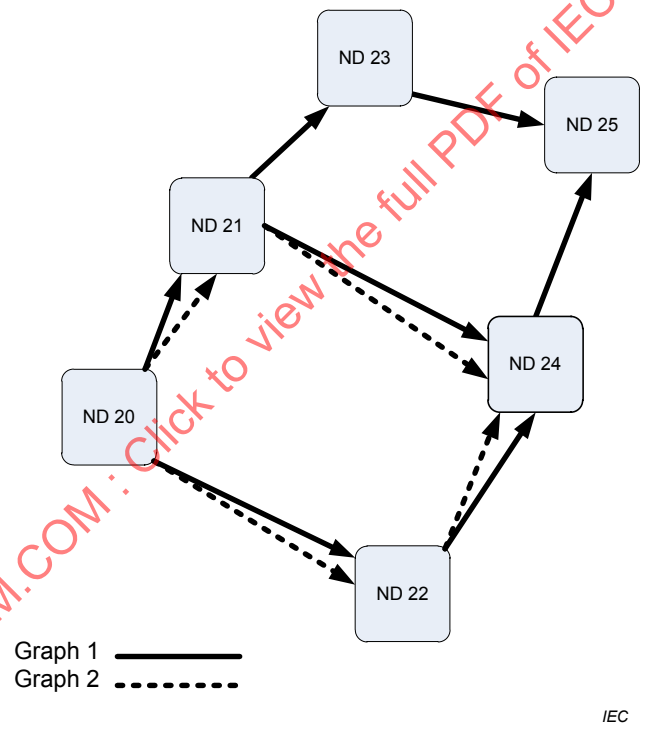

Anglais	Français
Graph 1	Graphe 1
Graph 2	Graphe 2

Figure 27 – Routage par graphe

Comme illustré à la Figure 27, pour le graphe 1, ND 20 est la source et ND 25 la destination; pour le graphe 2, ND 20 est la source et ND 24 la destination. Pour envoyer une NPDU en utilisant le graphe 1, ND 20 peut la transmettre soit à ND 21, soit à ND 22. La NPDU peut prendre plusieurs autres itinéraires, mais de toute manière, en suivant le graphe 1 elle aboutira à ND 25. Ainsi, une NPDU allant de ND 20 à ND 25 pourrait emprunter l'itinéraire passant par ND 21 et ND 23. Une autre NPDU allant de ND 20 à ND 25 pourrait emprunter l'itinéraire passant par ND 21 et ND 24. De même, pour communiquer avec ND 24, ND 20 envoie la NPDU en utilisant le graphe 2 passant soit par ND 21, soit par ND 22.

Un appareil doit prendre en charge le routage de supertrame. Les itinéraires de supertrame doivent utiliser le Graph_ID 0x0000-0x00FF. Lorsque le routage de supertrame est effectué, le Superframe_ID est placé dans la NPDU. L'appareil qui reçoit un Graph_ID inférieur à 0x0100 recherche un Superframe_ID de même valeur. Si le Graph_ID est trouvé, la NLE doit acheminer le paquet à tout voisin ayant une liaison d'émission de monodiffusion normale dans cette supertrame. Dans le cas du routage de supertrame, les liaisons candidates doivent être sélectionnées en fonction de leur numéro de Superframe_ID. En cas de routage par graphe, les liaisons candidates doivent être sélectionnées en fonction des entrées de la Table des graphes (Graph_ID et voisin).

6.6.1.3.3 Routage par source

Pour le routage par source, l'itinéraire complet allant de l'appareil d'origine à l'appareil de destination est spécifié dans la NPDU. À mesure que la NPDU est propagée, chaque NLE intermédiaire consulte la liste d'adresses de l'itinéraire par source et transmet la NPDU à la prochaine DLE de la liste. L'itinéraire doit être configuré dans la NLE, habituellement par le gestionnaire de réseau. Le routage par source spécifie un seul trajet et, si l'une des liaisons intermédiaires a une défaillance, la DLPDU est perdue. Le routage par source est moins fiable que le routage par graphe. Lorsqu'un itinéraire par source a une défaillance, la NLE au point de la défaillance notifie le gestionnaire de réseau. Il incombe au gestionnaire de réseau d'entreprendre une action corrective.

Comme indiqué à la Figure 28, l'itinéraire de ND 20 à ND 24 passe par ND 21, ND 23 et ND 25. La Table de routage dans la NLE du ND 20 est configurée avec ce trajet. La NLE source ajoute la liste d'adresses pour les ND 21, ND 23 et ND 25 dans l'en-tête de la NPDU et envoie la NPDU au ND 21. La NLE dans le ND 21 reçoit la NPDU en question, examine l'en-tête et transmet la NPDU au ND 23. La NLE dans le ND 23 transmet la NPDU au ND 25; qui la transmet alors au ND 24. L'itinéraire allant de ND 20 à ND 24 pourrait aussi avoir été configuré via ND 22 et ND 25.

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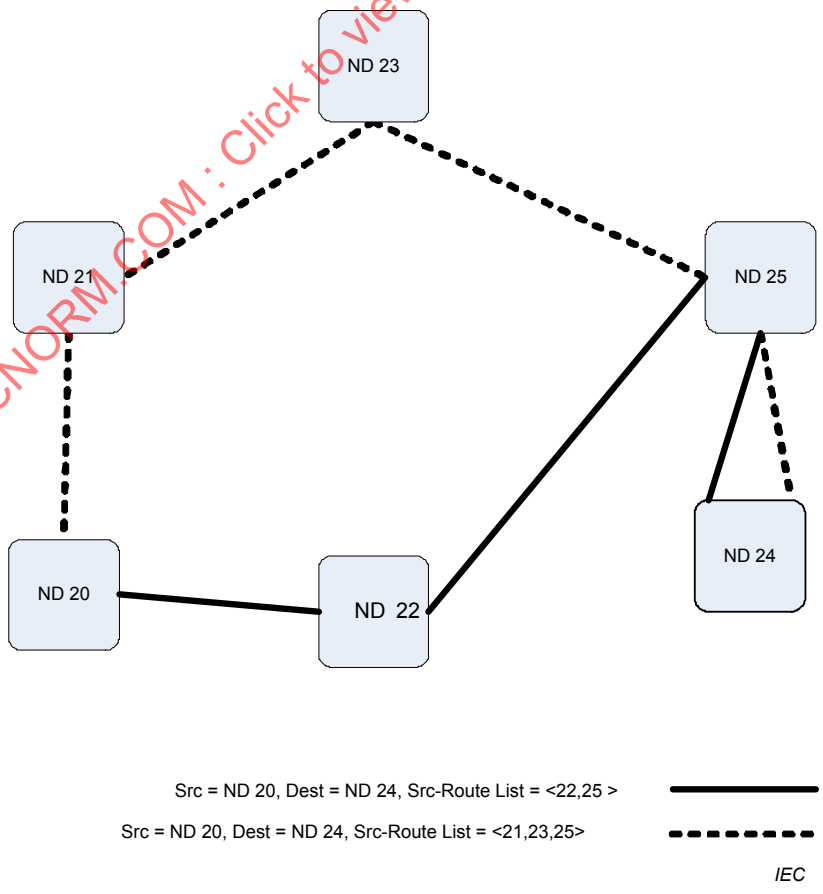

Figure 28 – Routage par source

6.6.2 Structure de NPDU

6.6.2.1 Généralités

La Figure 29 illustre la structure d'une NPDU. Chaque NPDU doit être constituée des champs dans une séquence décrite ci-dessous:

- le contrôle de NL de 1 octet;
- le compteur HTL de 1 octet;
- le numéro de séquence de 2 octets;
- le Graph_ID de 2 octets;
- les adresses de destination et de source dans cet ordre, l'une ou l'autre pouvant avoir une longueur de 2 ou de 8 octets;
- zéro ou plus octets de routage;
- le contrôle de sécurité de 1 octet;
- le compteur;
- un code d'intégrité de message de 4 octets; et
- les données utiles de la NL.

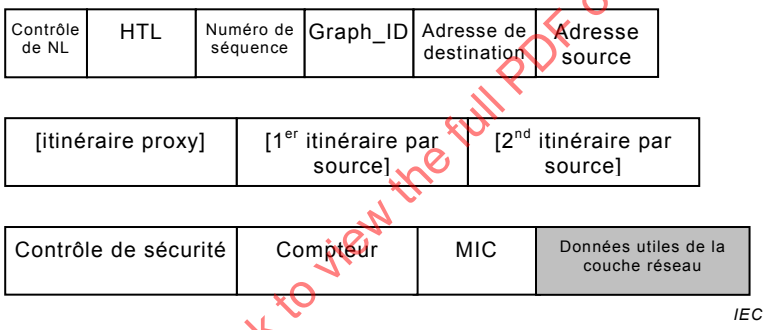

Figure 29 – Structure de NPDU

6.6.2.2 Octet de contrôle de NL

Ce champ spécifie la longueur et le type des adresses de destination, de source et la présence de champs de routage, comme illustré à la Figure 30. Le bit 7 spécifie le type d'adresse de destination; le bit 6 spécifie le type d'adresse source. Si la valeur de l'un de ces deux bits est "1", l'adresse dans la NPDU correspondant au bit en question est EUI-64, autrement il s'agit d'un surnom (voir 6.3.1.2.4). N'importe quelle combinaison de longueurs d'adresse peut être utilisée dans une DLPDU.

Les bits 5, 4 et 3 sont réservés pour un usage futur. La NLE doit mettre la valeur de ces bits à '000' avant l'émission. La NLE doit ignorer toute valeur de ces bits dans la NPDU reçue.

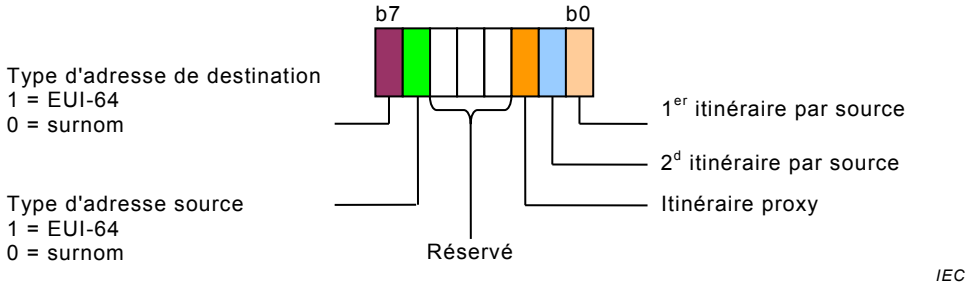

Figure 30 – Octet de contrôle de NPDU

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Si la valeur de l'un des bits 2, 1 et 0 est '1', le champ de routage correspondant doit être présent dans la NPDU.

- Le bit 2 spécifie la présence d'un champ de routage Proxy de 2 octets de longueur.
- Le bit 1 spécifie la présence d'un 2ème champ de routage source de 8 octets de longueur.
- Le bit 0 spécifie la présence d'un 1er champ de routage source de 8 octets de longueur.

NOTE La NPDU peut spécifier simultanément un Graph_ID valide et un itinéraire par source.

6.6.2.3 Sauts de vie résiduelle

Ce champ tient le compte du nombre de sauts restants que la NPDU peut parcourir avant d'être rejetée.

6.6.2.4 Numéro de séquence

Le numéro de séquence doit être fixé égal aux 2 octets de poids faible du Nombre d'intervalles absolus (ASN) au moment où la demande d'émission de NL est reçue. Ce champ donne une métrique de performance grossière, mais critique et des informations de diagnostic relatives au fonctionnement du réseau. Il fournit aussi, lorsque l'ASN complet est recréé, l'âge du paquet.

Si la valeur de HTL est valide, l'âge du paquet doit être comparé au Max_packet_age (âge maximal du paquet). Si l'âge du paquet est supérieur à Max_packet_age, le paquet doit être ignoré. La différence entre l'âge du paquet et Max_packet_age doit être fournie à la liaison de données comme expiration de délai.

6.6.2.5 Graph_ID

Le Graph_ID est utilisé pour acheminer le paquet vers sa destination finale. Le Graph_ID identifie indirectement une liste d'appareils, n'importe lequel de ceux-ci pouvant être utilisé pour transmettre la NPDU vers sa destination finale.

6.6.2.6 Adresse de destination et adresse source

La NL prend en charge deux types d'adresses: un surnom de 2 octets et une adresse IEEE EUI-64 de 8 octets. Voir 6.3.1.2.4 pour la définition et les formats de ces adresses. Ces deux adresses ne sont pas modifiées pendant la propagation de la NPDU.

6.6.2.7 Itinéraire proxy

Le routage proxy doit être utilisé pour communiquer avec les appareils qui n'ont pas encore été intégrés au réseau par le gestionnaire de réseau. Cela inclut les appareils qui sont en cours de rattachement. Le surnom de 2 octets du parent proxy pour la destination finale est indiqué dans l'adresse du Proxy.

Si l'adresse du Proxy correspond, le parent proxy est chargé d'acheminer la NPDU vers l'appareil indiqué par l'adresse de destination.

6.6.2.8 Itinéraire par source

Chaque champ Itinéraire par source contient un jeu de quatre adresses qui désigne l'itinéraire que le paquet doit suivre de l'appareil d'origine jusqu'à la destination finale du paquet. Chaque adresse est un surnom de 2 octets. Toute adresse non utilisée doit être mise à 0xFFFF. Si les deux champs "Itinéraire par source" sont utilisés, il peut être spécifié jusqu'à huit adresses intermédiaires. Les adresses doivent être spécifiées séquentiellement et les adresses non utilisées doivent être mises à 0xFFFF à la fin de la séquence. Lors de l'exploration d'une séquence d'itinéraires par source, le balayage se termine lorsque le premier 0xFFFF est rencontré. Lorsque la fin de l'itinéraire par source est atteinte, le paquet est remis à sa destination finale ou sur l'itinéraire par graphe dans la NPDU.

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Si le champ Itinéraire par source est présent, les adresses qu'il contient doivent être utilisées pour acheminer le paquet vers sa destination finale. Il convient d'utiliser les itinéraires par source uniquement pour soumettre à essai ou dépanner les trajets du réseau.

6.6.2.9 Contrôle de sécurité

Ce champ spécifie la stratégie de sécurité utilisée pour la NPDU, comme illustré à la Figure 31. Le sous-champ est constitué des bits 0 à 3 et doit être codé comme une énumération de la manière suivante.

0: Session chiffrée

1: Rattachement chiffré

autres valeurs: Réservé

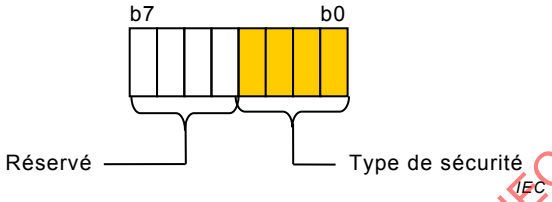

Figure 31 – Octet de contrôle de sécurité

Les bits 7, 6, 5 et 4 sont réservés pour un usage futur. La NLE doit mettre la valeur de ces bits à '0000' dans la NPDU à émettre. La NLE doit ignorer toute valeur de ces bits dans la NPDU reçue.

6.6.2.10 Compteur

Ce champ doit être mis à la valeur intégrale ou tronquée du compteur de nonces. La valeur et la longueur de ce champ dépendent du type de sécurité comme présenté au Tableau 48.

Tableau 48 – Valeur du Compteur

Type de sécurité	Valeur du Compteur
Session	8 bits de poids faible du compteur de nonces
Rattachement	L'ensemble des 32 bits du compteur de nonces

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6.6.2.11 Code d'intégrité de message

Un code d'intégrité de message (MIC) chiffré est utilisé pour l'authentification de la NPDU et le déchiffrement des données utiles de la sous-couche sécurité. Il a une longueur de 4 octets.

6.6.2.12 Données utiles de la NL

Les données utilisateur de NLS constituent les données utiles de la NL.

6.6.3 Fonction de sécurité

6.6.3.1 Généralités

La fonction de sécurité est fournie en diverses couches et à différents niveaux de fonctionnement de l'appareil. L'Annexe A spécifie la fonctionnalité de sécurité des communications et les aspects sécuritaires associés.

6.6.3.2 Session

6.6.3.2.1 Types de session

La sécurité est orientée session. Une session permet une communication privée et sécurisée entre une paire d'appareils de réseau. Un appareil de terrain contient toujours une session de rattachement. Quatre sessions sont établies dès que l'appareil rejoint le réseau.

- Session de monodiffusion entre l'appareil et le gestionnaire de réseau – elle est utilisée par le gestionnaire de réseau pour gérer l'appareil.
- Session de diffusion entre l'appareil et le gestionnaire de réseau – elle est utilisée pour gérer de manière globale les appareils. Par exemple, elle peut être utilisée pour rendre une nouvelle clé réseau disponible au profit de tous les appareils de réseau. Tous les appareils sur le réseau ont la même clé pour cette session.
- Monodiffusion entre l'appareil et la passerelle – elle transporte des communications normales (par exemple, données de processus) entre la passerelle et l'appareil.
- Session de diffusion entre l'appareil et la passerelle – elle est utilisée par la passerelle pour envoyer à tous les appareils des données d'application identiques.

En outre, chaque appareil a une session de rattachement et celle-ci ne peut pas être supprimée. La clé Join_key est unique; elle est la seule clé qui peut être écrite en se connectant directement au port de maintenance de l'appareil. Elle peut aussi être écrite par le gestionnaire de réseau.

Des sessions supplémentaires peuvent être ajoutées, si un terminal portatif ou une autre passerelle rejoint le réseau. Le gestionnaire de réseau crée toutes les sessions et leur clé correspondante, sauf la session de rattachement. Les sessions de rattachement doivent toujours être présentes dans l'appareil. Seul le gestionnaire de réseau doit créer ou modifier toutes les sessions, sauf la session de rattachement. D'autres types d'appareils ne sont pas permis. Les sessions de rattachement sont toujours présentes dans l'appareil de terrain et ne peuvent pas être supprimées.

Il est possible de déployer une session qui relie deux appareils arbitraires sur le réseau. Cependant, cela peut déboucher sur une communication non détectée et non surveillée entre les appareils et représente une menace à la sûreté et à la sécurité. Si le gestionnaire de réseau prend en charge des sessions entre homologues entre des appareils de terrain, il convient que toutes les communications résultantes soient acheminées via la passerelle pour permettre la détection et l'interruption de comportements malveillants.

6.6.3.2.2 Table des sessions

Le Tableau 49 présente les attributs de la session. La combinaison des adresses de correspondants et du Session_type (type de session) doit être unique, ce qui signifie que deux sessions ne sont pas autorisées à avoir des valeurs identiques pour les adresses de correspondants et le Session_type.

Si et seulement si une nouvelle session est créée, My_nonce_counter (compteur de nonces de l'appareil) doit être remis à zéro. Chaque élément dans Nonce_counter_history (historique de compteur de nonces) doit être mis à la valeur du compteur de nonces dans la commande Etablir NLM pour écrire les valeurs des attributs de session. Tous les bits dans le Nonce_counter_history doivent être établis à (1) lorsque la session est créée. L'appareil n'est pas autorisé à modifier la valeur de Session_key (clé de session) écrite par le gestionnaire de réseau. L'appareil de réseau ne doit permettre à aucun moyen de lire une clé de session.

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Tableau 49 – Attributs de Session

Nom d'attribut	Plage de valeurs	Valeurs de clé de rattachement	Définition
Session_type	Monodiffusion Diffusion Rattachement	Monodiffusion	Type De session
Peer_unique_ID (identifiant unique d'homologue)	0 à 2^{40}-1	0xF980000001	ID propre à l'appareil de correspondant comme défini en 3.2.105
Peer_nickname	0 à 65 534	0xF980	Surnom de l'appareil du correspondant comme défini en 3.2.74
Session_key	Nombre de 128 bits	0 to 2 ^{128}-1	Session_key active. Les clés de rattachement sont enregistrées dans une mémoire permanente.
Alt_key (clé Alt)	Nombre de 128 bits	Non utilisé	La clé de session en instance ou précédente.
Time_to_switch_keys (clés de temps de commutation)	40 bits	Non utilisé	ASN lorsque la clé en instance devient la clé active. Après cette ASN, Alt_key est la clé de session précédente. La clé précédente doit être ignorée après 2 * Max_PDU_age (âge maximal de la PDU).
Peer_nonce_counter (compteur de nonces de l'appareil homologue)	Nombre de 32 bits	Non utilisé	Valeur la plus élevée du compteur de nonces reçue de l'appareil du correspondant
Nonce_counter_history	Matrice de 32 bits	Tous les bits mis à 1 lorsque l'appareil entame son rattachement au réseau	Une matrice de bits enregistrant les compteurs de nonces reçus, le bit de poids fort étant toujours mis et correspondant à la valeur courante de Peer_nonce_counter. Le bit de poids faible correspond à '1 + Peer_nonce_counter – taille de Nonce_counter_history'. Cela crée une fenêtre glissante avec chaque bit enregistrant une NPDU reçue avec le compteur de nonces correspondant. La taille de Nonce_counter_history est égale au nombre des NPDU reçues qui ont été enregistrées. Lorsque le Nonce_counter_history est décalé vers la droite, l'historique de la plus ancienne NPDU est éliminé.
My_nonce_counter	Nombre de 32 bits	0 to 2 32-1	Compteur de nonces pour les paquets fournis par l'appareil. Pour les sessions de rattachement ces valeurs sont mises à 0x00000000 en usine et jamais réinitialisées ensuite (uniquement incrémentées).
Transport_table	Référence interne	Vide	Référence aux Tables de transport (normalement 2) associées au correspondant. Elles sont vides pour les sessions de rattachement (les demandes de rattachement ne sont pas des opérations de transport "acquittées").
Route_table	Référence interne	Référence interne	Référence aux Tables d'itinéraires associées à la destination de correspondant. Pour les clés de rattachement ces valeurs sont générées à partir de la PDU d'annonce reçue

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6.6.3.2.3 Session de rattachement

La session de rattachement est unique et doit être créée lorsque l'appareil de terrain est mis sous tension pour la première fois en usine. Un appareil a toujours une clé de rattachement. Les adresses de la session de rattachement doivent être réglées sur les adresses de gestionnaire de réseau standard. L'entrée du compteur My_nonce_counter doit être mise à zéro lorsque la session de rattachement est créée pour la première fois et doit être incrémentée au fur et à mesure de son utilisation. Le compteur My_nonce_counter n'est plus

jamais réinitialisé par la suite et demeure inchangé lorsque l'appareil de terrain est mis sous tension et hors tension. Le My_nonce_counter de l'appareil de réseau est utilisé tant pour les demandes de rattachement provenant de l'appareil de réseau que pour les réponses de rattachement provenant du gestionnaire de réseau. Pour se protéger des attaques de rejeu sur Join_key, My_nonce_counter doit être enregistré dans une mémoire permanente.

Plusieurs stratégies peuvent être utilisées par le gestionnaire de réseau pour créer la 'session de rattachement'. Par exemple, une 'session de rattachement' pour un appareil de terrain spécifique pourrait être créée en utilisant l'ID propre de l'appareil de terrain et la Join_key. Quelle que soit la stratégie utilisée pour créer la 'session de rattachement', lorsque le gestionnaire de réseau reçoit et valide une demande de rattachement, le champ compteur de NPDU est copié dans les entrées de compteur de nonces de la session et est utilisé pour construire la réponse de rattachement. Le Tableau 49 présente les attributs de la session de rattachement.

6.6.3.3 Eléments de procédure de la fonction sécurité

6.6.3.3.1 Réception d'une primitive de demande d'émission de NL

Lorsqu'une demande d'émission de NL est reçue, la NLE doit construire la partie en-tête de sécurité de la NPDU pour la demande en question. Un MIC chiffré est utilisé pour assurer que la NPDU arrive avec succès et sans altération en provenance de l'appareil d'origine indiqué. Le MIC est généré et confirmé en mode CCM* (compteur combiné avec CBC-MAC (corrigé)) conjointement au chiffrement par blocs de 128 bits AES pour assurer l'authentification comme spécifié à l'Annexe B de l'IEEE 802.15.4-2011. Ce chiffre exige quatre chaînes d'octets comme paramètres:

- 'a', les données complémentaires devant être authentifiées, mais pas chiffrées;
- 'm', le message devant être chiffré;
- 'N', qui est le nonce de 13 octets; et
- 'K', qui est la clé AES de 128 bits.

Les données utiles de la NL sont chiffrées et constituent la chaîne d'octets 'm'. L'en-tête de la NPDU, à partir de l'octet de contrôle de la NPDU jusqu'au MIC, est la chaîne d'octets 'a'. Les champs HTL, Compteur et MIC dans la chaîne d'octets 'a' sont mis à zéro lors de l'authentification de la NPDU. Ils sont remplacés par leurs valeurs effectives avant que le paquet ne soit émis.

Le nonce de la couche sécurité (la chaîne d'octets 'N') a une longueur de 13 octets. Le nonce est créé comme résumé au Tableau 50 et décrit ci-dessous.

Si Session_type est "Rattachement" et la primitive de demande d'émission de NL primitive est une réponse de rattachement

a) dans ce cas
   1) le LSB (octet numéro zéro) de 'N' doit être mis à '1';
   2) les quatre octets suivants de 'N' doivent être mis à la valeur de Peer_nonce_counter issue de la demande de rattachement correspondante en commençant par le MSB de Peer_nonce_counter;
   3) les huit octets suivants de 'N' doivent être mis à l'adresse EUI-64 de l'appareil candidat au rattachement;

NOTE La demande et la réponse de rattachement utilisent toujours l'adresse EUI-64, car l'appareil ne reçoit son surnom qu'après le rattachement réussi de l'appareil au réseau. La réponse de rattachement ne peut être émise qu'en provenance du gestionnaire de réseau.

b) sinon,
   1) le LSB (octet numéro zéro) de 'N' doit être mis à '0';
   2) My_nonce_counter doit être pré-incrémenté de un;

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3) les quatre octets suivants de 'N' doivent être mis à la valeur de My_nonce_counter en commençant par le MSB de My_nonce_counter;

4) les cinq octets suivants de 'N' doivent être mis à la valeur du champ adresse source dans la NPDU, qui est soit l'adresse EUI-64 soit, si l'appareil est actuellement sur le réseau, le surnom avec des zéros de bourrage.

Tableau 50 – Nonce de NPDU

Numéro d'octet	Description
0	Mis à 1 si réponse de rattachement, sinon mis à 0
1 – 4	Compteur de nonces commençant par le MSB en N[1]
Pour l'adresse de source EUI64:	
5 – 12	L'adresse EUI64 est copiée (de MSB à LSB) dans les octets N[5] à N[12]
Pour le surnom de 2 octets:	
5 – 10	Chaque octet est mis à 0x00
11 – 12	Le surnom est copié (de MSB à LSB) dans les octets N[11] et N[12]

Une fois le nonce construit, la NPDU est chiffrée; et ensuite les champs de sécurité de la NPDU sont remplis.

6.6.3.3.2 Réception de la NPDU adressée à l'appareil

6.6.3.3.2.1 Généralités

La NLE doit traiter la NPDU reçue en utilisant le moteur de chiffrement AES de 128 bits pour authentifier la NPDU et déchiffrer les données utiles. Ce chiffre exige quatre chaînes d'octets comme paramètres:

- 'a', qui est l'entête de la PDU, à partir de l'octet de contrôle de la NPDU jusqu'au MIC de la NPDU avec les champs HTU, compteur et MIC de la NPDU mis à zéro;
- 'm', qui représente les données utiles de la NL;
- 'N', qui est le nonce de 13 octets; et
- 'K', qui est la clé AES de 128 bits.

L'authentification et le déchiffrement commencent par localiser la session correcte (voir 6.6.2.9) pour déterminer la clé et les compteurs de nonces.

Si la NPDU reçue n'est pas rejetée, les données utiles doivent être transmises à l'utilisateur de NLS dans la primitive d'indication d'émission de NL. Les données utiles de la NL doivent être constituées des données utilisateur de NLS.

6.6.3.3.2.2 Reconstruction de nonce

La NLE doit reconstruire le nonce pour la NPDU reçue, comme résumé au Tableau 50 et décrit ci-dessous.

Si Session_type est "Rattachement"

a) dans ce cas

1) Si la NPDU reçue est une demande de rattachement, alors

i) le LSB (octet numéro zéro) de 'N' doit être mis à '0';

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ii) les quatre octets suivants de 'N' doivent être mis à la valeur du champ compteur de la NPDU reçue en commençant par le MSB du compteur;

NOTE La NPDU de demande de rattachement est reçue uniquement par le gestionnaire de réseau.

2) Sinon la NPDU reçue est une réponse de rattachement,

i) le LSB (octet numéro zéro) de 'N' doit être mis à '1';

ii) si le champ Compteur de la NPDU reçue est égal à My_nonce_counter, les quatre octets suivants de 'N' doivent être mis à la valeur de My_nonce_counter en commençant par le MSB de My_nonce_counter;

iii) sinon, la NLE doit rejeter la NPDU reçue.

3) Si la NPDU n'a pas été rejetée, les cinq octets suivants de 'N' doivent être mis à l'adresse EUI-64 de la source provenant de la NPDU reçue;

b) Dans le cas contraire, Session_type n'est pas "rattachement",

1) le LSB (octet numéro zéro) de 'N' doit être mis à '0';

2) les trois octets suivants de 'N' doivent être mis aux trois octets de poids fort de la valeur de Peer_nonce_counter correspondante en commençant par le MSB de Peer_nonce_counter;

3) si la valeur de compteur de 1 octet de la NPDU reçue est inférieure à la quantité (1 + MSB de Peer_nonce_counter – size of Nonce_counter_history), la valeur 24 bits dans les octets N[1] à N[3] doit être incrémentée;

4) l'octet suivant de 'N' doit être mis au champ compteur de la NPDU reçue;

5) les cinq octets suivants de 'N' doivent être mis au champ adresse de source de la NPDU reçue, qui est soit l'adresse EUI-64, soit le surnom avec des zéros de bourrage.

Le nombre de nonces reconstitué doit être comparé au Nonce_counter_history. S'il correspond à n'importe lesquels des bits mis dans le Nonce_counter_history, la NPDU reçue doit être ignorée. Si le nombre de nonces reconstitué est inférieur au Peer_nonce_counter – taille de (Nonce_counter_history) la NPDU reçue doit être ignorée.

6.6.3.3.2.3 Authentification

Si le nonce est construit avec succès et que la NPDU reçue n'est pas un doublon d'une NPDU reçue précédemment, l'authentification et le déchiffrement doivent être effectués. Si cette authentification échoue, le paquet doit être rejeté.

6.6.3.3.2.4 Protection contre le rejeu

Si le paquet est authentique, Nonce_counter_history doit être actualisé. Sachant que la NPDU peut arriver en désordre ou être complètement perdue, cet algorithme de fenêtre glissante est utilisé pour faciliter les communications et éliminer les paquets dupliqués. Peer_nonce_counter et Nonce_counter_history font ensemble la chronique des NPDU reçues par l'appareil.

Les octets 1 à 4 de 'N' constituent le compteur de nonces reconstitués. Le compteur de nonces reconstitués doit être comparé au Nonce_counter_history. S'il correspond à n'importe lesquels des bits mis dans Nonce_counter_history, la NPDU reçue est une duplication de NPDU reçue précédemment et la NPDU doit être rejetée. Si le compteur de nonces reconstitués se situe à l'extérieur de la fenêtre du Nonce_counter_history, la DLE doit rejeter la NPDU reçue.

Si le compteur de nonces reconstitués est inférieur à Peer_nonce_counter, le bit approprié dans Nonce_counter_history doit être mis. Autrement, Nonce_counter_history doit être décalé vers la droite et la valeur de Peer_nonce_counter actualisée. Cette opération s'effectue en soustrayant Peer_nonce_counter du compteur de nonces reconstitués. La différence obtenue indique le nombre de fois que Nonce_counter_history doit être décalé vers la droite. Après le décalage, le bit de poids fort de Nonce_counter_history doit être mis. Enfin, le compteur de

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nonces reconstitués doit être copié vers Peer_nonce_counter dans l'entrée de la Table des session.

6.6.4 Tables de couche réseau

6.6.4.1 Généralités

Tous les appareils doivent conserver une série de tables qui contrôlent les communications effectuées par l'appareil, fournir des informations de routage, prendre en charge les acquittements de bout en bout, assurer la confidentialité des communications et rassembler des statistiques sur ces communications.

Les tables contrôlant les activités de communication sont:

- La Table des sessions – une entrée dans cette table établit un tube sécurisé entre l'appareil et un appareil de correspondant spécifique. Aucune communication vers un appareil de correspondant n'est possible sans une session de sécurité (voir 6.6.3.2.1). Voir 6.6.3.2.2 pour les attributs de session.
- La Table des transports – elle est utilisée pour prendre en charge la transaction d'acquittements de bout en bout avec de nouvelles tentatives automatiques (voir 6.7.3).
- La Table des itinéraires – elle sert à ajouter des informations de routage à une nouvelle NPDU générée suite à une demande d'émission de NL (voir 6.6.4.2).
- La Table des itinéraires par source – elle est jointe à certains itinéraires (voir 6.6.4.3).
- La Table des indicateurs horaires – elle indique la destination, l'itinéraire et les quotas de programmation alloués par le gestionnaire de réseau (voir 6.6.4.4).

La relation entre ces tables est illustrée à la Figure 32. Au sein de l'appareil, la Table des sessions est centrale. La NLE utilise aussi la Table des voisins (voir 6.4.3.4) et la Table des graphes (voir 6.4.3.5) de la DLE. La figure illustre les relations autour d'un itinéraire donné. Un itinéraire est identifié par un Route_ID (identifiant d'itinéraire). Un itinéraire est associé à un correspondant spécifique. Un itinéraire peut contenir un itinéraire par source facultatif. Un itinéraire est toujours associé à un graphe. Dans certains cas, la forme spécialisée de graphe, "supertrame", est utilisée. Un graphe peut être associé à 0 (supertrame) voisin ou plusieurs. Un indicateur horaire est toujours associé à un seul itinéraire. Un itinéraire est associé à 0 indicateur horaire ou plusieurs. La relation avec les indicateurs horaires est orientée, car l'indicateur horaire a des informations concernant l'itinéraire, mais l'itinéraire peut ne pas en avoir sur l'indicateur horaire.

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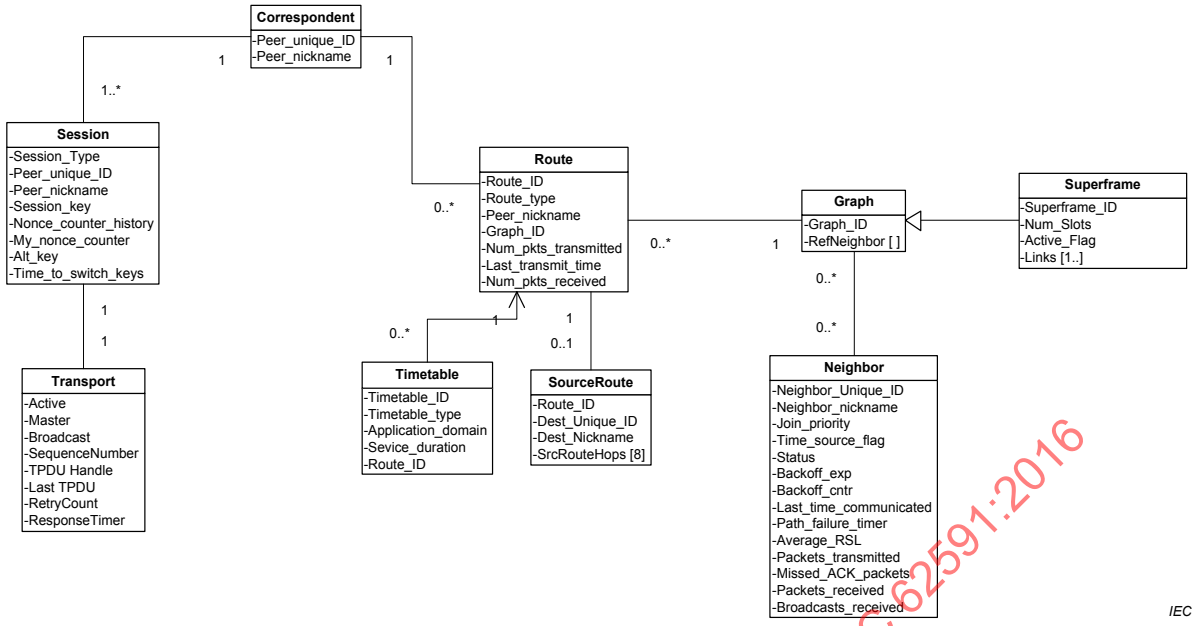

Anglais	Français
Active	Actif
Master	Maître
Broadcast	Diffusion
TPDU Handle	Traitement des TPDU
Last TPDU	Dernière TPDU
Correspondent	Correspondant
Timetable	Indicateur horaire
Route	Itinéraire
Graph	Graphe
Neighbor	Voisin
Status	Statut
Superframe	Supertrame

Figure 32 – Tables des NLE et relation

Les appareils doivent prendre en charge le nombre minimal d'entrées de chaque table et l'espace de tampon minimal présenté au Tableau 51.

Tableau 51 – Exigences d'espace minimales des tables de NLE

Nom de la Table	Nombre minimal d'entrées requis
Session	8
Appareil de correspondant	1 par session
Transport	2 par session
Itinéraire	8
Itinéraire par source	2
Indicateur horaire	16

Certains des attributs des tables décrites dans la présente norme peuvent être calculés ou dérivés d'autres d'informations et il n'est pas nécessaire de les stocker séparément.

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NOTE Bien que la mise en œuvre spécifique du stockage de données et de la configuration soit laissée au choix des concepteurs de l'appareil, une description générale des champs contenus dans les structures de données est importante pour le fonctionnement global.

6.6.4.2 Table des itinéraires

Le Tableau 52 présente les attributs d'itinéraire. La Table des itinéraires est associée à une session de sécurité et à une adresse de correspondant. Elle est utilisée pour aider à choisir le graphe utilisé pour la communication vers l'appareil de correspondant. La NLE doit rassembler des statistiques pour permettre au gestionnaire de réseau d'optimiser les ressources de communication au fil du temps.

Tableau 52 – Attributs d'itinéraire

Nom d'attribut	Plage de valeurs	Définition
Route_ID	0 à 255	Identifiant d'itinéraire
Route_type	Maintenance Edition Transfert par blocs Evénement	Indique le type d'itinéraire; Maintenance est la valeur par défaut.
Dest_nickname	0 à 65 534 – voir 6.3.1.2.4	Surnom de l'appareil de destination avec lequel l'itinéraire est établi
Graph_ID	256 à 65 535	Identifiant pour le graphe associé avec cet itinéraire. S'il est vide, il existe uniquement un itinéraire par source vers la destination. Un Graph_ID vide est indiqué par 0xFFFF.
Src_route_ID	0 à 255	Si non nul, l'identifiant de la Table des itinéraires par source pour cet itinéraire, sinon absence d'itinéraire par source pour cet itinéraire
Num_pkts_transmitted	0 à 65 535[a]	Nombre de paquets émis sur cet itinéraire
Last_transmit_time (temps de dernière émission)	0 à 2^{32}-1 en unités de 1/32 ms	L'heure à laquelle la dernière NPDU a été générée pour cet itinéraire
Num_pkts_received	0 à 65 535[a]	Nombre de paquets reçus sur cet itinéraire, actualisé en fonction du Graph_ID dans la NPDU
[a] La valeur des compteurs de paquets repasse de 65 535 à 0.		

6.6.4.3 Table des itinéraires par source

La Table des itinéraires par source contient une liste de 8 adresses d'appareil au maximum traçant l'itinéraire allant de cet appareil à l'appareil de correspondant comme présenté au Tableau 53.

Tableau 53 – Attributs d'itinéraires par source

Nom d'attribut	Plage de valeurs	Définition
Route_ID	1 à 255	Identifiant d'itinéraire
Dest_Unique_ID	0 à 2^{40}-1	ID propre à l'appareil de destination comme défini en 3.2.105
Dest_nickname	0 à 65 534	L'adresse courte du voisin comme définie en 3.2.74
Src_route_hops (sauts de vie d'itinéraire par source) [8]	Surnom d'appareil	Jusqu'à 8 surnoms peuvent conduire à la destination. Les adresses non utilisées doivent être mises au surnom de la destination.

6.6.4.4 Table des indicateurs horaires

Lorsqu'un appareil a besoin d'établir une connexion de communication avec un autre appareil, il envoie une demande au gestionnaire de réseau pour qu'il lui soit alloué un indicateur horaire pour la communication en question. Chaque ensemble destination et Application_domain (domaine d'application) a son propre indicateur horaire. Le Tableau 54

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présente les attributs d'indicateur horaire. Il identifie l'itinéraire conduisant à l'appareil de destination et les quotas de programmation alloués à cette communication. Lorsque l'appareil supprime un indicateur horaire, le gestionnaire de réseau est censé libérer les ressources réseau prenant en charge l'indicateur horaire en question. Le même itinéraire peut être utilisé par plusieurs indicateurs horaires.

Tableau 54 – Attributs de l'indicateur horaire

Nom d'attribut	Plage de valeurs	Définition
Timetable_ID	0 à 255	Identifiant d'indicateur horaire
Timetable_type	source | destination| intermittent	Indique le type d'indicateur horaire
Application_domain	Maintenance | Editer| Transfert par blocs | Evénement	Le domaine d'application utilisant cet indicateur horaire
Dest_nickname	0 à 65 534	L'adresse courte de la destination à laquelle cet indicateur horaire a été alloué
Service_duration	0 à 2^{32}-1 en unités de 1/32 ms	Pour les communications cycliques (par exemple édition de données), les paquets sont générés avec cette période. La latence pour la communication cyclique ne doit pas dépasser 1/3 de la période. Pour les communications intermittentes, il s'agit de la latence maximale requise.
Route_ID	0 à 255	Identifiant d'itinéraire pour cet indicateur horaire. Plusieurs indicateurs horaires peuvent utiliser le Route_ID.

6.6.5 Machine NLE

6.6.5.1 Fonctionnement général

La NLE avance par une série d'états commençant par l'état 'Repos' et se poursuivant jusqu'à ce que l'appareil soit 'Opérationnel' et participe pleinement au réseau maillé. Il existe cinq états décrits au Tableau 55.

Tableau 55 – Etats de NLE

Etat	Description
Repos	L'appareil est passif et son émetteur-récepteur sans fil n'est pas actif. Il n'a pas connaissance du réseau.
Rattachement	L'appareil est à l'écoute pour déceler le réseau, tentant d'acquérir une DLPDU d'annonce et demandant l'admission au réseau.
Quarantaine	L'appareil a rejoint avec succès le réseau, mais du point de vue de la sécurité, il n'est autorisé à parler qu'au gestionnaire de réseau. Il n'est ni disponible ni autorisé à accomplir une acquisition de données ou des fonctions de contrôle ou à communiquer de toute autre manière avec la passerelle.
Opérationnel	L'appareil est accessible à des applications hôtes via la passerelle. Il est intégré au fonctionnement du système.
Suspendu	L'appareil est passif. Toutes ses Tables de réseau sont intactes.

Le diagramme des transitions d'états est illustré à la Figure 33. Ce diagramme décrit les événements qui permettent à l'appareil de démarrer, de localiser et de rejoindre le réseau et finalement de progresser de son statut de nouveau membre du réseau à son statut d'appareil de réseau totalement opérationnel. En outre, le diagramme montre l'appareil (et le réseau) suspendu. De surcroît, l'appareil peut à tout instant être forcé de se déconnecter (par exemple d'être retiré du processus pour la maintenance au niveau dépôt) ou de se rattacher de nouveau.

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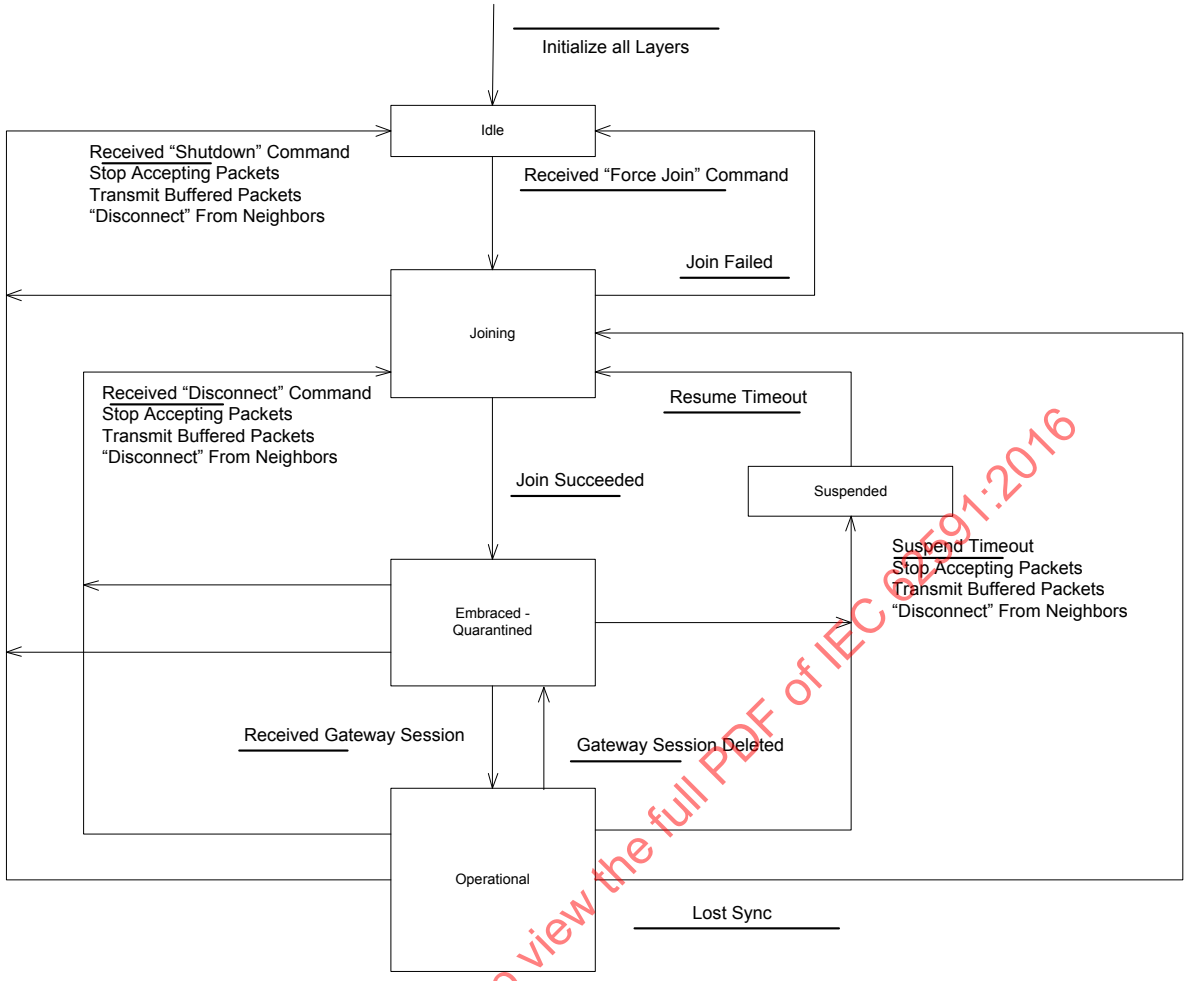

Anglais	Français
Initialize all Layers	Initialiser toutes les couches
Received "Shutdown" Command Stop Accepting Packets Transmit Buffered Packets "Disconnect" From Neighbors	Commande d'arrêt reçue Arrêter d'accepter des paquets Emettre paquets en tampon Déconnecter des voisins
Idle	Repos
Received "Force Join" Command Join failed	Commande de rattachement forcé reçue Echec du rattachement
Received "Disconnect" Command Stop Accepting Packets Transmit Buffered Packets "Disconnect" From Neighbors	Commande de déconnexion reçue Arrêter d'accepter des paquets Emettre paquets en tampon Déconnecter des voisins
Joining	Rattachement
Resume Timeout Join Succeeded Suspended	Reprendre Temporisation Rattachement réussi Suspendu
Suspend Timeout Stop Accepting Packets Transmit Buffered Packets	Suspendre Temporisation Arrêter d'accepter des paquets Emettre paquets en tampon

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Anglais	Français
"Disconnect" From Neighbors	Déconnecter des voisins
Embraced – Quarantined	"Quarantaine-restreint"
Received Gateway Session	Session de passerelle reçue
Gateway Session Deleted	Session de passerelle supprimée
Operational	Opérationnel
Lost sync	Perte de synchronisation

Figure 33 – Diagramme d'états de NLE

6.6.5.2 Etat de repos

Après réinitialisation d'un appareil ou à la mise sous tension, l'appareil doit entrer à l'état 'Repos'. Pendant qu'il est dans cet état, l'appareil ne doit pas tenter d'établir de communications sans fil. L'appareil doit actualiser Join_key et Network_ID s'ils sont écrits via le port de maintenance. Lorsque l'appareil reçoit la commande de rattachement provenant de la gestion de NL, la NLE doit passer à l'état 'Rattachement'.

6.6.5.3 Etat "Rattachement"

La NLE doit localiser le réseau et se synchroniser au réseau. Elle doit attendre de recevoir des paquets d'annonce. Après avoir reçu un ou plusieurs paquets d'annonce, la NLE doit demander l'admission au réseau, en utilisant Join_key. Le gestionnaire de réseau est censé envoyer la clé réseau et la session du gestionnaire de réseau à la NLE demandeuse. Le gestionnaire de réseau est également censé fournir à la DLE une supertrame, des graphes et des liaisons. Une fois que la NLE a reçu ces paramètres, elle doit passer à l'état 'Quarantaine'.

La demande de rattachement peut recevoir immédiatement une réponse de la part du gestionnaire de réseau ou bien la NLE peut avoir à répéter la demande. Un échec doit se produire si l'appareil envoie un nombre de demandes de rattachements égal à Max_join_retries (nombre maximal de tentatives de rattachement) (voir Tableau 58), sans recevoir les clés de sécurité et les paramètres de session de la part du gestionnaire de réseau. Dans ce cas, la NLE doit retourner à l'état 'Repos'.

Si la NLE reçoit la commande Déconnexion provenant de la gestion de NL, elle doit passer à l'état 'Repos'.

6.6.5.4 Etat "Quarantaine-Restreint"

Les appareils à l'état quarantaine-restreint sont des partenaires réseau limités. La NLE doit rester dans cet état jusqu'à ce qu'elle soit approuvée pour le déploiement dans l'application réseau. L'approbation peut avoir la forme d'une autorisation d'utiliser l'appareil dans le système par l'opérateur humain et d'une mise en service de l'appareil par celui-ci. Cette étape de quarantaine correspond à des pratiques normales dans l'industrie de transformation et ajoute une couche supplémentaire de sécurité au processus de rattachement.

Pendant qu'il est en quarantaine, l'appareil doit être autorisé par le gestionnaire de réseau à être source et puits pour les paquets. L'appareil doit également acheminer des paquets comme cela a été configuré par le gestionnaire de réseau. Des rapports de réseau normaux (par exemple des rapports de voisins) doivent être générés.

Après avoir reçu les paramètres de session de la passerelle, la NLE doit passer à l'état 'Opérationnel'.

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6.6.5.5 Opérationnel

Cela permet un accès d'application hôte à l'appareil et déclenche son interaction avec l'appareil.

Dans l'état opérationnel, l'appareil est un partenaire réseau complet et doit commencer à accomplir les tâches désignées par sa configuration. Il doit acheminer les paquets à travers le réseau vers leur destination finale. L'appareil doit aussi participer à l'émission d'annonces et à la prise en charge des nouveaux appareils rejoignant le réseau. S'il est configuré pour éditer des données, il doit demander la largeur de bande nécessaire à cet effet. Il doit recevoir des demandes et réponses d'utilisateur pour l'émission.

6.6.5.6 Etat "Suspendu"

Lorsqu'il est à l'état 'Quarantaine' ou 'Opérationnel', l'appareil peut être mis de force à l'état 'Suspendu' pendant la durée spécifiée. Il s'agit normalement d'une opération de brève durée qui est réalisée par exemple pour des raisons de sécurité pendant des opérations d'abattage aux explosifs. Dans cet état, l'appareil continue de surveiller le temps écoulé tout en laissant la radio désactivée. À l'expiration de la durée spécifiée, l'appareil doit passer à l'état 'Rattachement'.

6.6.6 Eléments de procédure NLE

6.6.6.1 Réception d'une primitive demande d'émission de NL

Lorsqu'une demande d'émission de NL est reçue de l'utilisateur de NLS, la NLE doit utiliser le Timetable_ID reçu dans la primitive de service pour localiser l'indicateur horaire de cette demande. Si la destination n'est pas le gestionnaire de réseau et si la largeur de bande restante dans l'indicateur horaire est insuffisante pour cette demande, une erreur doit être retournée et la demande doit être supprimée.

La NLE doit construire la NPDU pour la demande en question. Le champ doit être établi conformément aux procédures indiquées au Tableau 56. La NLE doit trouver le Route_ID dans l'attribut d'indicateur horaire comme présenté au Tableau 54. Une fois l'itinéraire identifié, le Graph_ID trouvé dans l'attribut d'itinéraire, comme présenté au Tableau 52, doit être copié dans la NPDU.

Les paquets doivent être acheminés par graphe, à moins que l'itinéraire ne soit en cours d'essai. Cependant, si un itinéraire par source est attaché à l'itinéraire, il doit être inclus dans la NPDU. Les entrées d'adresse d'itinéraire par source non utilisées dans la NPDU doivent être mises à 0xFFFF. Si le routage par source est utilisé, le Graph_ID doit aussi être valide.

Tableau 56 – Construction de la NPDU

Champ	Procédure
Contrôle	Etablir les bits d'adresse en fonction des tailles des adresses sources et de destination. Les adresses de destination sont indiquées dans la primitive de demande. Si la destination est une adresse de diffusion, la taille de l'adresse de destination doit être courte. L'adresse source doit être l'adresse EUI-64 de l'appareil jusqu'à ce que le surnom de l'appareil soit initialisé. Mettre les bits de routage en fonction des résultats de la sélection d'itinéraires.
HTL	Etablir à Default_HTL (valeur HTL par défaut).
Numéro de séquence	Etablir à la valeur ASN courante.
Graph_ID	Etablir en fonction des résultats de la sélection d'itinéraire.
Adresse de destination	Etablir à la valeur contenue dans la primitive de demande. Si l'adresse de destination est une adresse de diffusion, la valeur de ce champ doit être 0xFFFF.
Adresse source	Etablir à l'adresse EUI-64 si le surnom n'est pas initialisé, sinon mettre au surnom.
Itinéraire proxy	Etablir en fonction des résultats de la sélection d'itinéraire.
Itinéraire(s) par source	Etablir en fonction des résultats de la sélection d'itinéraire.

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6.6.6.2 Réception d'une primitive d'indication de RECEPTION DE DL

La NLE doit examiner l'adresse de destination dans la NPDU reçue de la DLE. Elle doit acheminer ces paquets vers la destination correcte: transmettre à la DLE suivante dans l'itinéraire, transmettre à l'appareil candidat au rattachement ou livrer à l'utilisateur de NLS local.

6.6.6.3 Réception d'une primitive de confirmation d'émission de DL

6.6.6.3.1 Généralités

La NLE doit supprimer toutes les données et tous les éléments de table pour le service associé au descripteur et retourner une confirmation à l'utilisateur de la NL.

6.6.6.3.2 NPDU adressée à l'appareil

Si la destination indiquée dans la NPDU reçue est l'utilisateur de NLS local, la NLE doit la transmettre à la fonction de sécurité.

6.6.6.3.3 NPDU avec adresse de diffusion

Si l'adresse de destination contenue dans la NPDU reçue est l'adresse de diffusion, la NLE doit transmettre la NPDU comme décrit en 6.6.6.3.4 et la transmettre aussi à la fonction de sécurité.

6.6.6.3.4 Transmission de la NPDU reçue

La NLE doit traiter la NPDU reçue dans la séquence décrite ci-dessous.

La NLE doit vérifier et actualiser HTL. Si le compte des HTL dans la NPDU reçue est zéro,

a) alors la NPDU doit être rejetée,

b) sinon,

   1) si HTL n'est pas 0xFF, la NLE doit la décrémenter de 1 et utiliser cette valeur pour construire la NPDU à transmettre;

   2) le numéro de séquence doit être vérifié et si l'âge du paquet de la NPDU reçue est supérieur à Max_packet_age, il doit être ignoré; autrement la différence entre l'âge du paquet et le Max_packet_age doit être fournie à la DLE comme expiration de délai;

   3) la NLE doit vérifier l'adresse de destination;

   4) si la NPDU contient une adresse de proxy qui correspond à l'adresse de la NLE locale,

      i) la destination finale est un appareil en cours de rattachement. La NLE doit acheminer le paquet vers l'appareil candidat au rattachement en transmettant la NPDU à la DLE indiquant comme adresse de destination de DLL celle de l'appareil candidat au rattachement;

      ii) sinon, si l'adresse de destination de la NPDU est en monodiffusion et correspond à un voisin, la NPDU doit être acheminée directement vers le voisin en question. L'appareil doit acheminer le paquet vers l'appareil voisin en transmettant la NPDU à la DLE indiquant comme adresse de destination de DLL celle de l'appareil voisin.

Lors de l'analyse d'une NPDU reçue, les colonnes de la Figure 34 doivent être évaluées de gauche à droite, c'est-à-dire en commençant par "Routage par source dans la NPDU". Un "Non" dans la colonne "Routage par graphe dans la NPDU" signifie que le Graph_ID reçu ne concorde pas soit avec un Graph_ID, soit avec un Superframe_ID trouvé dans l'appareil de terrain qui a reçu la NPDU. La décision se termine par un identifiant littéral pour la décision de routage, qui est décrite au Tableau 57.

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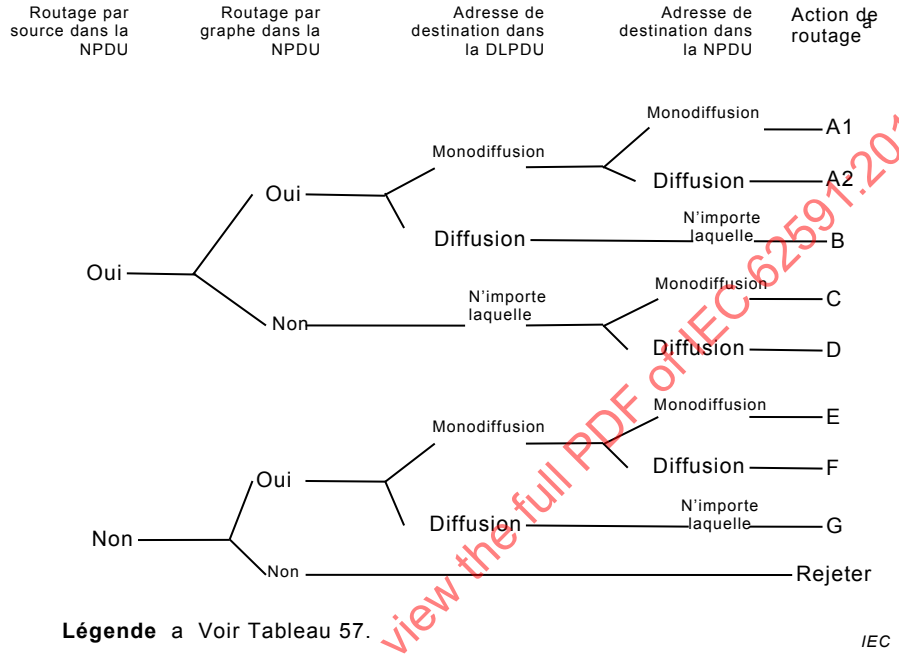
L'âge du paquet peut être calculé comme suit

```
If ((current ASN && 0xFFFF) < sequence number)
      Packet age = ((current ASN && 0xFFFF) – sequence number) + 63356
Else
      Packet age = (current ASN && 0xFFFF) – sequence number
End If
```

NOTE Si l'adresse de destination contenue dans la DLPDU reçue est une adresse de diffusion, le Graph_ID dans la NPDU en question détient le Superframe_ID pour identifier les liaisons de diffusion correspondantes.



Légende a Voir Tableau 57.

Figure 34 – Décision de routage de la NPDU

Tableau 57 – Actions de routage

Code d'action	Description d'action
A1	S'il s'agissait de la fin de la liste des itinéraires par source dans la NPDU reçue ou si l'adresse suivante dans l'itinéraire par source n'est pas celle d'un voisin, alors transmettre la NPDU reçue sur l'itinéraire par graphe dans la NPDU reçue, sinon transmettre la NPDU reçue vers l'adresse suivante dans l'itinéraire par source. Si l'itinéraire par graphe et l'itinéraire par source sont tous deux épuisés, alors signaler une erreur d'itinéraire par source.
A2	S'il s'agissait de la fin de la liste des itinéraires par source dans la NPDU reçue, alors diffuser vers Superframe_ID (Graph_ID contient Superframe_ID), sinon transmettre la NPDU reçue vers l'adresse suivante dans l'itinéraire par source.
B	Graph_ID doit être Superframe_ID. Continuer la diffusion selon le graphe. Utiliser la liaison de diffusion dans la supertrame.
C	Si la NPDU reçue a une autre destination valide dans la liste d'itinéraires par source, alors transmettre la NPDU vers l'adresse en question. Sinon, indiquer une erreur d'itinéraire par source au NLM.
D	Transmettre la NPDU reçue vers la nouvelle adresse dans l'itinéraire par source. La NPDU est ignorée à la fin de l'itinéraire par source.
E	Transmettre la NPDU reçue le long du graphe, en utilisant n'importe quelle liaison conduisant au voisin sur le graphe; si fin du graphe, alors indiquer une erreur d'itinéraire par graphe au NLM.
F	Transmettre la NPDU reçue à tous les voisins dans le graphe; rejeter la NPDU si fin du graphe.
G	Graph_ID est Superframe_ID; continuer à diffuser la NPDU en utilisant la liaison de diffusion dans la supertrame
Ignorer	La NPDU reçue n'est pas valide; la rejeter.

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La valeur d'expiration de délai à transmettre à la DLE doit être recalculée en utilisant l'ASN reçu.

La NLE doit transmettre la NPDU à la DLE afin qu'elle puisse être émise dans le prochain intervalle de temps, c'est-à-dire l'intervalle de temps suivant immédiatement l'intervalle de temps dans lequel la PDU a été reçue.

6.6.7 Informations de gestion de NL

6.6.7.1 Généralités

Plusieurs attributs de NL doivent être configurés avant qu'une NLE ne puisse fonctionner correctement. Ces attributs sont définis au 6.6.7.2. Les actions de la NLE qui peuvent être demandées par le biais de la gestion de la NL sont également récapitulées en 6.6.7.3.

6.6.7.2 Attributs de la NL

Les attributs d'une session sont présentés au Tableau 49.

Les attributs d'un itinéraire sont présentés au Tableau 52.

Les attributs d'itinéraire par source sont présentés au Tableau 53.

D'autres attributs sont définis au Tableau 58.

Tableau 58 – Attributs de la NL

Nom d'attribut	Plage de valeurs	Définition
Identifiant unique	0 à 2^{40}-1	ID propre à l'appareil comme défini en 3.2.105
Surnom	0 à 65 534	Surnom de l'appareil comme défini en 3.2.74
Default_HTL	0 à 255	Limite de durée de vie d'un paquet en termes de sauts; spécifiant le nombre de sauts qu'un paquet peut parcourir avant d'être rejeté; avec une valeur par défaut de 249
Max_packet_age	0 à 65 535	Limite de durée de vie d'un paquet en termes de temps utilisant l'ASN; indiquant le nombre d'intervalles de temps après lequel un paquet doit être rejeté; avec une valeur par défaut de 30 000 temps ASN (égal à 300 s). Peut être mis à une valeur entre 100 et 60000.
min_ads_needed	0 à 255	Nombre préférentiel d'annonces différentes avant de produire une demande de rattachement; avec une valeur par défaut de 3
Ad_wait_timeout	0 à 2^{32}-1 en unités de ms	Durée à attendre tout en tentant de recevoir des annonces supplémentaires; avec une valeur par défaut de 30 s
max_join_retries	0 à 255	Limite des tentatives de rattachement; avec une valeur par défaut de 5
Join_rsp_time	0 à 2^{32}-1 en unités de ms	Durée du délai de réponse de rattachement; avec une valeur par défaut de 120 s
Bcast_reply_time	0 à 2^{32}-1 en unités de ms	Durée maximale pour répondre à un message de diffusion; avec une valeur par défaut de 60 s
Health_report_time	0 à 65 535 en unités de ms	Intervalle auquel éditer des rapports de santé; avec une valeur par défaut de 15 minutes
Session_table_size	jusqu'à 255	Taille de la Table des sessions (à savoir, nombre maximal d'entrées)
Num_session_table_entries	jusqu'à 255	Nombre d'entrées actuelles dans la Table des sessions.
Route_table_size	jusqu'à 255	Taille de la Table des itinéraires (à savoir, nombre maximal d'entrées).
Num_route_table_entries	jusqu'à 255	Nombre d'entrées actuelles dans la Table des itinéraires

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6.6.7.3 Actions de la NLM

Les actions de la NLE que peut demander la gestion de la NL sont définies au Tableau 59.

Tableau 59 – Actions de la NL

Nom	Description
réinitialiser	Réinitialiser et initialiser la NLE. Toutes les tables du réseau sont effacées lorsque cette primitive est invoquée. Cette primitive est normalement invoquée à la mise sous tension de l'appareil ou lorsque l'appareil est en cours d'installation dans un nouveau réseau.
écrire session	Ajoute une nouvelle session
supprimer session	Supprime une session existante
ajouter itinéraire	Ajoute un nouvel itinéraire
supprimer itinéraire	Supprime un itinéraire existant
itinéraire par défaut	Etablit un itinéraire comme itinéraire par défaut
ajouter indicateur horaire	Ajoute un nouvel indicateur horaire
supprimer indicateur horaire	Supprime un indicateur horaire existant
rattacher	Change l'état "Repos" en "Rattachement"
déconnecter	Fait passer l'état à "repos"

6.6.7.4 Gestion de réseau

Le gestionnaire de réseau a la responsabilité de la gestion globale, de la programmation et de l'optimisation du réseau. La fonction de gestion de réseau est spécifiée à l'Annexe C.

6.7 Couche transport

6.7.1 Généralités

La couche transport est utilisée pour assurer que les données utilisateur de TLS sont communiquées à leur destination finale. La couche transport prend en charge les transactions tant acquittées que non acquittées.

Le service Non acquitté permet à un appareil d'envoyer des données utilisateur de TLS sans exiger d'acquittement de la part de l'extrémité de réception. Les données peuvent être livrées à l'appareil de destination dans un ordre différent de celui dans lequel elles ont été initialement envoyées de l'appareil d'origine.

Le service Acquitté est utilisé pour construire un tube de transport synchrone à travers le réseau reliant deux appareils. Ce tube permet aux appareils d'envoyer des données et de confirmer leur livraison. L'utilisateur du TLS peut envoyer des données qui seront livrées à l'utilisateur de TLS de réception sans perte, duplication ou ordre incorrect. Ce service convient à un trafic de demandes et de réponses. Lorsque le service acquitté est utilisé, la communication est synchrone. Une seule transaction en cours à la fois est autorisée à travers le réseau pour le tube de transport en question.

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6.7.2 Structure de TPDU

6.7.2.1 Généralités

La Figure 35 illustre la structure d'une NPDU. Elle doit être constituée de champs dans une séquence telle que décrite ci-dessous:

- Un contrôle de transport d'un seul octet, et
- les données utiles de la PL.

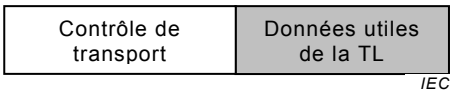

Figure 35 – Structure de TPDU

6.7.2.2 Contrôle de transport

Ce champ spécifie la longueur et le type de services comme illustré à la Figure 36. Il comporte quatre sous-champs.

tack: si le bit 7 est mis à '1', la TPDU correspond au service acquitté, sinon elle correspond au service non acquitté,

tresp: si le bit 6 est mis à '1', la TPDU correspond à la réponse comme paramètre de type transport spécifié de la primitive de TLS,

tbroad: si le bit 5 est mis à '1', la TPDU correspond au tube de diffusion; ce bit est mis à '1' aussi bien pour la demande que pour la réponse,

tseqn: les bits de 4 à 0 forment le numéro de séquence pour la TPDU afin de détecter un doublon de TPDU, une TPDU manquante et de corréler la réponse à la demande.

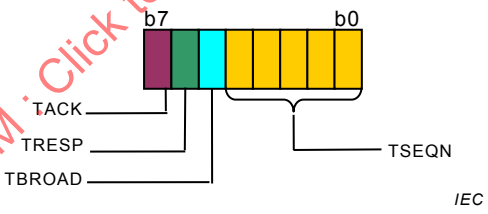

Figure 36 – Octet de contrôle de TPDU

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6.7.3 Table des tubes de transport

Le Tableau 60 présente les attributs de tube de transport. Pour chaque échange de données acquitté, une nouvelle entrée doit être créée dans la Table des tubes de transport. Un transfert de données non acquitté n'exige pas d'entrée dans cette table.

L'appareil de terrain doit avoir la capacité de suivre les tubes de transport:

- esclave pour échange de données de monodiffusion avec le gestionnaire de réseau,
- esclave pour échange de données de diffusion avec le gestionnaire de réseau,
- esclave pour échange de données de monodiffusion avec la passerelle,
- maître pour les notifications d'événements au gestionnaire de réseau, et
- maître pour les notifications d'événements à la passerelle.

La passerelle et le gestionnaire de réseau sont tenus de suivre plusieurs tubes de transport pour chaque appareil et de disposer de tubes pour tous les appareils de terrain connectés au

réseau. Lorsqu'une diffusion acquittée est générée par le gestionnaire de réseau ou la passerelle, la TLE doit s'assurer que les acquittements sont reçus de tous les appareils concernés, qui peuvent potentiellement être tous les appareils.

Chaque entrée de la Table des tubes de transport inclut des attributs indiquant si, oui ou non, elle est active (une transaction est en cours) et que l'appareil agit en maître et si, oui ou non, elle est de diffusion. La demande TL-Data-exchange émane de l'extrémité maître du tube. L'indication TL-Data-exchange est fournie au niveau de l'extrémité esclave du tube.

Si l'entrée de la Table des tubes de transport est pour l'extrémité maître du tube, le compteur de répétitions de tentatives et le temporisateur de tentatives sont également requis.

Tableau 60 – Attributs du tube de transport

Nom d'attribut	Plage de valeurs	Définition
Actif	vrai, faux	vrai si le tube de transport est actif
Maître	vrai, faux	vrai s'il s'agit de l'extrémité maître du tube
Diffusion	vrai, faux	vrai si le tube de transport est pour la demande de diffusion
Bcast_reply_time	0 à 65 535 en unités de ms	Durée maximale pour répondre à un message de diffusion; la valeur par défaut est 60 s
sequence_number	0 à 31	À l'extrémité maître du tube, le numéro de séquence de la demande en cours; À l'extrémité esclave du tube, le numéro de séquence acquitté le dernier
TPDU_handle	0 à 255	À l'extrémité maître du tube seulement, le descripteur contenu dans la demande d'échange de données de TL correspondant à Last_TPDU (dernière TDPU); n'est pas utilisé à l'extrémité esclave du tube.
last_TPDU		À l'extrémité maître du tube, la dernière TPDU acquittée (ou NUL si aucune); À l'extrémité esclave du tube, la dernière TPDU acquittée
retry_count	0 à 255	À l'extrémité maître du tube seulement, le nombre de tentatives de communication; n'est pas utilisé à l'extrémité esclave du tube.
max_reply_time		Durée à attendre une réponse à la demande en cours, avant de réessayer; la valeur par défaut est 30 s
max_retries	0 à 255	Nombre de tentatives de la couche transport pour accomplir une émission de paquet acquittée; la valeur par défaut est 5 s

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6.7.4 Eléments de procédure TLE

6.7.4.1 Réception d'une primitive de demande de transfert de données de TL

La TLE doit coder l'octet de contrôle de transport comme présenté au Tableau 61.

Tableau 61 – Codage du contrôle de transport pour la demande de transfert de données de TL

Type de transport	tbroad	tack	tresp
Demande de transfert par blocs	0	0	0
Réponse de transfert par blocs	0	0	1
Diffusion de recherche	1	0	0
Réponse de recherche	1	0	1
Diffusion d'édition	1	0	1
Diffusion de réponse	1	1	1
Edition en monodiffusion	0	0	1
NOTE D'autres valeurs de type de transport sont utilisées par d'autres services – voir Tableau 62 et Tableau 63.			

Sur le côté maître du tube de transport, la TLE doit incrémenter Sequence_number et copier ses cinq bits de poids faible dans le sous-champ TSEQN. Sur le côté esclave (récepteur) du tube de transport, la TLE doit copier les cinq bits de poids faible du Handle (descripteur), reçu dans la primitive de demande, dans le sous-champ TSEQN. La TLE doit transmettre la TPDU vers la NLE en utilisant la primitive de demande d'émission de NL. La valeur du paramètre Timetable_ID dans cette primitive de demande doit être utilisée dans la primitive de demande D'EMISSION DE NL.

6.7.4.2 Réception d'une primitive de demande d'échange de données de TL

6.7.4.2.1 Généralités

Si ce tube de transport attend un acquittement pour une TPDU précédente et qu'aucun autre tampon n'est disponible, le service échoue et la primitive de confirmation d'échange de données TL doit être retournée à l'utilisateur de TLS pour signaler l'erreur et la demande doit être rejetée.

Sinon, la TLE doit vérifier le paramètre "Type de transport" et coder l'octet de contrôle de transport comme présenté au Tableau 62. La valeur du paramètre Timetable_ID dans cette primitive de demande doit être utilisée dans la primitive de demande d'émission de NL.

Tableau 62 – Codage du contrôle de transport pour la demande d'échange de données TL

Type de transport	tbroad	tack	tresp
Demande en monodiffusion	0	1	0
Diffusion de demande	1	1	0
NOTE D'autres valeurs de type de transport sont utilisées par d'autres services – voir Tableau 61 et Tableau 63.			

6.7.4.2.2 Demande non acquittée

La demande ne nécessite pas une réponse de la destination. Par conséquent, le sous-champ tack du champ de contrôle de transport est mis à '0'. La TLE doit transmettre la TPDU vers la NLE en utilisant la primitive de demande d'émission de NL.

6.7.4.2.3 Demande acquittée

La demande exige une réponse de la destination. Par conséquent, le sous-champ tack du champ de contrôle de transport est mis à '1'. La TLE doit rechercher dans la Table des tubes de transport une entrée qui correspond à la primitive "service". Si une telle entrée n'existe pas, la TLE doit créer une entrée dans la Table des tubes de transport et mettre Sequence_number pour l'entrée en question à un nombre aléatoire.

Si un tube de transport est disponible et qu'il y a déjà une demande dans le tube de transport attendant un acquittement provenant de la TLE de destination et qu'aucun autre tampon n'est disponible, la demande échoue. La TLE doit transmettre la primitive de confirmation "confirmation d'échange de données de TL" à l'utilisateur de TLS avec statut d'erreur.

Si un tube de transport est disponible et qu'il n'y a aucune demande en instance dans ce tube de transport ou q'un tampon est disponible, alors Sequence_number issu de l'entrée de table doit être incrémenté et les cinq bits de poids faible doivent être copiés dans le sous-champ tseqn du champ "contrôle de transport". Dans l'entrée de tube de transport pour cette primitive "service", le fanion "Actif" doit être mis à vrai, Retry_count doit être remis à 0 et replyTimer (temporisateur de délai de réponse) doit être mis à Max_reply_time et lancé pour attendre la réponse.

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La TLE doit transmettre la TPDU vers la NLE en utilisant la primitive de demande d'émission de NL. La TPDU doit aussi être mise en tampon pour de possibles tentatives futures.

6.7.4.3 Réception d'une primitive de réponse d'échange de données de TL

La TLE doit scruter la Table des tubes de transport pour trouver l'entrée qui correspond à l'adresse du correspondant. Il peut y avoir deux entrées de cette nature pour chaque adresse de correspondant: de diffusion et de monodiffusion. La TLE doit utiliser le paramètre type de transport de la primitive pour trouver le tube de transport correct.

La TLE doit comparer le paramètre Handle (Sequence_number) contenu dans la primitive de réponse au Sequence_number contenu dans l'entrée de tube de transport. Si Sequence_number n'est pas supérieur à celui contenu dans l'entrée de tube de transport, le service échoue et la réponse doit être rejetée. La TLE ne doit pas transmettre de TPDU à la NLE.

Sinon, la TLE doit préparer la TPDU, actualiser Sequence_number dans l'entrée de tube de transport, coder l'octet de contrôle de transport comme présenté au Tableau 63. Si type de transport est Réponse en monodiffusion, la TPDU doit être immédiatement transmise à la NLE en utilisant la primitive de demande d'émission de NL. Sinon, type de transport est Diffusion de réponse; la TLE doit attendre une durée aléatoire entre zéro et la valeur de Bcast_reply_time (voir Tableau 60). Puis, à l'expiration de cette durée, la TLE doit transmettre la TPDU à la NLE en utilisant la primitive de demande d'émission de NL. La TLE doit aussi placer la TPDU dans un tampon en vue d'une éventuelle nouvelle tentative future.

Tableau 63 – Codage du contrôle de transport pour la réponse d'échange de données de TL

Type de transport	tbroad	tack	tresp
tresp	0	1	1
NOTE D'autres valeurs de type de transport sont utilisées par d'autres services – voir Tableau 61 et Tableau 62.			

6.7.4.4 Réception d'une primitive d'indication d'émission de NL

6.7.4.4.1 Généralités

Lorsque la TLE reçoit une primitive d'indication provenant de la NLE, elle doit examiner les sous-champs contrôle de transport tack et tresp, et l'utiliser pour traiter la TPDU reçue.

6.7.4.4.2 Transfert de données non acquitté

Si le sous-champ tack du contrôle de transport est faux, la TLE doit transmettre la TPDU reçue vers l'utilisateur de TLS dans la primitive d'indication de transfert de données de TL. Le sous-champ tseqn doit être transmis comme numéro de séquence.

6.7.4.4.3 Transfert de données d'indication acquitté

Si le sous-champ TACK de contrôle de transport est VRAI et TRESP est FAUX, la TLE doit valider le sous-champ TSEQN. La TLE doit scruter la Table des tubes de transport pour trouver l'entrée qui correspond à l'adresse du correspondant. Il peut y avoir deux entrées de cette nature pour chaque adresse de correspondant: de diffusion et de monodiffusion. La TLE doit utiliser le sous-champ tbroad de contrôle de transport pour trouver le tube de transport correct.

S'il n'y a pas une telle entrée dans la table des tubes de transport, la TLE doit créer une nouvelle entrée. La TLE doit mettre l'attribut "Actif" à vrai, le bit d'attribut "Maître" à faux et l'attribut Sequence_number à une unité de moins que le sous-champ tseqn contenu dans la

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TPDU reçue. La TLE doit transmettre la primitive d'indication d'échange de données de TL à l'utilisateur de TLS. Le type de transport et le numéro de séquence dans la primitive doivent être mis aux valeurs reçues dans le champ de contrôle de transport.

Si l'entrée existe dans la Table des tubes de transport, le sous-champ tseqn dans la TPDU reçue doit alors être comparé au Sequence_number dans cette entrée de la Table des tubes de transport. Si les deux sont identiques, la TPDU est un doublon et la TLDPU de réponse précédemment mise en tampon doit être transmise à la NLE dans la primitive de demande d'émission de NL. Sinon, si le sous-champ tseqn dans la TPDU reçue n'est pas supérieur d'une unité à celui contenu dans l'entrée de la Table des tubes de transport, la TPDU doit être rejetée.

Sinon, le sous-champ tseqn dans la TPDU reçue est supérieur d'une unité à celui contenu dans l'entrée de la Table des tubes de transport. La TLE doit transmettre les données utiles de TL reçues comme données utilisateur TLS dans la primitive d'indication d'échange de données de TL à l'utilisateur de TLS. Le type de transport et le numéro de séquence dans la primitive doivent être mis aux valeurs reçues dans le champ de contrôle de transport.

6.7.4.4.4 Transfert de données de réponse acquitté

Si le sous-champ tack de contrôle de transport est vrai et tresp est vrai, la TLE doit valider le sous-champ TSEQN. La TLE doit scruter la Table des tubes de transport pour trouver l'entrée qui correspond à l'adresse du correspondant. Il peut y avoir deux entrées de cette nature pour chaque adresse de correspondant: de diffusion et de monodiffusion. La TLE doit utiliser le sous-champ tbroad de contrôle de transport pour trouver le tube de transport correct.

S'il n'y a pas une telle entrée dans la Table des tubes de transport, la TLE doit rejeter la TPDU reçue.

Si l'entrée existe dans la Table des tubes de transport, le sous-champ tseqn dans la TPDU reçue doit alors être comparé au Sequence_number dans cette entrée de la Table des tubes de transport. Si les deux sont identiques, la TPDU est une réponse à une demande envoyée précédemment. La TLE doit mettre l'attribut "Actif" de l'entrée en question à faux, désactiver replyTimer (temporisateur de délai de réponse) et supprimer le tampon qui avait été utilisé pour stocker la TPDU pour la demande. La TLE doit transmettre les données utiles de TL reçues comme données utilisateur TLS dans la primitive de confirmation d'échange de données TL à l'utilisateur de TLS. Le Handle dans la primitive doit être mis aux valeurs reçues dans la primitive d'indication correspondante.

6.7.4.5 Réception d'une primitive de confirmation d'émission de NL

Si la demande d'émission de NL correspondante résulte de la demande de transfert de données de TL, la TLE doit transmettre la primitive de confirmation de transfert de données de TL à l'utilisateur de TLE. Si la demande d'émission de NL correspondante résulte de la demande d'échange de données TL, avec une valeur de type de transport égale à Diffusion de demande, la TLE doit transmettre la primitive de confirmation d'échange de données TL à l'utilisateur de TLE.

6.7.4.6 Expiration du délai replyTimer

Si replyTimer (temporisateur de délai de réponse) expire, cela indique la perte de la TPDU de demande ou de la TPDU de réponse correspondante. Si Retry_count n'est pas égal à Max_retries, la TLE doit envoyer la TPDU de demande et incrémenter Retry_count. Sinon, Retry_count est à sa valeur maximale, la demande a échoué et la TLE doit mettre l'attribut "Actif" de l'entrée en question à Faux, désactiver replyTimer et supprimer le tampon qui avait été utilisé pour stocker la TPDU pour la demande. La TLE doit transmettre la primitive de confirmation d'échange de données TL à l'utilisateur de TLS avec statut d'erreur. Le Handle dans la primitive doit être mis à la valeur reçue dans la primitive de demande correspondante.

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Si la demande a échoué, la TLE doit construire une réponse d'alarme de couche transport défaillante et l'envoyer au gestionnaire de réseau. À la réception de l'avis de défaillance de la couche de transport, le gestionnaire de réseau doit supprimer et rétablir la session correspondante. Si cela n'est pas possible, le gestionnaire de réseau doit forcer l'appareil à se rattacher de nouveau au réseau.

6.7.5 Diagrammes d'états de TLE

6.7.5.1 Diagramme d'états de transfert de données client

Les états sont illustrés à la Figure 37 et le diagramme d'états complet est décrit au Tableau 64.

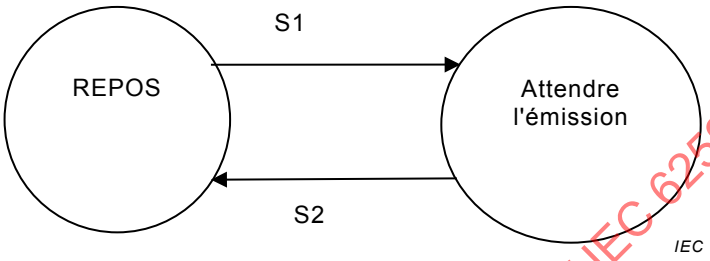

Figure 37 – Diagramme de transition d'états de transfert de données client

Tableau 64 – Table d'états de transfert de données client

#	Etat courant	Evénement ou condition => action	Etat suivant
S1	REPOS	TL-DATA-TRANSFER.request = NL-TRANSMIT.request { destination address:= TL-DATA-TRANSFER.request.destination address, priority:= TL-DATA-TRANSFER.request.priority, Timetable_ID:= TL-DATA-TRANSFER.request.Timetable_ID, NLS-user-data:= TLPDU } (voir 6.7.4.1)	Attendre l'émission
S2	Attendre l'émission	NL-TRANSMIT.confirm = TL-DATA-TRANSFER.confirm { Status:= status } (voir 6.7.4.5)	REPOS

6.7.5.2 Diagramme d'états d'échange de données client

Les états sont illustrés à la Figure 38 et le diagramme d'états complet est décrit au Tableau 65.

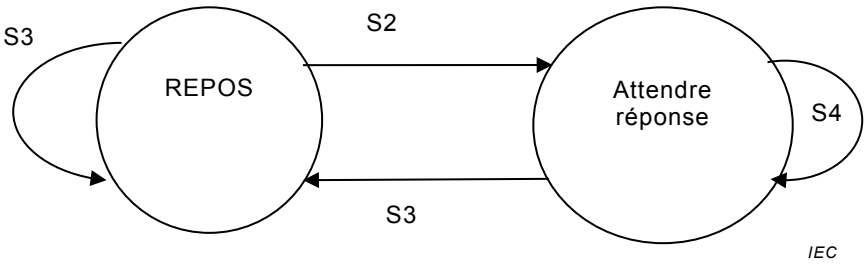

Figure 38 – Diagramme de transition d'états d'échange de données client

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Tableau 65 – Table d'états d'échange de données client

#	Etat courant	Evénement ou condition => action	Etat suivant

S1	REPOS	TLDataExchange.request && en attente d'acquittement pour une TPDU précédente
		=
		TL-DATA-TRANSFER.confirm {
		Statut:= échec
		}
			REPOS

S2	REPOS	TLDATA Exchange.request&& !en attente d'acquittement pour une TPDU précédente = Retry_count:=0, replyTimer:= Max_reply_time, NL-TRANSMIT.request { destination address:= TL-DATA-TRANSFER.request.destination address, priority:= TL-DATA-TRANSFER.request.priority, Timetable_ID:= TL-DATA-TRANSFER.request.Timetable_ID, NLS-user-data:= TLPDU } (voir 6.7.4.2)	Attendre réponse
S3	Attendre réponse	NLTRANSMIT.confirm && type de transport correspondant == Diffusion de demande = TL-DATA- EXCHANGE.confirm { Status:= status } (voir 6.7.4.5)	REPOS
S3	Attendre réponse	NL-TRANSMIT.indication && TLPDU.tack == vrai && TLPDU. tresp == vrai && l'entrée dans la Table des tubes de transport existe && TLPDU. tseqn == Sequence_number dans l'entrée dans la Table des tubes de transport = Désactiver replyTimer, Supprimer le tampon utilisé pour stocker la TPDU de la demande, TL-DATA- EXCHANGE.confirm { Données utilisateur TLS:= Données utiles de TLPDU, Status:= status } (voir 6.7.4.4.4)	REPOS
S4	Attendre réponse	replyTimer expire && Retry_count!= Max_retries = Incrémenter retry_count, NL-TRANSMIT.request { destination address:= TL-DATA-TRANSFER.request.destination address, priority:= TL-DATA-TRANSFER.request.priority, Timetable_ID:= TL-DATA-TRANSFER.request.Timetable_ID, NLS-user-data:= TLPDU } (voir 6.7.4.6)	Attendre réponse
S3	Attendre réponse	replyTimer expire && Retry_count == Max_retries = TL-DATA-TRANSFER.confirm { Statut:= échec } (voir 6.7.4.6)	REPOS

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6.7.5.3 Diagramme d'états de serveur

Les états sont illustrés à la Figure 39 et le diagramme d'états complet est décrit au Tableau 66.

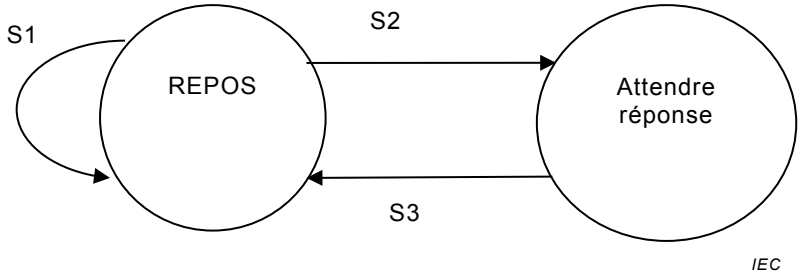

Figure 39 – Diagramme de transition d'états du serveur

Tableau 66 – Table d'états serveur

#	Etat courant	Evénement ou condition => action	Etat suivant
S1	REPOS	TL-DATA-TRANSFER.request => NL-TRANSMIT.request { destination address:= TL-DATA-TRANSFER.request.destination address, priority:= TL-DATA-TRANSFER.request.priority, Timetable_ID:= TL-DATA-TRANSFER.request.Timetable_ID, NLS-user-data:= TLPDU } (voir 6.7.4.1)	REPOS
S1	REPOS	NL-TRANSMIT.indication && TLPDU.tack == false => TL-DATA-TRANSFER.indication { adresse source:= NL-TRANSMIT.indication.source address, Transport-type:= TLPDU.transport-type, priority:= TLPDU priority, Données utilisateur TLS:= Données utiles de TLPDU } (voir 6.7.4.4.2)	REPOS
S1	REPOS	NL-TRANSMIT.indication && TLPDU.tack == vrai && TLPDU. tresp == faux && TLPDU. tseqn == sequence_number dans l'entrée de la Table des tubes de transport (indication double, voir 6.7.4.4.3) => NL-TRANSMIT.request { adresse de destination:= adresse de destination précédemment mise en tampon, priorité:= priorité précédemment mise en tampon, Timetable_ID:= Timetable_ID précédemment mis en tampon, Données utilisateur NLS:= TLPDU précédemment mise en tampon } (voir 6.7.4.4.3)	REPOS
S2	REPOS	NL-TRANSMIT.indication && TLPDU.tack == vrai && TLPDU. tresp == faux && TLPDU. tresp == faux && l'entrée dans la Table des tubes de transport n'existe pas => Créer entrée de Table des tubes de transport, Sequence_number dans l'entrée de la Table des tubes de transport = TLPDU. tseqn -1 TL-DATA- exchange.indication { adresse source:= NL-TRANSMIT.indication.source address, numéro de séquence:= TLPDU. tseqn, Transport-type:= TLPDU.transport-type, priority:= TLPDU priority, Données utilisateur TLS:= Données utiles de TLPDU } (voir 6.7.4.4.3)	Attendre réponse
S2	REPOS	NL-TRANSMIT.indication && TLPDU.tack == vrai && TLPDU. tresp == faux && l'entrée dans la Table des tubes de transport existe && TLPDU. tseqn == Sequence_number dans l'entrée dans la Table des tubes de transport + 1 => TL-DATA- exchange.indication { adresse source:= NL-TRANSMIT.indication.source address, numéro de séquence:= TLPDU. tseqn, Transport-type:= TLPDU.transport-type, priority:= TLPDU priority, Données utilisateur TLS:= Données utiles de TLPDU } (voir 6.7.4.4.3)	Attendre réponse

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#	Etat courant	Evénement ou condition => action	Etat suivant
S3	Attendre réponse	TL-DATA EXCHANGE.response && l'entrée dans la Table des tubes de transport existe && Sequence_number dans l'entrée de la Table des tubes de transport== numéro de séquence de réponse1 => Incrémenter Sequence_number dans l'entrée de la Table des tubes de transport, NL-TRANSMIT.request { adresse de destination:= TLDATA Exchange.response.destination address (adresse de destination de réponse d'échange de données de TL), priorité:= TLDATA Exchange.response.priority, Timetable_ID:= TLDATA Exchange.response.Timetable_ID, données utilisateur NLS:= TLPDU } (voir 6.7.4.3), TLPDU en tampon et NL-TRANSMIT.request parameters (.request parameters (paramètres de demande d'émission de NL)	REPOS

6.7.6 Informations de gestion de TL

Plusieurs attributs de TL doivent être configurés avant qu'une TLE ne puisse fonctionner correctement. Ces attributs sont définis au Tableau 60.

7 Définition des services de la couche application – Eléments de Type 20

7.1 Concepts communs

7.2 Généralités

Le présent document définit le service de Couche Application sans fil de Type 20 en complément du service de Couche Application câblée de Type 20 spécifiée dans l'IEC 61158-5-20.

Les concepts et modèles communs utilisés pour décrire le service de couche application de la présente norme sont détaillés à l'Article 9 de l'IEC 61158-1:2014.

7.3 ASE de Type de données

7.3.1 Vue d'ensemble

7.3.1.1 Généralités

Les types de données de bus de terrain spécifient la syntaxe indépendante de toute machine pour les données d'application acheminées par les services FAL. La couche application de bus de terrain prend en charge la définition et le transfert des types de données, qu'il s'agisse de types de données de base ou construits. Les règles de codage pour les types de données spécifiés dans le présent article sont fournies à l'Article 8.

Les types de base sont des types atomiques qui ne peuvent pas être décomposés en plus de types élémentaires. Les types construits sont des types composés de types de bases et d'autres types construits. Leur complexité et leur profondeur d'imbrication ne sont pas contraintes par la présente norme.

Les types de données sont définis comme des instances de la classe de types de données, comme illustré à la Figure 40.

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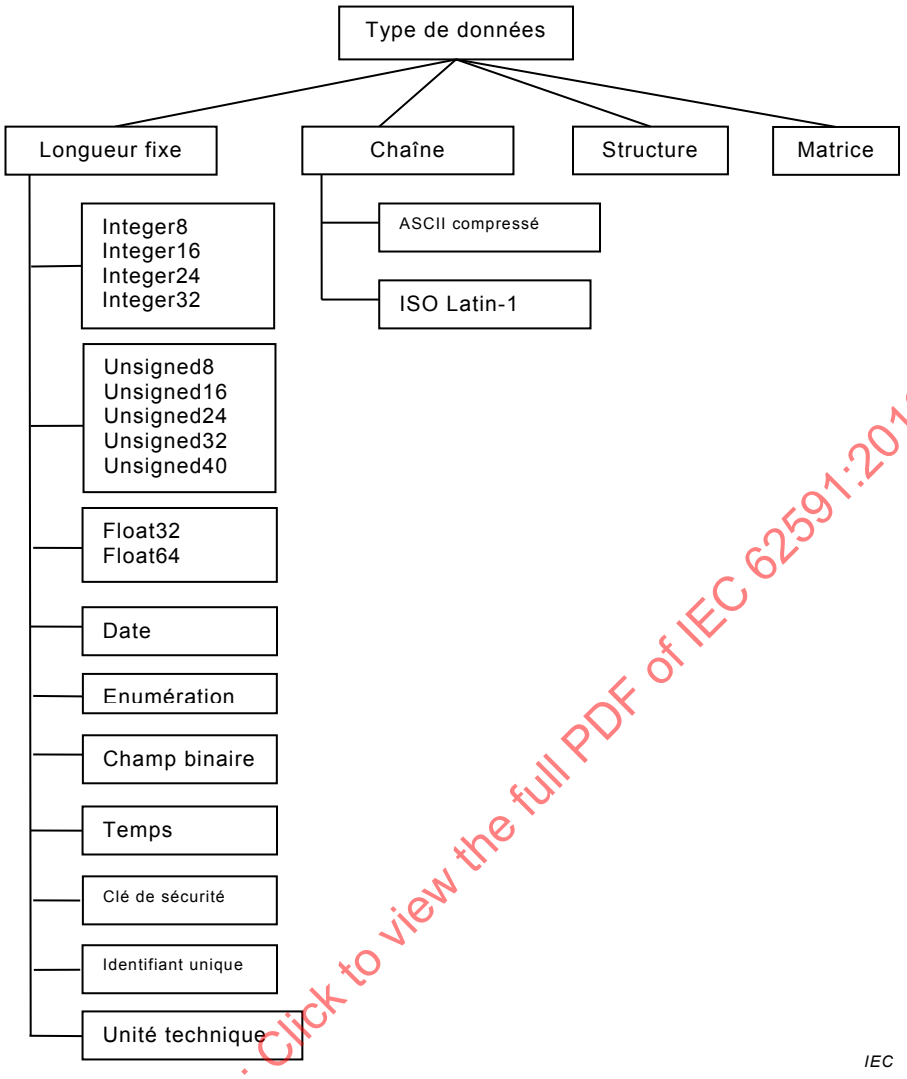

Figure 40 – Hiérarchie de la classe de types de données

Les définitions des types de données sont représentées sous la forme d'une structure classe/format/instance commençant par la classe de types de données intitulée "Type de données". Les formats pour les types de données sont définis par la classe de types de données.

Les classes de données de base sont utilisées pour définir des types de données de longueur fixe. Les types normalisés extraits de l'ISO/IEC 8824 sont appelés types de données simples. Les autres types de données de base normalisés sont définis spécifiquement pour les applications de bus de terrain et sont appelés types spécifiques.

Les types construits spécifiés dans la présente norme sont des chaînes, des matrices et des structures.

7.3.1.2 Vue d'ensemble des types de base

La plupart des types de base sont définis à partir d'un ensemble de types de l'ISO/IEC 8824 (types simples). Certains types de l'ISO/IEC 8824 ont été étendus pour une utilisation spécifique sur bus de terrain (types spécifiques).

Les types simples sont des types universels de l'ISO/IEC 8824. Ils sont définis dans la présente norme pour leur fournir des identificateurs de classe de Bus de terrain.

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Les types spécifiques sont des types de base définis spécifiquement pour utilisation dans l'environnement de bus de terrain. Ils sont définis comme des sous-types de classe simples.

Les types de base ont une longueur constante. Deux variantes sont définies, l'une pour définir les types de données dont la longueur est un nombre entier d'octets et l'autre pour définir les types de données dont la longueur est exprimée en bits.

NOTE Entier, ASCII compressé, ISO Latin-1 et Date sont définis dans la présente norme dans le but de leur attribuer des identifiants de classes de bus de terrain. La présente norme ne change pas leurs définitions telles que spécifiées dans l'ISO/IEC 8824.

7.3.1.3 Types de longueur fixe

La longueur des types de longueur fixe est un nombre entier d'octets.

7.3.1.4 Types construits

7.3.1.4.1 Vue d'ensemble

Les types de données construits sont nécessaires pour transmettre complètement la diversité des informations présentes sur le bus de terrain. Les types construits définis pour la présente norme sont de trois sortes: chaîne, matrice et structure.

7.3.1.4.2 String

Une chaîne est composée d'un ensemble ordonné d'un nombre variable d'éléments de longueur fixe typés de façon homogène.

7.3.1.4.3 Structure

Une structure est constituée d'un ensemble ordonné d'éléments typés de façon hétérogène appelés champs. La présente norme ne limite pas le type de données des champs. Cependant, les champs dans une structure peuvent ne pas être du même type.

7.3.1.4.4 Matrice

Une matrice est composée d'un jeu ordonné d'éléments typés de façon homogène. Le type de données des éléments d'une matrice peut être un type de base ou une structure de longueur fixe. Tous les éléments d'une matrice doivent être du même type.

7.3.1.4.5 Niveau d'imbrication

La présente norme permet aux structures et aux matrices de contenir des structures et des matrices.

7.3.1.5 Spécification des types de données définis par l'utilisateur

Les types définis par l'utilisateur ne sont pas pris en charge par la présente norme.

7.3.1.6 Transfert de données utilisateur

Les données utilisateur sont transférées entre applications par le protocole FAL. Tout le codage et le décodage sont accomplis par l'utilisateur de la FAL.

Les règles de codage des données utilisateur en unités de données du protocole FAL dépendent du type de données. Ces règles sont définies dans l'IEC 61158-6-20.

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7.3.2 Définition formelle des objets de types de données

7.3.2.1 Classe de types de données

La classe de types de données spécifie la racine de l'arbre de la classe des types de données. Sa classe parent "supérieure" indique le sommet de l'arbre de la classe FAL.

ASE de FAL: ASE de Type de données

CLASSE:		Type de données
ID de CLASSE:		Non utilisé
CLASSE PARENT:		Supérieure
ATTRIBUTS:		
(m)	Attribut-clé:	Nom de type de données
(m)	Attribut:	Format (LONGUEUR FIXE, CHAÎNE, STRUCTURE, MATRICE)
(c)	Contrainte:	Format = LONGUEUR FIXE | CHAÎNE
(m)	Attribut:	Longueur en octets
(c)	Contrainte:	Format = STRUCTURE
(m)	Attribut:	Nombre de champs
(m)	Attribut:	Liste de champs
(m)	Attribut:	Nom de champ
(m)	Attribut:	Type de données de champ
(c)	Contrainte:	Format = MATRICE
(m)	Attribut:	Nombre d'éléments de matrice
(m)	Attribut:	Type de données d'élément de matrice

7.3.2.2 Attributs

Format

Cet attribut identifie le type de données comme étant de longueur fixe, sous forme de chaîne, de structure ou de matrice.

Longueur en octets

Cet attribut conditionnel définit la représentation des dimensions de l'objet de type associé. Il est présent lorsque la valeur de l'attribut format est "LONGUEUR FIXE" ou "CHAÎNE". Pour les types de données LONGUEUR FIXE, il représente la longueur en octets. Pour les types de données CHAÎNE, il représente la longueur en octets pour un élément simple d'une chaîne.

Nombre de champs

Cet attribut conditionnel définit le nombre de champs dans une structure. Il est présent lorsque la valeur de l'attribut format est "STRUCTURE".

Liste de champs

Cet attribut conditionnel est une liste ordonnée de champs contenus dans la structure. Chaque champ est spécifié par son type. Les champs sont décrits dans l'ordre de leur apparition. L'accès partiel à des champs dans une structure n'est pas pris en charge.

Nom de champ

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Cet attribut conditionnel spécifie le nom du champ. Il est présent lorsque la valeur de l'attribut format est "STRUCTURE".

Type de données de champ

Cet attribut conditionnel spécifie le type de données du champ. Il est présent lorsque la valeur de l'attribut format est "STRUCTURE". Cet attribut peut lui-même spécifier un type de données construit en le référençant et en y intégrant sa définition.

Nombre d'éléments de matrice

Cet attribut conditionnel définit le nombre d'éléments de type matrice. Cet attribut est présent lorsque la valeur de l'attribut format est "MATRICE".

Type de données d'élément de matrice

Cet attribut conditionnel spécifie le type de données pour les éléments d'une matrice. Tous les éléments de la matrice ont le même type de données. Il est présent lorsque la valeur de l'attribut format est "MATRICE". Cet attribut peut lui-même spécifier un type de données construit en référençant sa définition par son identifiant numérique.

7.3.3 Types de données définis pour la FAL

7.3.3.1 Types de longueur fixe

7.3.3.1.1 Integer8

CLASSE:		**Type de données**
ATTRIBUTS:		
1	Nom de type de données	= Integer8
2	Format	= FIXED LENGTH
2.1	Longueur en octets	= 1

Ce type d'entier est un nombre binaire en complément à deux avec une longueur égale à un octet.

7.3.3.1.2 Integer16

CLASSE:		**Type de données**
ATTRIBUTS:		
1	Nom de type de données	= Integer16
2	Format	= FIXED LENGTH
2.1	Longueur en octets	= 2

Ce type d'entier est un nombre binaire en complément à deux avec une longueur égale à deux octets.

7.3.3.1.3 Integer24

CLASSE:		**Type de données**
ATTRIBUTS:		
1	Nom de type de données	= Integer24
2	Format	= FIXED LENGTH
2.1	Longueur en octets	= 3

Ce type d'entier est un nombre binaire en complément à deux avec une longueur égale à trois octets.

7.3.3.1.4 Integer32

CLASSE:		**Type de données**
ATTRIBUTS:		
1	Nom de type de données	= Integer32
2	Format	= FIXED LENGTH

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2.1 Longueur en octets = 4

Ce type d'entier est un nombre binaire en complément à deux avec une longueur égale à quatre octets.

7.3.3.1.5 Unsigned8

CLASSE: **Type de données**

ATTRIBUTS:

1 Nom de type de données = Unsigned8

2 Format = FIXED LENGTH

2.1 Longueur en octets = 1

Ce type est un nombre entier. Le bit de poids fort de l'octet de poids fort est toujours utilisé comme le bit de poids fort du nombre binaire; aucun bit de signe n'est inclus. Ce type a une longueur égale à un octet.

7.3.3.1.6 Unsigned16

CLASSE: **Type de données**

ATTRIBUTS:

1 Nom de type de données = Unsigned16

2 Format = FIXED LENGTH

2.1 Longueur en octets = 2

Ce type est un nombre entier. Le bit de poids fort de l'octet de poids fort est toujours utilisé comme le bit de poids fort du nombre binaire; aucun bit de signe n'est inclus. Ce type non signé a une longueur de deux octets.

7.3.3.1.7 Unsigned24

CLASSE: **Type de données**

ATTRIBUTS:

1 Nom de type de données = Unsigned24

2 Format = FIXED LENGTH

2.1 Longueur en octets = 3

Ce type est un nombre entier. Le bit de poids fort de l'octet de poids fort est toujours utilisé comme le bit de poids fort du nombre binaire; aucun bit de signe n'est inclus. Ce type non signé a une longueur de trois octets.

7.3.3.1.8 Unsigned32

CLASSE: **Type de données**

ATTRIBUTS:

1 Nom de type de données = Unsigned32

2 Format = FIXED LENGTH

2.1 Longueur en octets = 4

Ce type est un nombre entier. Le bit de poids fort de l'octet de poids fort est toujours utilisé comme le bit de poids fort du nombre binaire; aucun bit de signe n'est inclus. Ce type non signé a une longueur de quatre octets.

7.3.3.1.9 Unsigned40

CLASSE: **Type de données**

ATTRIBUTS:

1 Nom de type de données = Unsigned40

2 Format = FIXED LENGTH

2.1 Longueur en octets = 5

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Ce type est un nombre entier. Le bit de poids fort de l'octet de poids fort est toujours utilisé comme le bit de poids fort du nombre binaire; aucun bit de signe n'est inclus. Ce type non signé a une longueur de cinq octets.

7.3.3.1.10 Float32

CLASSE:		**Type de données**
ATTRIBUTS:		
1	Nom de type de données	= Float32
2	Format	= FIXED LENGTH
2.1	Longueur en octets	= 4

Ce type a une longueur de quatre octets. Le format pour Float32 est celui défini par IEEE 754 comme un format à simple précision.

7.3.3.1.11 Float64

CLASSE:		**Type de données**
ATTRIBUTS:		
1	Nom de type de données	= Float64
2	Format	= FIXED LENGTH
2.1	Longueur en octets	= 8

Ce type a une longueur de huit octets. Le format pour Float64 est celui défini par IEEE 754 comme double précision.

7.3.3.1.12 Date

CLASSE:		**Type de données**
ATTRIBUTS:		
1	Nom de type de données	= Date
2	Format	= FIXED LENGTH
2.1	Longueur en octets	= 3

Ce type de données est constitué du jour, du mois et de l'année moins 1900. Cela permet la représentation de n'importe quelle date entre le 1er janvier 1900 et le 31 décembre 2155.

7.3.3.1.13 Enumération

CLASSE:		**Type de données**
ATTRIBUTS:		
1	Nom de type de données	= Enumération
2	Format	= FIXED LENGTH
2.1	Longueur en octets	= 1

Les éléments de données qui ont une seule signification dans une liste ou dans une table sont codés comme Enumération. Ce type de données utilise l'entier non signé d'une longueur égale à un octet. La valeur entière la plus grande est réservée et n'est utilisée par aucun service.

7.3.3.1.14 Champ binaire

CLASSE:		**Type de données**
ATTRIBUTS:		
1	Nom de type de données	= Champ binaire
2	Format	= FIXED LENGTH
2.1	Longueur en octets	= 1 ou 2

Ce type de données est une série de huit bits numérotés de 0 à 7 ou de seize bits numérotés de 0 à 15. La communication d'informations codées sous forme de données d'un seul bit (telles que les informations relatives au statut et au diagnostic) utilise ce type de données.

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7.3.3.1.15 Temps

CLASSE: **Type de données**

ATTRIBUTS:

1	Nom de type de données	= Temps
2	Format	= FIXED LENGTH
2.1	Longueur en octets	= 4

Ce type de données est un entier binaire non signé et représente le temps par incréments de 1/32ème de millisecondes. Si ce type de données est utilisé pour représenter l'heure du jour, il indique le nombre de 1/32ème de millisecondes écoulées depuis minuit.

7.3.3.1.16 Clé de sécurité

CLASSE: **Type de données**

ATTRIBUTS:

1	Nom de type de données	= Clé de sécurité
2	Format	= FIXED LENGTH
2.1	Longueur en octets	= 16

Ce type est une chaîne de seize octets. Chaque octet peut avoir n'importe quelle valeur de 0 à 255. L'interprétation de ce type de données dépend de l'application.

7.3.3.1.17 Identifiant unique

CLASSE: **Type de données**

ATTRIBUTS:

1	Nom de type de données	= Identifiant unique
2	Format	= FIXED LENGTH
2.1	Longueur en octets	= 5

Ce type est une chaîne de cinq octets. Chaque octet peut avoir n'importe quelle valeur de 0 à 255. L'interprétation de ce type de données dépend de l'application.

7.3.3.1.18 Unité technique

CLASSE: **Type de données**

ATTRIBUTS:

1	Nom de type de données	= Unité technique
2	Format	= FIXED LENGTH
2.1	Longueur en octets	= 1

Ce type définit l'unité de mesure d'une variable mesurée. L'interprétation de ce type de données est spécifiée par le profil de communication (voir 9.3.1) et ne relève pas du domaine d'application de la présente norme.

7.3.3.2 Types de chaîne

7.3.3.2.1 ASCII compressé

CLASSE: **Type de données**

ATTRIBUTS:

1	Nom de type de données	= ASCII compressé
2	Format	= STRING
2.1	Longueur d'octet	= 1 à n

Ce type est un sous-ensemble modifié du jeu de caractères ASCII. Ce sous-ensemble est présenté en Tableau 379. Il est produit par la compression de quatre caractères ASCII compressés en trois octets de 8 bits.

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7.3.3.2.2 ISO Latin-1

CLASSE: **Type de données**

ATTRIBUTS:

1	Nom de type de données	= Latin-1
2	Format	= STRING
2.1	Longueur d'octet	= 1 à n

Ce type est un sous-ensemble du type de chaîne de caractères de l'ISO 8859-1 (ISO Latin-1). Ce sous-ensemble est présenté en Tableau 380.

7.3.4 Spécification du Service ASE de type de données

Il n'y a pas de services opérationnels définis pour l'objet type de données.

7.3.5 Résumé des types de données

Le présent article contient un résumé des types de données définis comme présenté au Tableau 67.

Tableau 67 – Résumé des types de données

Type de données	Paragraphe
Integer8	7.3.3.1.1
Integer16	7.3.3.1.2
Integer24	7.3.3.1.3
Integer32	7.3.3.1.4
Unsigned8	7.3.3.1.5
Unsigned16	7.3.3.1.6
Unsigned24	7.3.3.1.7
Unsigned32	7.3.3.1.8
Unsigned40	7.3.3.1.9
Float32	7.3.3.1.10
Float64	7.3.3.1.11
Date	7.3.3.1.12
Enumération	7.3.3.1.13
Champ binaire	7.3.3.1.14
Temps	7.3.3.1.15
Clé de sécurité	7.3.3.1.16
Identifiant unique	7.3.3.1.17
Unité technique	7.3.3.1.18
ASCII compressé	7.3.3.2.1
ISO Latin-1	7.3.3.2.2

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7.4 Spécification de modèle de communication

7.4.1 Paramètres communs

7.4.1.1 Généralités

De nombreux services disposent des paramètres spécifiés en 7.4.1.2 à 7.4.1.5. Au lieu de les définir avec chaque service, les définitions communes sont données en 7.4.1.

7.4.1.2 ID d'AREP

Ce paramètre spécifie des informations suffisantes pour identifier l'AREP de l'extrémité distante de l'AR. La valeur de ce paramètre peut être l'identifiant unique de l'extrémité distante. Une valeur de ce paramètre est réservée comme adresse de diffusion.

7.4.1.3 Code de réponse

En l'absence d'erreur de communication, ce paramètre spécifie un report d'achèvement de commande indiquant le statut de l'exécution de la commande par l'appareil. Les valeurs possibles de ce paramètre sont indiquées au Tableau 68. Son type de données est Enumération.

Tableau 68 – Valeurs du code de réponse

Valeur	Description
Succès	La commande (Lireou Ecrire) a été exécutée correctement.
Avertissement	La commande (Lire) a été exécutée avec l'écart décrit dans la réponse (par exemple, une valeur a été mise à sa valeur licite la plus proche).
Erreur	La commande (Lire ou Ecrire) n'a pas été exécutée correctement. Le code de réponse en indique la raison (par exemple, l'appareil est protégé en écriture).

7.4.1.4 Statut de processus d'application

Ce paramètre indique le statut fourni par l'utilisateur de la FAL et n'est associé à l'achèvement d'aucune commande. Sa longueur est d'un octet.

7.4.1.5 Statut étendu

Ce paramètre indique le statut du VFD. Il n'est associé à l'achèvement d'aucune commande. Sa longueur est d'un octet.

7.4.2 ASE

7.4.2.1 ASE d'appareil de terrain virtuel

L'ASE d'un appareil de terrain virtuel (VFD) doit être conforme à l'IEC 61158-5-20: 2014, 6.2.1.

7.4.2.2 ASE de Variable

7.4.2.2.1 Vue d'ensemble

L'ASE de variable fournit des services permettant de lire ou écrire un objet Variable dans l'appareil serveur. La variable est identifiée par un numéro. Cet identifiant numérique décrit de manière exhaustive le type de données et la structure de l'objet. Cet objet peut être de n'importe lequel des types définis en 7.3.3.

7.4.2.2.2 Modèle de variable – commun

7.4.2.2.2.1 Variable simple

####### 7.4.2.2.2.1.1 Modèle formel

L'objet variable simple représente une variable simple unique qui est caractérisée par un Type de données défini.

ASE: **ASE de VARIABLE**
CLASSE: **Variable simple**
CLASSE PARENT: **Supérieure**

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ATTRIBUTS:

1	(m)	Key Attribute:	Identifiant numérique
2	(o)	Attribut:	Nom de variable
3	(m)	Attribut:	Nom de type de données

SERVICES:

1	(m)	OpsService:	Read (Lecture)
2	(o)	OpsService:	Ecrire
3	(o)	OpsService:	Rapport d'informations

7.4.2.2.2.1.2 Attributs

Identifiant numérique

Identifie une instance de cette classe d'objets.

Nom de variable

Il s'agit du nom attribué à l'objet.

Nom de type de données

Il s'agit du nom attribué au type de données tel que spécifié en 7.3.3.1.

7.4.2.2.2.1.3 Services

Read (Lecture)

Ce service confirmé permet à un client de lire la valeur d'une variable.

Ecrire

Ce service confirmé permet à un client d'écrire la valeur d'une variable.

Rapport d'informations

Ce service non confirmé permet à un serveur d'envoyer la valeur d'une variable vers n'importe lequel ou l'ensemble des clients.

7.4.2.2.2.2 Variable de structure

7.4.2.2.2.2.1 Généralités

L'objet enregistrement consiste en un ensemble de variables simples ou en une matrice de variables de structure de différents types de données. L'objet enregistrement est accessible dans son ensemble et ses champs individuels ne sont pas accessibles séparément.

ASE:			**ASE de VARIABLE**
CLASSE:			**VARIABLE de structure**
CLASSE PARENT:			**Supérieure**

ATTRIBUTS:

1	(m)	Key Attribute:	Identifiant numérique
2	(o)	Attribut:	Nom de variable
3	(m)	Attribut:	Nombre de champs
4	(m)	Attribut:	Liste de champs
4,1	(o)	Attribut:	Nom de champ
4,2	(m)	Attribut:	Nom de type de données de champ

SERVICES:

1	(m)	OpsService:	Read (Lecture)
2	(o)	OpsService:	Ecrire
3	(o)	OpsService:	Rapport d'informations

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7.4.2.2.2.2 Attributs

Identifiant numérique

Identifie une instance de cette classe d'objets.

Nom de variable

Il s'agit du nom attribué à l'objet.

Nombre de champs

Cet attribut définit le nombre de champs dans une structure.

Nom de champ

Cet attribut facultatif spécifie le nom du champ.

Nom de type de données de champ

Il s'agit du nom attribué au type de données tel que spécifié en 7.3.3.1.

7.4.2.2.2.3 Services

Read (Lecture)

Ce service confirmé permet à un client de lire la valeur d'une variable.

Ecrire

Ce service confirmé permet à un client de lire la valeur d'une variable.

Rapport d'informations

Ce service non confirmé permet à un serveur d'envoyer la valeur d'une variable vers n'importe lequel ou l'ensemble des clients.

7.4.2.2.3 Matrice de variable simple

7.4.2.2.3.1 Modèle formel

Cet objet Matrice est utilisé pour définir une variable construite dans laquelle tous les éléments sont de type de données et de longueur identiques et de la classe Variable Simple. Il est possible d'accéder à un ou à plusieurs objets de ce type à la fois en spécifiant le sous-indice de départ et le nombre d'éléments auxquels accéder.

ASE:			**ASE de VARIABLE**
CLASSE:			**Matrice de variable simple**
CLASSE PARENT:			**Variable simple**
ATTRIBUTS:			
ATTRIBUTS:			
1	(m)	Attribut:	Taille de matrice

7.4.2.2.3.2 Attributs

Taille de matrice

Cet attribut énonce le nombre d'éléments contenus dans la matrice. Si sa valeur est "Variable", le nombre d'éléments n'est pas fixe.

7.4.2.2.4 Matrice de variable de structure

7.4.2.2.4.1 Modèle formel

Cet objet Matrice est utilisé pour définir une variable construite dans laquelle tous les éléments sont de type de données et de longueur identiques et de la classe Variable de structure. Il est possible d'accéder à un ou à plusieurs objets de ce type à la fois en spécifiant le sous-indice de départ et le nombre d'éléments auxquels accéder.

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ASE:	**ASE de VARIABLE**
CLASSE:	**Matrice de VARIABLE de structure**
CLASSE PARENT:	**Variable de structure**
ATTRIBUTS:	
ATTRIBUTS:	

1 (m) Attribut: Taille de matrice

7.4.2.2.2.4.2 Attributs

Taille de matrice

Cet attribut énonce le nombre d'éléments contenus dans la matrice. Si sa valeur est "Variable", le nombre d'éléments n'est pas fixe.

7.4.2.2.3 Spécification de services ASE de variable

7.4.2.2.3.1 Services pris en charge

Ce paragraphe comporte la définition des services uniques à cet ASE. Les services définis pour cet ASE sont:

– Lire la variable dans l'appareil serveur,
– Ecrire la variable dans l'appareil serveur, et
– Envoyer un rapport d'informations à partir d'un appareil serveur.

Il y a des services séparés pour chaque variable, comme identifié par un nombre. Le format commun du service Lire est défini en 7.4.2.2.3.3. Le format commun du service Ecrire est défini en 7.4.2.2.3.4. Le format commun du service de rapport d'informations est défini en 7.4.2.2.3.5.

Pour chaque variable, il y a un service de lecture et un service d'écriture distincts. Ces services sont définis en 7.4.2.4, 7.4.2.5, 7.4.2.6 et 7.4.2.7.

NOTE Les définitions des services dans le présent paragraphe ne sont pas indépendantes de la variable à laquelle on accède. Le présent paragraphe montre seulement le format du service. Les définitions spécifiques de services incluent le modèle de variable et les paramètres spécifiques aux services.

7.4.2.2.3.2 Corrélation de primitives

Au niveau du client, il n'y a qu'une seule demande en cours pour une valeur de l'identifiant d'AREP. L'ID d'AREP est acheminé comme adresse de destination dans les primitives "service" de la couche transport. Par conséquent, la primitive de confirmation est corrélée à la primitive de demande en utilisant l'identifiant d'AREP. Au niveau du serveur, il n'y a qu'une seule primitive d'indication en cours à un instant donné. Par conséquent, la primitive de réponse est corrélée à la primitive d'indication attendant la réponse.

7.4.2.2.3.3 Service "Lire" – format commun

7.4.2.2.3.3.1 Aperçu du service

Ce service permet à un client de lire la valeur d'une variable sur le serveur.

7.4.2.2.3.3.2 Primitives de service

Les paramètres de service correspondants sont présentés au Tableau 69.

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Tableau 69 – Paramètres du service "Lire"

Nom de paramètre	Req	Ind	Rsp	Cnf
Argument				
ID d'AREP	M	M (=)		
Identifiant numérique	M	M (=)	M (=)	M (=)
Identifiant supplémentaire	C	M (=)	M (=)	M (=)
Sous-indice	C	M (=)	M (=)	M (=)
Nombre d'éléments	C	M (=)	CM	M (=)
Taille de matrice			C	M (=)
Résultat (+)				
Valeur de variable			S	S (=)
Code de réponse			M	M (=)
Statut de processus d'application			M	M (=)
Statut étendu			M	M (=)
Résultat (-)			S	S (=)
Statut				S
Code de réponse			M	M (=)
Statut de processus d'application			M	M (=)
Statut étendu			M	M (=)

Argument

L'argument contient les paramètres de la demande de service.

Identifiant numérique

Ce paramètre identifie la variable. Il est l'attribut clé attribué à la valeur devant être lue. Il est aussi appelé numéro de commande.

Identifiant supplémentaire

Pour certains des identifiants numériques, ce paramètre fournit des informations complémentaires indispensables pour identifier la/les variable(s) devant être lue(s).

Sous-indice

Ce paramètre identifie l'élément individuel dans une variable de matrice par sa position au sein de la variable. Il peut s'agir d'une valeur numérique ou d'une Enumération.

Nombre d'éléments

Ce paramètre spécifie le nombre d'éléments de la matrice devant être lus. Ce paramètre n'est présent que si la variable est une variable de matrice et si le sous-indice est une valeur numérique. La valeur par défaut de ce paramètre est un (1). Dans les primitives "demande" et "indication", sa valeur est le nombre souhaité d'éléments devant être lus. Dans les primitives "réponse" et "confirmation", sa valeur est le nombre effectif d'éléments lus.

Taille de matrice

Ce paramètre spécifie le nombre total d'éléments disponibles de la matrice. Ce paramètre n'est présent que si la variable est une variable de matrice.

Valeur de variable

Ce paramètre spécifie la valeur lue issue du serveur.

Statut

Ce paramètre spécifie la raison locale de la défaillance, telle qu'une expiration de délai de communication. Si le serveur envoie une réponse, mais ne pouvait pas envoyer la "Valeur de variable", cela est indiqué dans le code de réponse.

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7.4.2.2.3.4 Service "Ecrire" – format commun

7.4.2.2.3.4.1 Aperçu du service

Ce service permet à un client d'écrire la valeur d'une variable sur le serveur.

7.4.2.2.3.4.2 Primitives de service

Les paramètres de service correspondants sont présentés au Tableau 70.

Tableau 70 – Paramètres du service "Ecrire"

Nom de paramètre	Req	Ind	Rsp	Cnf
Argument				
ID d'AREP	M	M (=)		
Identifiant numérique	M	M (=)	M (=)	M (=)
Identifiant supplémentaire	C	M (=)	M (=)	M (=)
Sous-indice	C	M (=)	M (=)	M (=)
Valeur de variable	M	M (=)		
Résultat (+)				
Valeur de variable			S	S (=)
Code de réponse			M	M (=)
Statut de processus d'application			M	M (=)
Statut étendu			M	M (=)
Résultat (-)				
Statut				S
Code de réponse			M	M (=)
Statut de processus d'application			M	M (=)
Statut étendu			M	M (=)

Argument

L'argument contient les paramètres de la demande de service.

Identifiant numérique

Ce paramètre identifie la variable. Il est l'attribut clé attribué à la valeur devant être lue. Il est aussi appelé numéro de commande.

Identifiant supplémentaire

Pour certains des identifiants numériques, ce paramètre fournit des informations complémentaires indispensables pour identifier la/les variable(s) devant être lue(s).

Sous-indice

Ce paramètre identifie l'élément individuel dans une variable de matrice par sa position au sein de la variable. Il peut s'agir d'une valeur numérique ou d'une Enumération.

Valeur de variable

Dans la primitive de demande, ce paramètre spécifie la valeur souhaitée pour la variable devant être écrite. Dans la primitive de réponse, ce paramètre énonce la valeur effective pour la variable qui a été écrite. Dans certains cas, le serveur de réponse écrit une valeur différente de la valeur contenue dans la primitive d'indication, par exemple il peut arrondir la valeur à la valeur la plus proche autorisée ou à la valeur la plus proche que le serveur peut prendre en charge.

NOTE La valeur de la variable retournée peut servir à l'utilisateur de la FAL pour valider l'opération d'écriture.

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Statut

Ce paramètre spécifie la raison locale de la défaillance, telle qu'une expiration de délai de communication. Si le serveur envoie une réponse, mais ne pouvait pas écrire la "Valeur de variable", cela est indiqué dans le code de réponse.

7.4.2.2.3.5 Service de rapport d'informations – format commun

7.4.2.2.3.5.1 Aperçu du service

Ce service permet à un maître ou à un esclave d'envoyer la valeur d'une variable. Il est utilisé pour éditer des données de variable, envoyer des informations sur des événements ou acquitter un événement.

7.4.2.2.3.5.2 Primitives de service

Les paramètres de service correspondants sont présentés au Tableau 71.

Tableau 71 – Paramètres du service de rapport d'informations

Nom de paramètre	Req	Ind
Argument		
ID d'AREP	M	M (=)
Identifiant numérique	M	M (=)
Sous-indice	C	M (=)
Valeur de variable	M	M (=)
Code de rapport	M	M (=)
Statut de processus d'application	M	M (=)
Statut étendu	M	M (=)

Argument

L'argument contient les paramètres de la demande de service.

Identifiant numérique

Ce paramètre identifie la variable. Il est l'attribut clé attribué à la valeur devant être lue. Il est aussi appelé numéro de commande.

Sous-indice

Ce paramètre identifie l'élément individuel dans une variable de matrice par sa position au sein de la variable. Il peut s'agir d'une valeur numérique ou d'une Enumération.

Valeur de variable

Ce paramètre spécifie la valeur rapportée issue du serveur.

7.4.2.3 ASE Action

7.4.2.3.1 Aperçu du service

Ce service permet à un client de commander une action spécifiée du serveur. Le format commun du service Action est défini dans le présent paragraphe. Pour chaque action, il y a un service distinct.

NOTE Les définitions des services en 7.4.2.3 ne sont pas indépendantes de l'action demandée. Le paragraphe 7.4.2.3 montre seulement le format du service. Les définitions spécifiques de services incluent le comportement et les paramètres spécifiques aux services.

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7.4.2.3.2 Corrélation de primitives

Au niveau du client, il n'y a qu'une seule demande en cours pour une valeur de l'identifiant d'AREP. L'ID d'AREP est acheminé comme adresse de destination dans les primitives "service" de la couche transport. Par conséquent, la primitive de confirmation est corrélée à la primitive de demande en utilisant l'identifiant d'AREP. Au niveau du serveur, il n'y a qu'une seule primitive d'indication en cours à un instant donné. Par conséquent, la primitive de réponse est corrélée à la primitive d'indication attendant la réponse.

7.4.2.3.3 Modèle d'actions

7.4.2.3.3.1 Généralités

Certaines des actions exigent une variable pour valider l'action. Le modèle pour de telles actions est défini dans le présent paragraphe.

7.4.2.3.3.2 Modèle formel

ASE: **Simple Action**
CLASSE PARENT: **Supérieure**
ATTRIBUTS:

1	(m)	Key Attribute:	Identifiant numérique

ASE: **Action qualifiée**
CLASSE PARENT: **Supérieure**
ATTRIBUTS:

1	(m)	Key Attribute:	Identifiant numérique
2	(m)	Attribut:	Nom qualificatif
3	(m)	Attribut:	Nom de type de données

ASE: **Action de variable simple**
CLASSE PARENT: **Supérieure**
ATTRIBUTS:

1	(m)	Key Attribute:	Identifiant numérique
2	(m)	Attribut:	Nom de variable
3	(m)	Attribut:	Nom de type de données

ASE: **Action de Variable de Structure**
CLASSE PARENT: **Supérieure**
ATTRIBUTS:

1	(m)	Key Attribute:	Identifiant numérique
2	(m)	Attribut:	Nom de variable
3	(m)	Attribut:	Nombre de champs
4	(m)	Attribut:	Liste de champs
4,1	(o)	Attribut:	Nom de champ
4,2	(m)	Attribut:	Nom de type de données de champ

7.4.2.3.3.3 Attributs

Voir 7.4.2.2.2 pour la définition des attributs.

7.4.2.3.4 Primitives de service Action – format commun

Les paramètres de service correspondants sont présentés au Tableau 72.

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Tableau 72 – Paramètres du service Action

Nom de paramètre	Req	Ind	Rsp	Cnf
Argument				
ID d'AREP	M	M (=)		
Identifiant numérique	M	M (=)	M (=)	M (=)
Qualificatif d'action	C	M (=)	M (=)	M (=)
Sous-indice	C	M (=)	M (=)	M (=)
Valeur de variable	C	M (=)		
Résultat (+)				
Valeur de variable			S	S (=)
Code de réponse			M	M (=)
Statut de processus d'application			M	M (=)
Statut étendu			M	M (=)
Résultat (-)				
Statut				S
Code de réponse			M	M (=)
Statut de processus d'application			M	M (=)
Statut étendu			M	M (=)

Argument

L'argument contient les paramètres de la demande de service.

Identifiant numérique

Ce paramètre identifie l'action. Il est aussi appelé numéro de commande.

Qualificatif d'action

Pour certains des identifiants numériques, ce paramètre fournit des informations complémentaires indispensables pour identifier l'action à accomplir. Si l'action exige une variable et si l'identifiant numérique n'est pas suffisant, ce paramètre identifie la variable en question.

Sous-indice

Si l'action exige une variable de matrice, ce paramètre identifie l'élément individuel dans la variable de matrice en question. Ce paramètre peut être une valeur numérique ou une Enumération.

NOTE Ce paramètre est présent si l'action consiste à ajouter un élément à la matrice ou à supprimer un élément de la matrice.

Valeur de variable

Si l'action exige une variable, ce paramètre spécifie la valeur de la variable. Si l'action est "ajouter", cela spécifie la valeur souhaitée de la valeur à ajouter dans le paramètre de demande; dans la primitive de réponse, ce paramètre énonce la valeur effective pour la variable qui a été ajoutée.

Statut

Ce paramètre spécifie la raison locale de la défaillance, telle qu'une expiration de délai de communication. Si le serveur envoie une réponse, mais ne pouvait pas parachever l'action avec succès, cela est indiqué dans le code de réponse.

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7.4.2.4 Services d'application d'appareil

7.4.2.4.1 Lire variable primaire

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.2.3.3.

7.4.2.4.2 Lire courant de boucle et pourcentage de la plage

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.2.

7.4.2.4.3 Lire variables dynamiques et courant de boucle

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.3.

7.4.2.4.4 Ecrire configuration de boucle

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.4.

7.4.2.4.5 Lire configuration de boucle

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.5.

7.4.2.4.6 Lire classifications de familles de variables dynamiques

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.6.

7.4.2.4.7 Lire variables d'appareil avec statut

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.7.

7.4.2.4.8 Lire message

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.8.

7.4.2.4.9 Lire marqueur, descripteur et date

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.9.

7.4.2.4.10 Lire informations de transducteur de variable primaire

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.10.

7.4.2.4.11 Lire informations d'appareil

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.11.

7.4.2.4.12 Lire numéro de montage final

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.12.

7.4.2.4.13 Ecrire message

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.13.

7.4.2.4.14 Ecrire marqueur, descripteur et date

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.14.

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7.4.2.4.15 Ecrire numéro de montage final

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.15.

7.4.2.4.16 Lire le marqueur long

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.16.

7.4.2.4.17 Ecrire le marqueur long

Ce service est spécifié dans l'IEC 61158-5-20:2014, 6.2.4.17.

7.4.2.4.18 Réinitialiser fanion de configuration modifiée

7.4.2.4.18.1 Aperçu du service

Ce service réinitialise le bit "configuration modifiée" associé au client émettant ce service d'écriture.

7.4.2.4.18.2 Paramètres de demande

CLASSE:		**Action de variable simple**
ATTRIBUTS:		
1	Identifiant numérique	= 38
2	Nom de variable	= Compteur de modification de configuration
3	Nom de type de données	= Unsigned16

7.4.2.4.19 Effectuer autotest

7.4.2.4.19.1 Aperçu du service

Ce service déclenche la fonction d'autotest dans l'appareil.

7.4.2.4.19.2 Paramètres de demande

CLASSE:		**Simple Action**
ATTRIBUTS:		
1	Identifiant numérique	= 41

7.4.2.4.20 Effectuer réinitialisation de l'appareil

7.4.2.4.20.1 Aperçu du service

Ce service déclenche la fonction d'autotest dans l'appareil.

7.4.2.4.20.2 Paramètres de demande

CLASSE:		**Simple Action**
ATTRIBUTS:		
1	Identifiant numérique	= 42

7.4.2.4.21 Lire statut supplémentaire d'appareil

7.4.2.4.21.1 Aperçu du service

Ce service lit les informations de statut de l'appareil qui ne sont pas incluses dans le code de réponse ou l'octet Statut de l'appareil.

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7.4.2.4.21.2 Modèle de variable

Il y a trois modèles différents de variables en fonction du type d'appareil. L'appareil répond avec un seul de ces trois types de variables. Si l'appareil prend en charge plusieurs canaux analogiques, il prend en charge "Statut supplémentaire d'appareil 2". Certains des appareils peuvent utiliser "Statut supplémentaire d'appareil 3". Tous les autres appareils prennent en charge "Statut supplémentaire d'appareil 1".

CLASSE:			**VARIABLE DE STRUCTURE**
ATTRIBUTS:			
1		Identifiant numérique	= 48
2		Nom de variable	= Statut supplémentaire d'appareil 1
3		Nombre de champs	= variable
4		Liste des champs	
4.1	(m)	Nom de champ	= Statut spécifique à l'appareil 0
4.2	(m)	Nom de type de données de champ	= Champ binaire
4.3	(m)	Nom de champ	= Statut étendu
4.4	(m)	Nom de type de données de champ	= Champ binaire
4.5	(m)	Nom de champ	= Mode de fonctionnement d'appareil
4.6	(m)	Nom de type de données de champ	= Champ binaire
4.7	(m)	Nom de champ	= Statut normalisé 0
4.8	(m)	Nom de type de données de champ	= Champ binaire

CLASSE:			**VARIABLE DE STRUCTURE**
ATTRIBUTS:			
5		Identifiant numérique	= 48
6		Nom de variable	= Statut supplémentaire d'appareil 2
7		Nombre de champs	= variable
8		Liste des champs	
8.1	(m)	Nom de champ	= Statut spécifique à l'appareil 0
8.2	(m)	Nom de type de données de champ	= Champ binaire
8.3	(m)	Nom de champ	= Statut étendu
8.4	(m)	Nom de type de données de champ	= Champ binaire
8.5	(m)	Nom de champ	= Mode de fonctionnement d'appareil
8.6	(m)	Nom de type de données de champ	= Champ binaire
8.7	(m)	Nom de champ	= Statut normalisé 0
8.8	(m)	Nom de type de données de champ	= Champ binaire
8.9	(m)	Nom de champ	= Statut normalisé 1
8.10	(m)	Nom de type de données de champ	= Champ binaire
8.11	(m)	Nom de champ	= Canal analogique saturé
8.12	(m)	Nom de type de données de champ	= Champ binaire
8.13	(m)	Nom de champ	= Statut normalisé 2
8.14	(m)	Nom de type de données de champ	= Champ binaire
8.15	(m)	Nom de champ	= Statut normalisé 3
8.16	(m)	Nom de type de données de champ	= Champ binaire
8.17	(m)	Nom de champ	= Canal analogique fixé
8.18	(m)	Nom de type de données de champ	= Champ binaire

CLASSE:			**VARIABLE DE STRUCTURE**
ATTRIBUTS:			
9		Identifiant numérique	= 48
10		Nom de variable	= Statut supplémentaire d'appareil 3
11		Nombre de champs	= variable
12		Liste des champs	

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12.1	(m)	Nom de champ	= Statut spécifique à l'appareil 0
12.2	(m)	Nom de type de données de champ	= Champ binaire
12.3	(m)	Nom de champ	= Statut étendu
12.4	(m)	Nom de type de données de champ	= Champ binaire
12.5	(m)	Nom de champ	= Mode de fonctionnement d'appareil
12.6	(m)	Nom de type de données de champ	= Champ binaire
12.7	(m)	Nom de champ	= Statut normalisé 0
12.8	(m)	Nom de type de données de champ	= Champ binaire
12.9	(m)	Nom de champ	= Statut normalisé 1
12.10	(m)	Nom de type de données de champ	= Champ binaire
12.11	(m)	Nom de champ	= Canal analogique saturé
12.12	(m)	Nom de type de données de champ	= Champ binaire
12.13	(m)	Nom de champ	= Statut normalisé 2
12.14	(m)	Nom de type de données de champ	= Champ binaire
12.15	(m)	Nom de champ	= Statut normalisé 3
12.16	(m)	Nom de type de données de champ	= Champ binaire
12.17	(m)	Nom de champ	= Canal analogique fixé
12.18	(m)	Nom de type de données de champ	= Champ binaire
12.19	(m)	Nom de champ	= Statut spécifique à l'appareil 1
12.20	(m)	Nom de type de données de champ	= Matrice de statut

CLASSE: **Type de données**

ATTRIBUTS:

1	Nom de type de données de champ	= Matrice de statut
2	Format	= MATRICE
2.1	Nombre d'éléments de matrice	= 1 à 11
2.2	Type de données d'élément de matrice	= Champ binaire

7.4.2.4.22 Réinitialiser "Encore plus de statuts disponibles"

7.4.2.4.22.1 Aperçu du service

Ce service réinitialise le bit "Encore plus de statuts disponibles" correspondant à l'appareil demandeur (maître primaire, maître secondaire ou passerelle). Le nombre de champs dans la variable de structure associée dépend du serveur et il est de 4 au minimum et de 10 au maximum.

7.4.2.4.22.2 Paramètres de demande

CLASSE: **Action de Variable de Structure**

ATTRIBUTS:

1	Identifiant numérique		48
2	Nom de variable		= Statut supplémentaire d'appareil
3	Nombre de champs		= variable
4	Liste des champs		
4.1	(m)	Nom de champ	= Statut spécifique à l'appareil 0
4.2	(m)	Nom de type de données de champ	= Champ binaire
4.3	(m)	Nom de champ	= Statut étendu
4.4	(m)	Nom de type de données de champ	= Champ binaire
4.5	(m)	Nom de champ	= Mode de fonctionnement d'appareil
4.6	(m)	Nom de type de données de champ	= Champ binaire
4.7	(m)	Nom de champ	= Statut normalisé 0
4.8	(m)	Nom de type de données de champ	= Champ binaire
4.9	(m)	Nom de champ	= Statut normalisé 1
4.10	(m)	Nom de type de données de champ	= Champ binaire

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4.11	(m)	Nom de champ	= Canal analogique saturé
4.12	(m)	Nom de type de données de champ	= Champ binaire
4.13	(m)	Nom de champ	= Statut normalisé 2
4.14	(m)	Nom de type de données de champ	= Champ binaire
4.15	(m)	Nom de champ	= Statut normalisé 3
4.16	(m)	Nom de type de données de champ	= Champ binaire
4.17	(m)	Nom de champ	= Canal analogique fixé
4.18	(m)	Nom de type de données de champ	= Champ binaire
4.19	(m)	Nom de champ	= Statut spécifique à l'appareil 1
4.20	(m)	Type de données	= Matrice de statut

CLASSE: **Type de données**

ATTRIBUTS:

1	Nom de type de données de champ	= Matrice de statut
2	Format	= MATRICE
2.1	Nombre d'éléments de matrice	= 1 à 11
2.2	Type de données d'élément de matrice	= Champ binaire

7.4.2.4.23 Lire Informations de variables d'appareil

7.4.2.4.23.1 Aperçu du service

Ce service lit les paramètres liés à la variable d'appareil.

7.4.2.4.23.2 Paramètres de demande

1	Identifiant numérique	= 54
2	Sous-indice	
2.1	Nom de sous-indice	= Code de variable
2.2	Type de données de sous-indice	= Unsigned8

7.4.2.4.23.3 Paramètres de réponse

1	Identifiant numérique	= 54
2	Sous-indice	
2.1	Nom de sous-indice	= Code de variable
2.2	Type de données de sous-indice	= Unsigned8

7.4.2.4.23.4 Modèle de variable

CLASSE: **Matrice de VARIABLE de structure**

ATTRIBUTS:

Identifiant numérique	= 54
Nom de variable	= Informations de variables d'appareil
Nombre de champs	= 9
Liste de champs	
Nom de champ	= Numéro de série de transducteur
Nom de type de données de champ	= Unsigned24
Nom de champ	= Elément transducteur
Nom de type de données de champ	= Enumération
Nom de champ	= Limite supérieure du transducteur
Nom de type de données de champ	= Float32
Nom de champ	= Limite inférieure du transducteur
Nom de type de données de champ	= Float32

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Nom de champ = Valeur d'amortissement
Nom de type de données de champ = Float32
Nom de champ = Intervalle de mesure minimal
Nom de type de données de champ = Float32
Nom de champ = Classification de variables d'appareil
Nom de type de données de champ = Enumération
Nom de champ = Famille de variables d'appareil
Nom de type de données de champ = Enumération
Nom de champ = Période d'actualisation
Nom de type de données de champ = Temps
Taille de matrice = Variable

1 Identifiant numérique = 54
2 Nom de variable = Informations de variables d'appareil
3 Nombre de champs = 9
4 Liste des champs
4.1 Nom de champ = Numéro de série de transducteur
4.2 Nom de type de données de champ = Unsigned24
4.3 Nom de champ = Elément transducteur
4.4 Nom de type de données de champ = Enumération
4.5 Nom de champ = Limite supérieure du transducteur
4.6 Nom de type de données de champ = Float32
4.7 Nom de champ = Limite inférieure du transducteur
4.8 Nom de type de données de champ = Float32
4.9 Nom de champ = Valeur d'amortissement
4.10 Nom de type de données de champ = Float32
4.11 Nom de champ = Intervalle de mesure minimal
4.12 Nom de type de données de champ = Float32
4.13 Nom de champ = Classification de variables d'appareil
4.14 Nom de type de données de champ = Enumération
4.15 Nom de champ = Famille de variables d'appareil
4.16 Nom de type de données de champ = Enumération
4.17 Nom de champ = Période d'actualisation
4.18 Nom de type de données de champ = Temps
5 Taille de matrice = variable

7.4.2.4.24 Ecrire variable d'appareil

7.4.2.4.24.1 Aperçu du service

Ce service permet de forcer temporairement une variable d'appareil à avoir une valeur fixe.

7.4.2.4.24.2 Paramètres de demande

1 Identifiant numérique = 79
2 Sous-indice
2.1 Nom de sous-indice = Code de variable
2.2 Type de données de sous-indice = Unsigned8

7.4.2.4.24.3 Paramètres de réponse

1 Identifiant numérique = 79
2 Sous-indice
2.1 Nom de sous-indice = Code de variable
2.2 Type de données de sous-indice = Unsigned8

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7.4.2.4.24.4 Modèle de variable

CLASSE: **Matrice de VARIABLE de structure**

ATTRIBUTS:

1 Identifiant numérique = 79
2 Nom de variable = Enregistrement de variable d'appareil
3 Nombre de champs = 4
4 Liste des champs
4.1 Nom de champ = Commande de variable d'appareil
4.2 Nom de type de données de champ = Enumération
4.3 Nom de champ = Unité de variables d'appareil
4.4 Nom de type de données de champ = Unité technique
4.5 Nom de champ = Valeur de variable d'appareil
4.6 Nom de type de données de champ = Float32
4.7 Nom de champ = Statut de variable d'appareil
4.8 Nom de type de données de champ = Champ binaire
5 Taille de matrice = variable

7.4.2.4.25 Lire horloge temps réel

7.4.2.4.25.1 Aperçu du service

Ce service lit l'horloge temps réel, y compris l'heure courante telle qu'estimée par l'appareil et la dernière fois que l'horloge a été réglée.

7.4.2.4.25.2 Modèle de variable

CLASSE: **VARIABLE DE STRUCTURE**

ATTRIBUTS:

1 Identifiant numérique = 90
2 Nom de variable = Horloge temps réel
3 Nombre de champs = 5
4 Liste des champs
4.1 Nom de champ = Date
4.2 Nom de type de données de champ = Date
4.3 Nom de champ = Heure courante
4.4 Nom de type de données de champ = Temps
4.5 Nom de champ = Dernier réglage de la date
4.6 Nom de type de données de champ = Date
4.7 Nom de champ = Dernier réglage du temps
4.8 Nom de type de données de champ = Temps
4.9 Nom de champ = Fanions d'horloge temps réel
4.10 Nom de type de données de champ = Champ binaire

7.4.2.4.26 Ecrire période d'édition de données

7.4.2.4.26.1 Aperçu du service

Ce service sélectionne la période d'actualisation minimale et maximale d'un message d'édition de données.

7.4.2.4.26.2 Paramètres de demande

1 Identifiant numérique = 103
2 Sous-indice

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2.1 Nom de sous-indice = Réf. de message d'édition de données
2.2 Type de données de sous-indice = Unsigned8

7.4.2.4.26.3 Paramètres de réponse

1 Identifiant numérique = 103
2 Sous-indice
2.1 Nom de sous-indice = Réf. de message d'édition de données
2.2 Type de données de sous-indice = Unsigned8

7.4.2.4.26.4 Modèle de variable

CLASSE: **Matrice de VARIABLE de structure**
ATTRIBUTS:
Identifiant numérique = 103
Nom de variable = Période d'édition de données
Nombre de champs = 2
Liste de champs
Nom de champ = Période d'actualisation
Nom de type de données de champ = Temps
Nom de champ = Période maximale d'actualisation
Nom de type de données de champ = Temps
Taille de matrice = Variable

7.4.2.4.27 Ecrire déclencheur d'édition de données

7.4.2.4.27.1 Aperçu du service

Ce service configure le déclencheur qui force l'édition des données

7.4.2.4.27.2 Paramètres de demande

Identifiant numérique = 104
Sous-indice
Nom de sous-indice = Réf. de message d'édition de données
Type de données de sous-indice = Unsigned8

7.4.2.4.27.3 Paramètres de réponse

Identifiant numérique = 104
Sous-indice
Nom de sous-indice = Réf. de message d'édition de données
Type de données de sous-indice = Unsigned8

7.4.2.4.27.4 Modèle de variable

CLASSE: **Matrice de VARIABLE de structure**
ATTRIBUTS:
Identifiant numérique = 104
Nom de variable = Déclencheur d'édition de données
Nombre de champs = 4
Liste de champs
Nom de champ = Mode déclenchement
Nom de type de données de champ = Enumération
Nom de champ = Classification de variables d'appareil
Nom de type de données de champ = Enumération

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Nom de champ = Unité de variables d'appareil
Nom de type de données de champ = Unité technique
Nom de champ = Niveau déclenchement
Nom de type de données de champ = Float32
Taille de matrice = Variable

7.4.2.4.28 Lire Configuration du mode "édition de données"

7.4.2.4.28.1 Aperçu du service

Ce service lit la configuration du mode "édition de données".

7.4.2.4.28.2 Paramètres de demande

Identifiant numérique = 105
Sous-indice
Nom de sous-indice = Réf. de message d'édition de données
Type de données de sous-indice = Unsigned8

7.4.2.4.28.3 Paramètres de réponse

Identifiant numérique = 105
Sous-indice
Nom de sous-indice = Réf. de message d'édition de données
Type de données de sous-indice = Unsigned8

7.4.2.4.28.4 Modèle de variable

CLASSE: **Matrice de VARIABLE de structure**
ATTRIBUTS:
Identifiant numérique = 105
Nom de variable = Configuration du mode "édition de données"
Nombre de champs = 18
Liste de champs
Nom de champ = Contrôle du mode "édition de données"
Nom de type de données de champ = Enumération
Nom de champ = Expansion du numéro de commande
Nom de type de données de champ = Unsigned8
Nom de champ = Code de variables d'appareil 0
Nom de type de données de champ = Unsigned8
Nom de champ = Code de variables d'appareil 1
Nom de type de données de champ = Unsigned8
Nom de champ = Code de variables d'appareil 2
Nom de type de données de champ = Unsigned8
Nom de champ = Code de variables d'appareil 3
Nom de type de données de champ = Unsigned8
Nom de champ = Code de variables d'appareil 4
Nom de type de données de champ = Unsigned8
Nom de champ = Code de variables d'appareil 5
Nom de type de données de champ = Unsigned8
Nom de champ = Code de variables d'appareil 6
Nom de type de données de champ = Unsigned8
Nom de champ = Code de variables d'appareil 7
Nom de type de données de champ = Unsigned8
Nom de champ = Nombre maximal d'édition de données

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Nom de type de données de champ = Unsigned8
Nom de champ = Numéro de commande étendu
Nom de type de données de champ = Unsigned16
Nom de champ = Période d'actualisation
Nom de type de données de champ = Temps
Nom de champ = Période maximale d'actualisation
Nom de type de données de champ = Temps
Nom de champ = Mode déclenchement
Nom de type de données de champ = Enumération
Nom de champ = Classification de variables d'appareil
Nom de type de données de champ = Enumération
Nom de champ = Unité de variables d'appareil
Nom de type de données de champ = Unité technique
Nom de champ = Niveau déclenchement
Nom de type de données de champ = Float32
Taille de matrice = Variable

7.4.2.4.29 Purger réponses différées

7.4.2.4.29.1 Aperçu du service

Cette commande efface toutes les réponses différées en instance pour le maître qui a émis la commande.

7.4.2.4.29.2 Paramètres de demande

CLASSE: Simple Action
ATTRIBUTS:
Identifiant numérique = 106

7.4.2.4.30 Ecrire variable d'appareil d'édition de données

7.4.2.4.30.1 Aperçu du service

Ce service sélectionne les variables d'appareil qui doivent être utilisées par un appareil éditeur en mode "édition de données".

7.4.2.4.30.2 Paramètres de demande

Identifiant numérique = 107
Sous-indice
Nom de sous-indice = Réf. de message d'édition de données
Type de données de sous-indice = Unsigned8

7.4.2.4.30.3 Paramètres de réponse

Identifiant numérique = 107
Sous-indice
Nom de sous-indice = Réf. de message d'édition de données
Type de données de sous-indice = Unsigned8

7.4.2.4.30.4 Modèle de variable

CLASSE: Matrice de VARIABLE de structure
ATTRIBUTS:
Identifiant numérique = 107
Nom de variable = Variables d'appareil d'édition de données

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Nombre de champs = 8
Liste de champs
Nom de champ = Code de variables d'appareil 0
Nom de type de données de champ = Unsigned8
Nom de champ = Code de variables d'appareil 1
Nom de type de données de champ = Unsigned8
Nom de champ = Code de variables d'appareil 2
Nom de type de données de champ = Unsigned8
Nom de champ = Code de variables d'appareil 3
Nom de type de données de champ = Unsigned8
Nom de champ = Code de variables d'appareil 4
Nom de type de données de champ = Unsigned8
Nom de champ = Code de variables d'appareil 5
Nom de type de données de champ = Unsigned8
Nom de champ = Code de variables d'appareil 6
Nom de type de données de champ = Unsigned8
Nom de champ = Code de variables d'appareil 7
Nom de type de données de champ = Unsigned8
Taille de matrice = Variable

7.4.2.4.31 Ecrire Numéro de commande du mode "édition de données"

7.4.2.4.31.1 Aperçu du service

Ce service sélectionne le message de réponse que l'appareil éditeur émet en mode "édition de données".

7.4.2.4.31.2 Paramètres de demande

Identifiant numérique = 108
Sous-indice
Nom de sous-indice = Réf. de message d'édition de données
Type de données de sous-indice = Unsigned8

7.4.2.4.31.3 Paramètres de réponse

Identifiant numérique = 108
Sous-indice
Nom de sous-indice = Réf. de message d'édition de données
Type de données de sous-indice = Unsigned8

7.4.2.4.31.4 Modèle de variable

CLASSE: **Matrice de variable simple**
ATTRIBUTS:
Identifiant numérique = 108
Nom de variable = Numéro de commande du mode "édition de données"
Nom de type de données = Unsigned16/Unsigned8
Taille de matrice = Variable

7.4.2.4.32 Ecrire Contrôle de mode "édition de données"

7.4.2.4.32.1 Aperçu du service

Ce service est utilisé pour activer ou désactiver le mode "édition de données" pour les appareils.

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7.4.2.4.32.2 Paramètres de demande

Identifiant numérique = 109
Sous-indice
Nom de sous-indice = Réf. de message d'édition de données
Type de données de sous-indice = Unsigned8

7.4.2.4.32.3 Paramètres de réponse

Identifiant numérique = 109
Sous-indice
Nom de sous-indice = Réf. de message d'édition de données
Type de données de sous-indice = Unsigned8

7.4.2.4.32.4 Modèle de variable

CLASSE: Matrice de variable simple
ATTRIBUTS:
Identifiant numérique = 109
Nom de variable = Contrôle du mode "édition de données"
Nom de type de données = Enumération
Taille de matrice = Variable

7.4.2.4.33 Lire résumé de notification d'événement

7.4.2.4.33.1 Aperçu du service

Ce service lit la configuration de la Notification d'événement.

7.4.2.4.33.2 Paramètres de demande

Identifiant numérique = 115
Sous-indice
Nom de sous-indice = Réf. de numéro d'événement
Type de données de sous-indice = Unsigned8

7.4.2.4.33.3 Paramètres de réponse

Identifiant numérique = 115
Sous-indice
Nom de sous-indice = Réf. de numéro d'événement
Type de données de sous-indice = Unsigned8

7.4.2.4.33.4 Modèle de variable

CLASSE: Matrice de VARIABLE de structure
ATTRIBUTS:
Identifiant numérique = 115
Nom de variable = Résumé de notification d'événement
Nombre de champs = 9
Liste de champs
Nom de champ = Nombre maximal d'événements
Nom de type de données de champ = Unsigned8
Nom de champ = Statut de l'événement
Nom de type de données de champ = Champ binaire
Nom de champ = Contrôle de notification d'événement
Nom de type de données de champ = Champ binaire

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Nom de champ = Heure d'occurrence de l'événement
Nom de type de données de champ = Temps
Nom de champ = Délai de nouvelle tentative de notification d'événement
Nom de type de données de champ = Temps
Nom de champ = Temps maximal d'actualisation
Nom de type de données de champ = Temps
Nom de champ = Intervalle antirebond d'événement
Nom de type de données de champ = Temps
Nom de champ = Masque de statut de l'appareil
Nom de type de données de champ = Champ binaire
Nom de champ = Masque d'événement
Nom de type de données de champ = Taille de matrice variable de champ binaire
Taille de matrice = Variable

7.4.2.4.34 Ecrire Masque binaire de notification d'événement

7.4.2.4.34.1 Aperçu du service

Ce service établit le masque d'événement utilisé pour déclencher une notification d'événement.

7.4.2.4.34.2 Paramètres de demande

Identifiant numérique = 116
Sous-indice
Nom de sous-indice = Réf. de numéro d'événement
Type de données de sous-indice = Unsigned8

7.4.2.4.34.3 Paramètres de réponse

Identifiant numérique = 116
Sous-indice
Nom de sous-indice = Réf. de numéro d'événement
Type de données de sous-indice = Unsigned8

7.4.2.4.34.4 Modèle de variable

CLASSE: Matrice de variable simple
ATTRIBUTS:
Identifiant numérique = 116
Nom de variable = Masque de statut de l'appareil
Nom de type de données = Champ binaire
Nom de variable = Ecrire Masque binaire de notification d'événement

7.4.2.4.35 Ecrire Temporisation de notification d'événement

7.4.2.4.35.1 Aperçu du service

Ce service fixe les paramètres de temporisation pour la notification d'événement.

7.4.2.4.35.2 Paramètres de demande

Identifiant numérique = 117
Sous-indice
Nom de sous-indice = Réf. de numéro d'événement
Type de données de sous-indice = Unsigned8

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7.4.2.4.35.3 Paramètres de réponse

Identifiant numérique = 117
Sous-indice
Nom de sous-indice = Réf. de numéro d'événement
Type de données de sous-indice = Unsigned8

7.4.2.4.35.4 Modèle de variable

CLASSE: **Matrice de VARIABLE de structure**
ATTRIBUTS:
Identifiant numérique = 117
Nom de variable = Temporisation de notification d'événement
Nombre de champs = 3
Liste de champs
Nom de champ = Délai de nouvelle tentative de notification d'événement
Nom de type de données de champ = Temps
Nom de champ = Temps maximal d'actualisation
Nom de type de données de champ = Temps
Nom de champ = Intervalle antirebond d'événement
Nom de type de données de champ = Temps
Taille de matrice = Variable

7.4.2.4.36 Ecrire Contrôle de notification d'événement

7.4.2.4.36.1 Aperçu du service

Ce service est utilisé pour activer ou désactiver la notification d'événement.

7.4.2.4.36.2 Paramètres de demande

Identifiant numérique = 118
Sous-indice
Nom de sous-indice = Réf. de numéro d'événement
Type de données de sous-indice = Unsigned8

7.4.2.4.36.3 Paramètres de réponse

Identifiant numérique = 118
Sous-indice
Nom de sous-indice = Réf. de numéro d'événement
Type de données de sous-indice = Unsigned8

7.4.2.4.36.4 Modèle de variable

CLASSE: **Matrice de variable simple**
ATTRIBUTS:
Identifiant numérique = 118
Nom de variable = Contrôle de notification d'événement
Nom de type de données = Champ binaire
Taille de matrice = Variable

7.4.2.4.37 Ecrire Acquittement de notification d'événement

7.4.2.4.37.1 Aperçu du service

Ce service est utilisé pour acquitter la notification d'événement.

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7.4.2.4.37.2 Paramètres de demande

Identifiant numérique = 119
Sous-indice
Nom de sous-indice = Réf. de numéro d'événement
Type de données de sous-indice = Unsigned8

7.4.2.4.37.3 Paramètres de réponse

Identifiant numérique = 119
Sous-indice
Nom de sous-indice = Réf. de numéro d'événement
Type de données de sous-indice = Unsigned8

7.4.2.4.37.4 Modèle de variable

CLASSE: **Matrice de VARIABLE de structure**
ATTRIBUTS:
Identifiant numérique = 119
Nom de variable = Acquittement de notification d'événement
Nombre de champs = 4
Liste de champs
Nom de champ = Heure d'occurrence de l'événement
Nom de type de données de champ = Temps
Nom de champ = Compteur de modification de configuration
Nom de type de données de champ = Unsigned16
Nom de champ = Statut de processus d'application
Nom de type de données de champ = Champ binaire
Nom de champ = Statut supplémentaire d'appareil
Nom de type de données de champ = Voir Note
Taille de matrice = Variable

Le "Statut supplémentaire d'appareil" est identique à l'ensemble de la variable de structure définie en 7.4.2.4.21.2.

7.4.2.5 Services de gestion de couche

7.4.2.5.1 Ecrire Join_key

7.4.2.5.1.1 Aperçu du service

Cette commande modifie la Join_key des appareils. La commande peut être émise par le gestionnaire de réseau ou être saisie via un outil de maintenance local (par exemple un terminal portatif).

7.4.2.5.1.2 Modèle de variable

CLASSE: **Variable simple**
ATTRIBUTS:
Identifiant numérique = 768
Nom de variable = Join_key
Nom de type de données = Clé de sécurité

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7.4.2.5.2 Lire statut de rattachement

7.4.2.5.2.1 Aperçu du service

Ce service lit le statut de l'appareil de terrain lorsqu'il effectue des transitions par le biais du processus de rattachement.

7.4.2.5.2.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 769
Nom de variable	= Statut de rattachement
Nombre de champs	= 7
Liste de champs	
Nom de champ	= Mode sans fil
Nom de type de données de champ	= Enumération
Nom de champ	= Statut de rattachement
Nom de type de données de champ	= Champ binaire
Nom de champ	= Voisins
Nom de type de données de champ	= Unsigned8
Nom de champ	= Paquets d'annonce
Nom de type de données de champ	= Unsigned8
Nom de champ	= Max_join_retries
Nom de type de données de champ	= Unsigned8
Nom de champ	= Join_rsp_time
Nom de type de données de champ	= Temps
Nom de champ	= Temps de recherche
Nom de type de données de champ	= Temps

7.4.2.5.3 Ecrire Active_search_shed_time

7.4.2.5.3.1 Aperçu du service

Cette commande demande une annonce plus rapide. En général, elle est reçue localement par un membre de réseau à partir d'un outil de maintenance local (par exemple, un terminal portatif) et est propagée vers le gestionnaire de réseau.

7.4.2.5.3.2 Modèle de variable de demande

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 770
Nom de variable	= Active_search_shed_time
Nom de type de données	= Temps

7.4.2.5.3.3 Modèle de variable de réponse

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 770
Nom de variable	= Shed_time
Nombre de champs	= 3
Liste de champs	
Nom de variable	= Active_search_shed_time
Nom de type de données	= Temps
Nom de variable	= Advertise_time

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Nom de type de données = Temps
Nom de champ = Voisins
Nom de type de données de champ = Unsigned8

7.4.2.5.4 Ecrire Configuration du mode de rattachement

7.4.2.5.4.1 Aperçu du service

Cette commande permet à un système hôte ou terminal portatif de forcer un appareil de terrain à entrer en mode de rattachement actif.

7.4.2.5.4.2 Modèle de variable

CLASSE: **VARIABLE DE STRUCTURE**
ATTRIBUTS:
Identifiant numérique = 771
Nom de variable = Configuration du mode de rattachement
Nombre de champs = 3
Liste de champs
Nom de champ = Mode de rattachement
Nom de type de données de champ = Enumération
Nom de variable = Active_search_shed_time
Nom de type de données = Temps
Nom de variable = max_join_retries
Nom de type de données = Unsigned8

7.4.2.5.5 Lire Configuration du mode de rattachement

7.4.2.5.5.1 Aperçu du service

Cette commande lit la configuration du mode de rattachement à partir d'un appareil de réseau.

7.4.2.5.5.2 Modèle de variable

CLASSE: **VARIABLE DE STRUCTURE**
ATTRIBUTS:
Identifiant numérique = 772
Nom de variable = Configuration du mode de rattachement
Nombre de champs = 3
Liste de champs
Nom de champ = Mode de rattachement
Nom de type de données de champ = Enumération
Nom de variable = Active_search_shed_time
Nom de type de données = Temps
Nom de variable = max_join_retries
Nom de type de données = Unsigned8

7.4.2.5.6 Ecrire Network_ID

7.4.2.5.6.1 Aperçu du service

Cette commande configure l'appareil pour reconnaître le Network_ID correct. Il convient que cette commande soit émise seulement par le gestionnaire de réseau ou via le port de maintenance. L'appareil recevant cette commande est tenu de rejeter cette commande si elle provient de n'importe quelle autre source.

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7.4.2.5.6.2 Modèle de variable de demande

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 773
Nom de variable	= nouveau Network_ID
Nom de type de données	= Unsigned16

7.4.2.5.6.3 Modèle de variable de réponse

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 773
Nom de variable	= nouveau Network_ID
Nom de type de données	= Unsigned16
Nom de variable	= Network_ID actuel
Nom de type de données	= Unsigned16

7.4.2.5.7 Lire Network_ID

7.4.2.5.7.1 Aperçu du service

Cette commande lit la valeur de réglage courante du Network_ID dans un appareil donné.

7.4.2.5.7.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 774
Nom de variable	= nouveau Network_ID
Nom de type de données	= Unsigned16
Nom de variable	= Network_ID actuel
Nom de type de données	= Unsigned16

7.4.2.5.8 Ecrire Network_tag

7.4.2.5.8.1 Aperçu du service

Cette commande lit le marqueur pour le réseau. Le Network_tag est un proxy pour le Network_ID et, de ce fait, le réseau peut être identifié sous une forme textuelle au niveau de l'application. Il convient que le même Network_tag soit écrit dans les appareils sur le même réseau.

7.4.2.5.8.2 Modèle de variable

CLASSE:	**VARIABLE Chaîne de caractères**
ATTRIBUTS:	
Identifiant numérique	= 775
Nom de variable	= Network_tag
Nom de type de données	= Latin-1
Longueur en octets	= 32

7.4.2.5.9 Lire Network_tag

7.4.2.5.9.1 Aperçu du service

Cette commande lit la valeur de réglage courante du marqueur du réseau.

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7.4.2.5.9.2 Modèle de variable

CLASSE:	**VARIABLE Chaîne de caractères**
ATTRIBUTS:	
Identifiant numérique	= 776
Nom de variable	= Network_tag
Nom de type de données	= Latin-1
Longueur en octets	= 32

7.4.2.5.10 Lire Capacités de l'appareil sans fil

7.4.2.5.10.1 Aperçu du service

Ce service est utilisé pour déterminer des caractéristiques opérationnelles de l'appareil de réseau. Le gestionnaire de réseau est censé utiliser le débit de crête des paquets et le temps de récupération pour prendre en charge des appareils rechargeables ou récupérateurs d'énergie.

7.4.2.5.10.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 777
Nom de variable	= Capacités de l'appareil sans fil
Nombre de champs	= 8
Liste de champs	
Nom de champ	= Source d'énergie
Nom de type de données de champ	= Enumération
Nom de champ	= Débit de crête des paquets
Nom de type de données de champ	= Float32
Nom de champ	= Durée de charge
Nom de type de données de champ	= Temps
Nom de champ	= Temps de récupération
Nom de type de données de champ	= Temps
Nom de champ	= Niveau de signal reçu correct
Nom de type de données de champ	= Integer8
Nom de champ	= Min Keep_alive_time
Nom de type de données de champ	= Temps
Nom de champ	= Nombre de voisins
Nom de type de données de champ	= Unsigned16
Nom de champ	= Tampon de paquets
Nom de type de données de champ	= Unsigned16

7.4.2.5.11 Lire Durée de vie de la batterie

7.4.2.5.11.1 Aperçu du service

Ce service lit l'état courant de la batterie dans un appareil de réseau.

7.4.2.5.11.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 778
Nom de variable	= Durée de vie de la batterie
Nom de type de données	= Unsigned16

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7.4.2.5.12 Rendre compte de la santé de l'appareil

7.4.2.5.12.1 Aperçu du service

Cette réponse de commande est périodiquement éditée par l'appareil de terrain.

7.4.2.5.12.2 Modèle de variable

CLASSE: **VARIABLE DE STRUCTURE**
ATTRIBUTS:
Identifiant numérique = 779
Nom de variable = Santé de l'appareil
Nombre de champs = 14
Liste de champs
Nom de champ = Paquets générés
Nom de type de données de champ = Unsigned16
Nom de champ = Paquets terminés
Nom de type de données de champ = Unsigned16
Nom de champ = Défaillances MIC de la DLL
Nom de type de données de champ = Unsigned8
Nom de champ = Défaillances MIC de la NL
Nom de type de données de champ = Unsigned8
Nom de champ = Statut d'énergie
Nom de type de données de champ = Enumération
Nom de champ = Erreurs de CRC
Nom de type de données de champ = Unsigned8
Nom de champ = Paquets manqués
Nom de type de données de champ = Unsigned8
Nom de champ = File d'attente maximale de tampon
Nom de type de données de champ = Unsigned8
Nom de champ = File d'attente moyenne de tampon
Nom de type de données de champ = Float32
Nom de champ = Latence moyenne
Nom de type de données de champ = Temps
Nom de champ = Variance de la latence
Nom de type de données de champ = Temps
Nom de champ = Paquets reçus
Nom de type de données de champ = Unsigned32
Nom de champ = Paquets en retard ou perdus
Nom de type de données de champ = Unsigned32
Nom de champ = Session inconnue
Nom de type de données de champ = Unsigned8

7.4.2.5.13 Lire Liste de santé des voisins

7.4.2.5.13.1 Aperçu du service

Ce service lit les entrées de la Table des voisins à partir de l'appareil de réseau.

7.4.2.5.13.2 Paramètres de demande

Identifiant numérique = 780
Sous-indice
Nom de sous-indice = Indice de Table
Type de données de sous-indice = Unsigned8
Nombre d'éléments

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Nom du nombre d'éléments = Nombre d'entrées
Type de données du nombre d'éléments = Unsigned8

7.4.2.5.13.3 Paramètres de réponse

Identifiant numérique = 780
Sous-indice
Nom de sous-indice = Indice de Table
Type de données de sous-indice = Unsigned8
Nombre d'éléments
Nom du nombre d'éléments = Nombre d'entrées
Type de données du nombre d'éléments = Unsigned8
Taille de matrice
Nom de taille de matrice = Nombre de voisins
Type de données de taille de matrice = Unsigned8

7.4.2.5.13.4 Modèle de variable

CLASSE: **Matrice de VARIABLE de structure**
ATTRIBUTS:
Identifiant numérique = 780
Nom de variable = Santé des voisins
Nombre de champs = 6
Liste de champs
Nom de champ = Neighbor_nickname
Nom de type de données de champ = Unsigned16
Nom de champ = Fanions de voisins
Nom de type de données de champ = Champ binaire
Nom de champ = Average_RSL
Nom de type de données de champ = Integer8
Nom de champ = Packets_transmitted
Nom de type de données de champ = Unsigned16
Nom de champ = Missed_ACK_packets
Nom de type de données de champ = Unsigned16
Nom de champ = Packets_received
Nom de type de données de champ = Unsigned16
Taille de matrice = Variable

7.4.2.5.14 Lire surnom d'appareil

7.4.2.5.14.1 Aperçu du service

Ce service lit un surnom d'appareil de réseau (adresse courte).

7.4.2.5.14.2 Modèle de variable

CLASSE: **Variable simple**
ATTRIBUTS:
Identifiant numérique = 781
Nom de variable = Surnom d'appareil
Nom de type de données = Unsigned16

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7.4.2.5.15 Lire liste de sessions

7.4.2.5.15.1 Aperçu du service

Ce service lit les entrées de la Table des sessions à partir de l'appareil de réseau.

7.4.2.5.15.2 Paramètres de demande

Identifiant numérique	= 782
Sous-indice	
Nom de sous-indice	= Indice de Table
Type de données de sous-indice	= Unsigned8
Nombre d'éléments	
Nom du nombre d'éléments	= Nombre d'entrées
Type de données du nombre d'éléments	= Unsigned8

7.4.2.5.15.3 Paramètres de réponse

Identifiant numérique	= 782
Sous-indice	
Nom de sous-indice	= Indice de Table
Type de données de sous-indice	= Unsigned8
Nombre d'éléments	
Nom du nombre d'éléments	= Nombre d'entrées
Type de données du nombre d'éléments	= Unsigned8
Taille de matrice	
Nom de taille de matrice	= Nombre de sessions
Type de données de taille de matrice	= Unsigned8

7.4.2.5.15.4 Modèle de variable

CLASSE: Matrice de VARIABLE de structure

ATTRIBUTS:

Identifiant numérique	= 782
Nom de variable	= Session
Nombre de champs	= 5
Liste de champs	
Nom de champ	= Session_type
Nom de type de données de champ	= Enumération
Nom de champ	= Peer_nickname
Nom de type de données de champ	= Unsigned16
Nom de champ	= Peer_unique_ID
Nom de type de données de champ	= Identifiant unique
Nom de champ	= Peer_nonce_counter
Nom de type de données de champ	= Unsigned32
Nom de champ	= My_nonce_counter
Nom de type de données de champ	= Unsigned32
Taille de matrice	= Variable

7.4.2.5.16 Lire liste de supertrames

7.4.2.5.16.1 Aperçu du service

Ce service lit les entrées de la Table des supertrames à partir de l'appareil de réseau.

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7.4.2.5.16.2 Paramètres de demande

Identifiant numérique	= 783
Sous-indice	
Nom de sous-indice	= Indice de Table
Type de données de sous-indice	= Unsigned8
Nombre d'éléments	
Nom du nombre d'éléments	= Nombre d'entrées
Type de données du nombre d'éléments	= Unsigned8

7.4.2.5.16.3 Paramètres de réponse

Identifiant numérique	= 783
Sous-indice	
Nom de sous-indice	= Indice de Table
Type de données de sous-indice	= Unsigned8
Nombre d'éléments	
Nom du nombre d'éléments	= Nombre d'entrées
Type de données du nombre d'éléments	= Unsigned8
Taille de matrice	
Nom de taille de matrice	= Nombre de supertrames
Type de données de taille de matrice	= Unsigned8

7.4.2.5.16.4 Modèle de variable

CLASSE: Matrice de VARIABLE de structure

ATTRIBUTS:

Identifiant numérique	= 783
Nom de variable	= Supertrame
Nombre de champs	= 3
Liste de champs	
Nom de champ	= Superframe_ID
Nom de type de données de champ	= Unsigned8
Nom de champ	= Num_Slots
Nom de type de données de champ	= Unsigned16
Nom de champ	= Mode supertrame
Nom de type de données de champ	= Champ binaire
Taille de matrice	= Variable

7.4.2.5.17 Lire liste des liaisons

7.4.2.5.17.1 Aperçu du service

Ce service lit les entrées de la Table des liaisons à partir de l'appareil de réseau.

7.4.2.5.17.2 Paramètres de demande

Identifiant numérique	= 784
Sous-indice	
Nom de sous-indice	= Indice de Table
Type de données de sous-indice	= Unsigned16
Nombre d'éléments	
Nom du nombre d'éléments	= Nombre d'entrées
Type de données du nombre d'éléments	= Unsigned8

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7.4.2.5.17.3 Paramètres de réponse

Identifiant numérique	= 784
Sous-indice	
Nom de sous-indice	= Indice de Table
Type de données de sous-indice	= Unsigned16
Nombre d'éléments	
Nom du nombre d'éléments	= Nombre d'entrées
Type de données du nombre d'éléments	= Unsigned8
Taille de matrice	
Nom de taille de matrice	= Nombre de liaisons
Type de données de taille de matrice	= Unsigned16

7.4.2.5.17.4 Modèle de variable

CLASSE: Matrice de VARIABLE de structure

ATTRIBUTS:

Identifiant numérique	= 784
Nom de variable	= Liaison
Nombre de champs	= 6
Liste de champs	
Nom de champ	= Link_ID
Nom de type de données de champ	= Unsigned8
Nom de champ	= Intervalle de temps
Nom de type de données de champ	= Unsigned16
Nom de champ	= Channel_Offset
Nom de type de données de champ	= Unsigned8
Nom de champ	= Neighbor_nickname
Nom de type de données de champ	= Unsigned16
Nom de champ	= Options de liaison
Nom de type de données de champ	= Champ binaire
Nom de champ	= Link_type
Nom de type de données de champ	= Enumération
Taille de matrice	= Variable

7.4.2.5.18 Lire liste des graphes

7.4.2.5.18.1 Aperçu du service

Ce service lit un élément dans la Table des graphes à partir de l'appareil de réseau.

7.4.2.5.18.2 Paramètres de demande

Identifiant numérique	= 785
Sous-indice	
Nom de sous-indice	= Indice de Table
Type de données de sous-indice	= Unsigned8

7.4.2.5.18.3 Paramètres de réponse

Identifiant numérique	= 785
Sous-indice	
Nom de sous-indice	= Indice de Table
Type de données de sous-indice	= Unsigned8
Taille de matrice	
Nom de taille de matrice	= Nombre de graphes

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Type de données de taille de matrice = Unsigned8

7.4.2.5.18.4 Modèle de variable de réponse

CLASSE: Matrice de VARIABLE de structure
ATTRIBUTS:

Identifiant numérique	= 785
Nom de variable	= Graphe
Nombre de champs	= 3
Liste de champs	
Nom de champ	= Graph_ID
Nom de type de données de champ	= Unsigned16
Nom de champ	= Nombre de voisins
Nom de type de données de champ	= Unsigned8
Nom de champ	= Liste des voisins
Nom de type de données de champ	= Matrice de Neighbor_nickname
Taille de matrice	= Variable

CLASSE: Type de données
ATTRIBUTS:

Nom de type de données	= Matrice de Neighbor_nickname
Format	= MATRICE
Nombre d'éléments de matrice	= valeur de Nombre de voisins
Type de données d'élément de matrice	= Unsigned16

7.4.2.5.19 Lire fanion d'attribut de voisin

7.4.2.5.19.1 Aperçu du service

Cette commande lit les attributs d'un voisin à partir de l'appareil de réseau.

7.4.2.5.19.2 Paramètres de demande

Identifiant numérique	= 786
Identifiant supplémentaire	
Nom	= Neighbor_nickname
Type de données	= Unsigned8

7.4.2.5.19.3 Paramètres de réponse

Identifiant numérique	= 786
Identifiant supplémentaire	
Nom	= Neighbor_nickname
Type de données	= Unsigned8

7.4.2.5.19.4 Modèle de variable de réponse

CLASSE: Variable simple
ATTRIBUTS:

Identifiant numérique	= 786
Nom de variable	= Fanions de voisins
Nom de type de données	= Champ binaire

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7.4.2.5.20 Lire niveau de signal du voisin

7.4.2.5.20.1 Aperçu du service

Ce service lit le niveau de signal de la Table des voisins à partir de l'appareil de réseau.

7.4.2.5.20.2 Paramètres de demande

Identifiant numérique	= 787
Sous-indice	
Nom de sous-indice	= Indice de Table
Type de données de sous-indice	= Unsigned16
Nombre d'éléments	
Nom du nombre d'éléments	= Nombre d'entrées
Type de données du nombre d'éléments	= Unsigned8

7.4.2.5.20.3 Paramètres de réponse

Identifiant numérique	= 787
Sous-indice	
Nom de sous-indice	= Indice de Table
Type de données de sous-indice	= Unsigned16
Nombre d'éléments	
Nom du nombre d'éléments	= Nombre d'entrées
Type de données du nombre d'éléments	= Unsigned8
Taille de matrice	
Nom de taille de matrice	= Nombre de voisins
Type de données de taille de matrice	= Unsigned16

7.4.2.5.20.4 Modèle de variable

CLASSE:	**Matrice de VARIABLE de structure**
ATTRIBUTS:	
Identifiant numérique	= 787
Nom de variable	= Niveau de signal du voisin
Nombre de champs	= 2
Liste de champs	
Nom de champ	= Neighbor_nickname
Nom de type de données de champ	= Unsigned16
Nom de champ	= Average_RSL
Nom de type de données de champ	= Integer8
Taille de matrice	= Variable

7.4.2.5.21 Rendre compte de l'alarme de trajet défaillant

7.4.2.5.21.1 Aperçu du service

L'appareil édite la réponse d'alarme de trajet défaillant en utilisant ce service.

7.4.2.5.21.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 788
Nom de variable	= Neighbor_nickname
Nom de type de données	= Unsigned16

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7.4.2.5.22 Rendre compte de l'alarme d'itinéraire par source défaillant

7.4.2.5.22.1 Aperçu du service

L'appareil édite la réponse d'alarme d'itinéraire par source défaillant en utilisant ce service.

7.4.2.5.22.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 789
Nom de variable	= Défaillance d'itinéraire par source
Nombre de champs	= 2
Liste de champs	
Nom de champ	= Voisin injoignable
Nom de type de données de champ	= Unsigned16
Nom de champ	= NL MIC
Nom de type de données de champ	= Unsigned32

7.4.2.5.23 Rendre compte de l'alarme d'itinéraire par graphe défaillant

7.4.2.5.23.1 Aperçu du service

L'appareil édite la réponse d'alarme d'itinéraire par graphe défaillant en utilisant ce service.

7.4.2.5.23.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 790
Nom de la variable	= Graph_ID
Nom de type de données	= Unsigned16

7.4.2.5.24 Rendre compte de l'alarme de couche transport défaillante

7.4.2.5.24.1 Aperçu du service

L'appareil édite la réponse d'alarme de couche transport défaillante en utilisant ce service.

7.4.2.5.24.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 791
Nom de variable	= Homologue injoignable
Nom de type de données	= Unsigned16

7.4.2.5.25 Ecrire mapping de temps TUC

7.4.2.5.25.1 Aperçu du service

Dans un appareil de réseau, ce service met l'heure de début de l'ASN zéro à l'heure contenue dans cette demande.

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7.4.2.5.25.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 793
Nom de variable	= Mapping de temps TUC
Nombre de champs	= 2
Liste de champs	
Nom de champ	= Date
Nom de type de données de champ	= Date
Nom de variable	= Heure du Jour
Nom de type de données	= Temps

7.4.2.5.26 Lire mapping de temps TUC

7.4.2.5.26.1 Aperçu du service

Ce service lit le temps TUC auquel l'ASN zéro a débuté, comme réglé dans l'appareil de réseau.

7.4.2.5.26.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 794
Nom de variable	= Mapping de temps TUC
Nombre de champs	= 2
Liste de champs	
Nom de champ	= Date
Nom de type de données de champ	= Date
Nom de variable	= Heure du Jour
Nom de type de données	= Temps

7.4.2.5.27 Ecrire intervalle de temporisateur

7.4.2.5.27.1 Aperçu du service

Ce service établit la durée pour le temporisateur spécifié par le Timer_type (type de temporisateur) dans un appareil de réseau.

7.4.2.5.27.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 795
Nom de variable	= Intervalle
Nombre de champs	= 2
Liste de champs	
Nom de champ	= Timer_type
Nom de type de données	= Enumération
Nom de champ	= Intervalle de temporisateur
Nom de type de données de champ	= Unsigned32

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7.4.2.5.28 Lire intervalle de temporisateur

7.4.2.5.28.1 Aperçu du service

Ce service lit la durée pour le temporisateur spécifié par le Timer_type dans un appareil de réseau.

7.4.2.5.28.2 Modèle de variable de demande

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 796
Nom de champ	= Timer_type
Nom de type de données	= Enumération

7.4.2.5.28.3 Modèle de variable de réponse

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 796
Nom de variable	= Intervalle
Nom de type de données	= Enumération
Nombre de champs	= 2
Liste de champs	
Nom de champ	= Timer_type
Nom de type de données	= Enumération
Nom de champ	= Intervalle de temporisateur
Nom de type de données de champ	= Unsigned32

7.4.2.5.29 Ecrire Puissance de sortie radio

7.4.2.5.29.1 Aperçu du service

Ce service établit la puissance de sortie radio pour un appareil ou une passerelle.

7.4.2.5.29.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 797
Nom de variable	= Puissance d'émission
Nom de type de données	= Integer8

7.4.2.5.30 Lire Puissance de sortie radio

7.4.2.5.30.1 Aperçu du service

Ce service lit la puissance de sortie radio dans un appareil ou une passerelle.

7.4.2.5.30.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 798
Nom de variable	= Puissance d'émission
Nom de type de données	= Integer8

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7.4.2.5.31 Demander Indicateur horaire

7.4.2.5.31.1 Aperçu du service

Ce service est utilisé par un appareil sans fil pour ajouter une connexion de service à un autre appareil sans fil avec des caractéristiques spécifiées de largeur de bande et de latence.

7.4.2.5.31.2 Modèle de variable de demande

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 799
Nom de variable	= Indicateur horaire
Nombre de champs	= 5
Liste de champs	
Nom de champ	= Timetable_ID
Nom de type de données de champ	= Unsigned8
Nom de champ	= Timetable_type
Nom de type de données de champ	= Champ binaire
Nom de champ	= Domaine d'application
Nom de type de données de champ	= Enumération
Nom de champ	= Peer_nickname
Nom de type de données de champ	= Unsigned16
Nom de variable	= Durée
Nom de type de données	= Temps

7.4.2.5.31.3 Modèle de variable de réponse

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 799
Nom de variable	= Indicateur horaire
Nombre de champs	= 6
Liste de champs	
Nom de champ	= Timetable_ID
Nom de type de données de champ	= Unsigned8
Nom de champ	= Timetable_type
Nom de type de données de champ	= Champ binaire
Nom de champ	= Domaine d'application
Nom de type de données de champ	= Enumération
Nom de champ	= Peer_nickname
Nom de type de données de champ	= Unsigned16
Nom de variable	= Durée
Nom de type de données	= Temps
Nom de variable	= Route_ID
Nom de type de données	= Unsigned8

7.4.2.5.32 Lire liste d'indicateur horaires

7.4.2.5.32.1 Aperçu du service

Ce service lit les entrées de la Table des indicateurs horaires à partir de l'appareil de réseau.

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7.4.2.5.32.2 Paramètres de demande

Identifiant numérique	= 800
Sous-indice	
Nom de sous-indice	= Indice de Table
Type de données de sous-indice	= Unsigned8
Nombre d'éléments	
Nom du nombre d'éléments	= Nombre d'entrées
Type de données du nombre d'éléments	= Unsigned8

7.4.2.5.32.3 Paramètres de réponse

Identifiant numérique	= 800
Sous-indice	
Nom de sous-indice	= Indice de Table
Type de données de sous-indice	= Unsigned8
Nombre d'éléments	
Nom du nombre d'éléments	= Nombre d'entrées
Type de données du nombre d'éléments	= Unsigned8
Taille de matrice	
Nom de taille de matrice	= Nombre d'indicateurs horaires
Type de données de taille de matrice	= Unsigned8

7.4.2.5.32.4 Modèle de variable

CLASSE:	**Matrice de VARIABLE de structure**
ATTRIBUTS:	
Identifiant numérique	= 800
Nom de variable	= Indicateur horaire
Nombre de champs	= 6
Liste de champs	
Nom de champ	= Timetable_ID
Nom de type de données de champ	= Unsigned8
Nom de champ	= Timetable_type
Nom de type de données de champ	= Champ binaire
Nom de champ	= Domaine d'application
Nom de type de données de champ	= Enumération
Nom de champ	= Peer_nickname
Nom de type de données de champ	= Unsigned16
Nom de champ	= Service_duration
Nom de type de données de champ	= Temps
Nom de champ	= Route_ID
Nom de type de données de champ	= Unsigned8
Taille de matrice	= Variable

7.4.2.5.33 Supprimer connexion à un indicateur horaire

7.4.2.5.33.1 Aperçu du service

Ce service notifie la suppression d'indicateur horaire à un appareil.

7.4.2.5.33.2 Paramètres de demande

CLASSE:	**Action qualifiée**
ATTRIBUTS:	
Identifiant numérique	= 801

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Nom de variable	= Timetable_ID
Nom de type de données	= Unsigned8
Nom qualificatif	= Raison
Nom de type de données	= Enumération

7.4.2.5.33.3 Paramètres de réponse

CLASSE:	**Action qualifiée**
ATTRIBUTS:	
Identifiant numérique	= 801
Nom de variable	= Timetable_ID
Nom de type de données	= Unsigned8
Nom qualificatif	= Raison
Nom de type de données	= Enumération

7.4.2.5.33.4 Modèle de variable de réponse

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 801
Nom de variable	= Nombre d'indicateurs horaires
Nom de type de données	= Unsigned8

7.4.2.5.34 Lire liste des itinéraires

7.4.2.5.34.1 Aperçu du service

Ce service lit les entrées Table des graphes à partir de l'appareil de réseau.

7.4.2.5.34.2 Paramètres de demande

Identifiant numérique	= 802
Sous-indice	
Nom de sous-indice	= Indice de Table
Type de données de sous-indice	= Unsigned8
Nombre d'éléments	
Nom du nombre d'éléments	= Nombre d'entrées
Type de données du nombre d'éléments	= Unsigned8

7.4.2.5.34.3 Paramètres de réponse

Identifiant numérique	= 802
Sous-indice	
Nom de sous-indice	= Indice de Table
Type de données de sous-indice	= Unsigned8
Nombre d'éléments	
Nom du nombre d'éléments	= Nombre d'entrées
Type de données du nombre d'éléments	= Unsigned8
Taille de matrice	
Nom de taille de matrice	= Nombre d'itinéraires
Type de données de taille de matrice	= Unsigned8

7.4.2.5.34.4 Modèle de variable

CLASSE:	**Matrice de VARIABLE de structure**
ATTRIBUTS:	

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Identifiant numérique = 802
Nom de variable = Itinéraire
Nombre de champs = 5
Liste de champs
Nom de champ = Itinéraires restants
Nom de type de données de champ = Unsigned8
Nom de champ = Route_ID
Nom de type de données de champ = Unsigned8
Nom de champ = Surnom de l'appareil de destination
Nom de type de données de champ = Unsigned16
Nom de champ = Graph_ID
Nom de type de données de champ = Unsigned16
Nom de champ = Fanion d'itinéraire par source
Nom de type de données de champ = Unsigned8
Taille de matrice = Variable

7.4.2.5.35 Lire itinéraire par source

7.4.2.5.35.1 Aperçu du service

Ce service lit le contenu d'un itinéraire par source particulier.

7.4.2.5.35.2 Paramètres de demande

Identifiant numérique = 803
Identifiant supplémentaire
Nom = Route_ID
Type de données = Unsigned8

7.4.2.5.35.3 Paramètres de réponse

Identifiant numérique = 803
Identifiant supplémentaire
Nom = Route_ID
Type de données = Unsigned8

7.4.2.5.35.4 Modèle de variable

CLASSE: **VARIABLE DE STRUCTURE**
ATTRIBUTS:
Identifiant numérique = 803
Nom de variable = Itinéraires par source
Nombre de champs = 2
Liste de champs
Nom de champ = Nombre de sauts
Nom de type de données de champ = Unsigned8
Nom de champ = Liste des sauts
Nom de type de données de champ = Matrice de sauts

CLASSE: **Type de données**
ATTRIBUTS:
Nom de type de données = Matrice de sauts
Format = MATRICE
Nombre d'éléments de matrice = Valeur de nombre de sauts
Type de données d'élément de matrice = Unsigned16

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7.4.2.5.36 Lire mode CCA

7.4.2.5.36.1 Aperçu du service

Ce service lit le mode évaluation de canal libre (CCA) dans un appareil de réseau.

7.4.2.5.36.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 804
Nom de variable	= mode CCA
Nom de type de données	= Enumération

7.4.2.5.37 Ecrire mode CCA

7.4.2.5.37.1 Aperçu du service

Ce service écrit le mode évaluation de canal libre (CCA) dans un appareil de réseau.

7.4.2.5.37.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 805
Nom de variable	= mode CCA
Nom de type de données	= Enumération

7.4.2.5.38 Lire supertrame de terminal portatif

7.4.2.5.38.1 Aperçu du service

Ce service est utilisé pour déterminer si la supertrame de terminal portatif dans un appareil en réseau est active.

7.4.2.5.38.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 806
Nom de variable	= Supertrame
Nombre de champs	= 3
Liste de champs	
Nom de champ	= Superframe_ID
Nom de type de données de champ	= Unsigned8
Nom de champ	= Num_Slots
Nom de type de données de champ	= Unsigned16
Nom de variable	= Mode supertrame
Nom de type de données de champ	= Champ binaire

7.4.2.5.39 Ecrire Supertrame de terminal portatif

7.4.2.5.39.1 Aperçu du service

Ce service permet à un terminal portatif de demander à ce que l'équipement en réseau active la supertrame du terminal portatif afin que la maintenance puisse être effectuée.

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7.4.2.5.39.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 807
Nom de variable	= Supertrame
Nombre de champs	= 2
Liste de champs	
Nom de variable	= Superframe_ID
Nom de type de données de champ	= Unsigned8
Nom de variable	= Mode supertrame
Nom de type de données de champ	= Champ binaire

7.4.2.5.40 Lire Nombre de sauts de vie résiduelle de paquet

7.4.2.5.40.1 Aperçu du service

Ce service lit la valeur courante du nombre de sauts de vie résiduelle de paquet configuré pour un appareil de réseau.

7.4.2.5.40.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 808
Nom de variable	= Saut de vie résiduelle
Nom de type de données	= Unsigned8

7.4.2.5.41 Ecrire Nombre de sauts de vie résiduelle de paquet

7.4.2.5.41.1 Aperçu du service

Ce service écrit la valeur du Nombre de sauts de vie résiduelle de paquet dans un appareil de réseau.

7.4.2.5.41.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 809
Nom de variable	= Saut de vie résiduelle
Nom de type de données	= Unsigned8

7.4.2.5.42 Lire Join_priority

7.4.2.5.42.1 Aperçu du service

Ce service lit la valeur courante de Join_priority dans un appareil de réseau.

7.4.2.5.42.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 810
Nom de variable	= Join_priority
Nom de type de données	= Unsigned8

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7.4.2.5.43 Ecrire Join_priority

7.4.2.5.43.1 Aperçu du service

Ce service écrit la valeur de Join_priority dans un appareil de réseau.

7.4.2.5.43.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 811
Nom de variable	= Join_priority
Nom de type de données	= Unsigned8

7.4.2.5.44 Lire Priority_threshold de réception

7.4.2.5.44.1 Aperçu du service

Ce service lit la valeur courante de Priority_threshold de réception dans un appareil de réseau.

7.4.2.5.44.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 812
Nom de variable	= Priority_threshold
Nom de type de données	= Unsigned8

7.4.2.5.45 Ecrire Priority_threshold de réception

7.4.2.5.45.1 Aperçu du service

Ce service écrit la valeur de Priority_threshold de réception dans un appareil de réseau.

7.4.2.5.45.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 813
Nom de variable	= Priority_threshold
Nom de type de données	= Unsigned8

7.4.2.5.46 Lire liste des appareils

7.4.2.5.46.1 Aperçu du service

Ce service lit les entrées dans la Table des appareils pour le type de liste spécifié par le "code d'appareil" dans la demande.

7.4.2.5.46.2 Paramètres de demande

Identifiant numérique	= 814
Identifiant supplémentaire	
Nom	= Code d'appareil
Type de données	= Enumération
Sous-indice	
Nom de sous-indice	= Indice de Table

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Type de données de sous-indice	= Unsigned16
Nombre d'éléments	
Nom du nombre d'éléments	= Nombre d'entrées
Type de données du nombre d'éléments	= Unsigned8

7.4.2.5.46.3 Paramètres de réponse

Identifiant numérique	= 802
Identifiant supplémentaire	
Nom	= Code d'appareil
Type de données	= Enumération
Sous-indice	
Nom de sous-indice	= Indice de Table
Type de données de sous-indice	= Unsigned16
Nombre d'éléments	
Nom du nombre d'éléments	= Nombre d'entrées
Type de données du nombre d'éléments	= Unsigned8
Taille de matrice	
Nom de taille de matrice	= Nombre d'appareils
Type de données de taille de matrice	= Unsigned16

7.4.2.5.46.4 Modèle de variable

CLASSE:	**Matrice de variable simple**
ATTRIBUTS:	
Identifiant numérique	= 814
Nom de variable	= Liste des appareils
Nom de type de données	= Identifiant unique
Taille de matrice	= Variable

7.4.2.5.47 Ajouter Entrée de liste d'appareils

7.4.2.5.47.1 Aperçu du service

Ce service ajoute un appareil dans la Table des appareils pour le type de liste spécifié par le code d'appareil.

7.4.2.5.47.2 Paramètres de demande

CLASSE:	**Action qualifiée**
ATTRIBUTS:	
Identifiant numérique	= 815
Nom de variable	= Code d'appareil
Nom de type de données	= Enumération
Nom qualificatif	= ID unique
Nom de type de données	= Identifiant unique

7.4.2.5.47.3 Paramètres de réponse

CLASSE:	**Action qualifiée**
ATTRIBUTS:	
Identifiant numérique	= 815
Nom de variable	= Code d'appareil
Nom de type de données	= Enumération
Nom qualificatif	= ID unique
Nom de type de données	= Identifiant unique

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7.4.2.5.47.4 Modèle de variable de réponse

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 815
Nom de variable	= Nombre d'appareils
Nom de type de données	= Unsigned16

7.4.2.5.48 Supprimer Entrée de liste d'appareils

7.4.2.5.48.1 Aperçu du service

Ce service supprime un appareil dans la Table des appareils pour le type de liste spécifié par le code d'appareil dans une passerelle ou un gestionnaire de réseau.

7.4.2.5.48.2 Paramètres de demande

CLASSE:	**Action qualifiée**
ATTRIBUTS:	
Identifiant numérique	= 816
Nom de variable	= Code d'appareil
Nom de type de données	= Enumération
Nom qualificatif	= ID unique
Nom de type de données	= Identifiant unique

7.4.2.5.48.3 Paramètres de réponse

CLASSE:	**Action qualifiée**
ATTRIBUTS:	
Identifiant numérique	= 816
Nom de variable	= Code d'appareil
Nom de type de données	= Enumération
Nom qualificatif	= ID unique
Nom de type de données	= Identifiant unique

7.4.2.5.48.4 Modèle de variable de réponse

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 816
Nom de variable	= Nombre d'appareils
Nom de type de données	= Unsigned16

7.4.2.5.49 Lire liste noire de canaux

7.4.2.5.49.1 Aperçu du service

Ce service lit la liste noire de canaux courante et la liste noire qui doit être utilisée après le prochain redémarrage.

7.4.2.5.49.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 817
Nom de variable	= Lire liste noire de canaux

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Nombre de champs	= 3
Liste de champs	
Nom de champ	= Nombre de canaux
Nom de type de données de champ	= Unsigned8
Nom de champ	= Carte courante de canaux
Nom de type de données de champ	= Champ binaire
Nom de champ	= Carte de canaux en instance
Nom de type de données de champ	= Champ binaire

7.4.2.5.50 Ecrire Liste noire de canaux

7.4.2.5.50.1 Aperçu du service

Ce service écrit la carte de canaux en instance, qui est la liste noire, dans la passerelle. Il est utilisé au redémarrage suivant.

7.4.2.5.50.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 818
Nom de variable	= Lire liste noire de canaux
Nombre de champs	= 2
Liste de champs	
Nom de champ	= Nombre de canaux
Nom de type de données de champ	= Unsigned8
Nom de champ	= Carte de canaux en instance
Nom de type de données de champ	= Champ binaire

7.4.2.5.51 Lire Exposant de repli

7.4.2.5.51.1 Aperçu du service

Ce service lit la valeur courante de Max_backoff_exp dans un appareil de réseau.

7.4.2.5.51.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 819
Nom de variable	= Max_backoff_exp
Nom de type de données	= Unsigned8

7.4.2.5.52 Ecrire Exposant de repli

7.4.2.5.52.1 Aperçu du service

Ce service écrit la valeur de Max_backoff_exp dans un appareil de réseau.

7.4.2.5.52.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 820
Nom de variable	= Max_backoff_exp
Nom de type de données	= Unsigned8

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7.4.2.5.53 Ecrire mode d'accès au réseau

7.4.2.5.53.1 Aperçu du service

Ce service écrit la valeur du mode d'accès au réseau dans un appareil de réseau.

7.4.2.5.53.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 821
Nom de variable	= Mode d'accès au réseau
Nom de type de données	= Enumération

7.4.2.5.54 Lire mode d'accès au réseau

7.4.2.5.54.1 Aperçu du service

Ce service lit la valeur courante du mode d'accès au réseau dans un appareil de réseau.

7.4.2.5.54.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 822
Nom de variable	= Mode d'accès au réseau
Nom de type de données	= Enumération

7.4.2.5.55 Demander session

7.4.2.5.55.1 Aperçu du service

Ce service demande une session de monodiffusion d'un terminal portatif à un appareil de réseau.

7.4.2.5.55.2 Paramètres de demande

Identifiant numérique	= 823
Identifiant supplémentaire	
Nom	= Peer_nickname
Type de données	= Unsigned16

7.4.2.5.55.3 Paramètres de réponse

Identifiant numérique	= 823
Identifiant supplémentaire	
Nom	= Peer_nickname
Type de données	= Unsigned16

7.4.2.5.55.4 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 823
Nom de variable	= Session
Nombre de champs	= 2
Liste de champs	
Nom de champ	= Peer_nonce_counter

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Nom de type de données de champ = Unsigned32
Nom de champ = Join_key
Nom de type de données de champ = Clé de sécurité

7.4.2.6 Services de passerelle et de gestionnaire de réseau

7.4.2.6.1 Lire Identité d'appareil de réseau en utilisant l'identifiant unique

7.4.2.6.1.1 Aperçu du service

Ce service lit dans la passerelle les informations relatives à l'identité de l'appareil avec l'identifiant d'appareil correspondant.

7.4.2.6.1.2 Paramètres de demande

Identifiant numérique = 832
Identifiant supplémentaire
Nom = ID unique
Nom de type de données = Identifiant unique

7.4.2.6.1.3 Paramètres de réponse

Identifiant numérique = 832
Identifiant supplémentaire
Nom = ID unique
Nom de type de données = Identifiant unique

7.4.2.6.1.4 Modèle de variable

CLASSE: **VARIABLE DE STRUCTURE**
ATTRIBUTS:
Identifiant numérique = 832
Nom de variable = Identité de l'appareil
Nombre de champs = 2
Liste de champs
Nom de champ = Surnom d'appareil
Nom de type de données de champ = Unsigned16
Nom de champ = Long_tag
Nom de type de données de champ = Latin-1
Longueur en octets = 32

7.4.2.6.2 Lire Santé des voisins de l'appareil

7.4.2.6.2.1 Aperçu du service

Ce service lit, à partir de la passerelle, les informations relatives à la qualité de la connexion vers chaque voisin actif ou voisin potentiel pour l'appareil spécifié dans la demande.

7.4.2.6.2.2 Paramètres de demande

Identifiant numérique = 833
Identifiant supplémentaire
Nom = ID unique
Nom de type de données = Identifiant unique
Sous-indice
Nom de sous-indice = Indice de Table
Type de données de sous-indice = Unsigned8

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Nombre d'éléments
Nom du nombre d'éléments = Nombre d'entrées
Type de données du nombre d'éléments = Unsigned8

7.4.2.6.2.3 Paramètres de réponse

Identifiant numérique = 833
Identifiant supplémentaire
Nom = ID unique
Nom de type de données = Identifiant unique
Sous-indice
Nom de sous-indice = Indice de Table
Type de données de sous-indice = Unsigned8
Nombre d'éléments
Nom du nombre d'éléments = Nombre d'entrées
Type de données du nombre d'éléments = Unsigned8

7.4.2.6.2.4 Modèle de variable

CLASSE: **Matrice de VARIABLE de structure**
ATTRIBUTS:
Identifiant numérique = 833
Nom de variable = Santé des voisins
Nombre de champs = 5
Liste de champs
Nom de champ = Neighbor_nickname
Nom de type de données de champ = Unsigned16
Nom de champ = Average_RSL
Nom de type de données de champ = Integer8
Nom de champ = Packets_transmitted
Nom de type de données de champ = Unsigned32
Nom de champ = Missed_ACK_packets
Nom de type de données de champ = Unsigned32
Nom de champ = Packets_received
Nom de type de données de champ = Unsigned32
Nom de champ = Fanions de voisins
Nom de type de données de champ = Champ binaire
Taille de matrice = Variable

7.4.2.6.3 Lire Informations de topologie du réseau

7.4.2.6.3.1 Aperçu du service

Ce service lit un élément dans la Table des graphes pour l'appareil de réseau spécifié à partir de la passerelle. En lisant la liste des appareils au moyen du service Lire liste des appareils, Commande 814, la Couche Application peut déterminer le nombre de graphes auxquels un appareil particulier participe et utilise pour ce faire le service "Lire Liste des graphes" (voir 7.4.2.5.18). Ce service peut alors être émis autant de fois que nécessaire pour déterminer les Graph_ID spécifiques auxquels l'appareil participe.

7.4.2.6.3.2 Paramètres de demande

Identifiant numérique = 834
Identifiant supplémentaire
Nom = ID unique
Nom de type de données = Identifiant unique

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Sous-indice
Nom de sous-indice = Indice de Table
Type de données de sous-indice = Unsigned16

7.4.2.6.3.3 Paramètres de réponse

Identifiant numérique = 834
Identifiant supplémentaire
Nom = ID unique
Nom de type de données = Identifiant unique
Sous-indice
Nom de sous-indice = Indice de Table
Type de données de sous-indice = Unsigned16
Taille de matrice
Nom de taille de matrice = Nombre de graphes
Type de données de taille de matrice = Unsigned16

7.4.2.6.3.4 Modèle de variable de réponse

CLASSE: **Matrice de VARIABLE de structure**
ATTRIBUTS:
Identifiant numérique = 834
Nom de variable = Graphe
Nombre de champs = 3
Liste de champs
Nom de champ = Graph_ID
Nom de type de données de champ = Unsigned16
Nom de champ = Nombre de voisins
Nom de type de données de champ = Unsigned16
Nom de champ = Liste des voisins
Nom de type de données de champ = Matrice des voisins
Taille de matrice = Variable

CLASSE: **Type de données**
ATTRIBUTS:
Nom de type de données de champ = Matrice des voisins
Format = MATRICE
Nombre d'éléments de matrice = valeur de Nombre de voisins
Type de données d'élément de matrice = Unsigned16

7.4.2.6.4 Lire liste des messages d'édition de données

7.4.2.6.4.1 Aperçu du service

Ce service lit, dans la passerelle, la liste des messages d'édition de données à laquelle participe l'appareil spécifié, y compris le nombre de commandes de mode "édition de données" auxquelles l'appareil spécifié participe. L'application demandeuse peut utiliser ce service pour dresser la liste de tout le trafic du mode "édition de données" du système.

7.4.2.6.4.2 Paramètres de demande

Identifiant numérique = 835
Identifiant supplémentaire
Nom = ID unique
Nom de type de données = Identifiant unique

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7.4.2.6.4.3 Paramètres de réponse

Identifiant numérique	= 835
Identifiant supplémentaire	
Nom	= ID unique
Nom de type de données	= Identifiant unique

7.4.2.6.4.4 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 835
Nom de variable	= Liste des messages d'édition de données
Nombre de champs	= 2
Liste de champs	
Nom de champ	= Nombre d'édition de données
Nom de type de données de champ	= Unsigned8
Nom de champ	= Edition de données
Nom de type de données de champ	= Matrice d'édition de données

CLASSE:	**Type de données**
ATTRIBUTS:	
Nom de type de données	= Matrice d'édition de données
Format = MATRICE	
Nombre d'éléments de matrice	= Valeur de nombre d'édition de données
Type de données d'élément de matrice	= Edition de données

CLASSE:	**Type de données**
ATTRIBUTS:	
Nom de type de données	= Edition de données
Format	= STRUCTURE
Nombre de champs	= 2
Liste de champs	
Nom de champ	= Commande d'édition
Nom de type de données de champ	= Unsigned16
Nom de champ	= Nombre de paquets
Nom de type de données de champ	= Unsigned32

7.4.2.6.5 Purger Réponses mises en cache pour un appareil

7.4.2.6.5.1 Aperçu du service

Ce service purge les réponses mises en cache dans la passerelle, pour l'appareil spécifié.

7.4.2.6.5.2 Paramètres de demande

CLASSE:	**Action qualifiée**
ATTRIBUTS:	
Identifiant numérique	= 836
Nom de variable	= ID unique
Nom de type de données	= Identifiant unique

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7.4.2.6.6 Lire statistiques d'appareil de réseau

7.4.2.6.6.1 Aperçu du service

Ce service lit dans la passerelle les statistiques de l'appareil spécifié.

7.4.2.6.6.2 Paramètres de demande

Identifiant numérique	= 840
Identifiant supplémentaire	
Nom	= ID unique
Nom de type de données	= Identifiant unique

7.4.2.6.6.3 Paramètres de réponse

Identifiant numérique	= 840
Identifiant supplémentaire	
Nom	= ID unique
Nom de type de données	= Identifiant unique

7.4.2.6.6.4 Modèle de variable de réponse

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 840
Nom de variable	= Statistiques de l'appareil
Nombre de champs	= 25
Liste de champs	
Nom de champ	= Nombre de graphes
Nom de type de données de champ	= Unsigned16
Nom de champ	= Nombre de supertrames
Nom de type de données de champ	= Unsigned16
Nom de champ	= Compteur de liaisons
Nom de type de données de champ	= Unsigned16
Nom de champ	= Nombre de voisins
Nom de type de données de champ	= Unsigned8
Nom de champ	= Latence amont
Nom de type de données de champ	= Temps
Nom de champ	= Nombre de rattachements
Nom de type de données de champ	= Unsigned16
Nom de champ	= Date de rattachement
Nom de type de données de champ	= Date
Nom de champ	= Heure de rattachement
Nom de type de données de champ	= Temps
Nom de champ	= Paquets générés
Nom de type de données de champ	= Unsigned32
Nom de champ	= Paquets terminés
Nom de type de données de champ	= Unsigned32
Nom de champ	= Défaillances MIC de la DLL
Nom de type de données de champ	= Unsigned32
Nom de champ	= Défaillances MIC de la NL
Nom de type de données de champ	= Unsigned32
Nom de champ	= Erreurs de CRC
Nom de type de données de champ	= Unsigned32
Nom de champ	= Paquets manqués

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Nom de type de données de champ = Unsigned32
Nom de champ = Compteur de nonces manqués
Nom de type de données de champ = Unsigned32
Nom de champ = Ecart type de latence amont
Nom de type de données de champ = Temps
Nom de champ = Latence aval moyenne
Nom de type de données de champ = Temps
Nom de champ = Ecart-type de latence aval
Nom de type de données de champ = Temps
Nom de champ = Disponibilité amont
Nom de type de données de champ = Temps
Nom de champ = Disponibilité aval
Nom de type de données de champ = Temps
Nom de champ = File d'attente maximale
Nom de type de données de champ = Unsigned32
Nom de champ = File d'attente moyenne
Nom de type de données de champ = Float32
Nom de champ = Statut de connexion
Nom de type de données de champ = Champ binaire
Nom de champ = Statut de santé
Nom de type de données de champ = Champ binaire
Nom de champ = Compteur de sessions
Nom de type de données de champ = Unsigned8

7.4.2.6.7 Lire Identité d'appareil de réseau en utilisant le surnom

7.4.2.6.7.1 Aperçu du service

Ce service lit dans la passerelle les informations relatives à l'identité de l'appareil avec le surnom d'appareil correspondant.

7.4.2.6.7.2 Paramètres de demande

Identifiant numérique = 841
Identifiant supplémentaire
Nom = Device_nickname
Type de données = Unsigned16

7.4.2.6.7.3 Paramètres de réponse

Identifiant numérique = 841
Identifiant supplémentaire
Nom = Device_nickname
Type de données = Unsigned16

7.4.2.6.7.4 Modèle de variable

CLASSE: **VARIABLE DE STRUCTURE**
ATTRIBUTS:
Identifiant numérique = 841
Nom de variable = Identité de l'appareil
Nombre de champs = 2
Liste de champs
Nom de champ = ID unique
Nom de type de données de champ = Identifiant unique

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Nom de champ	= Long_tag
Nom de type de données de champ	= Latin-1
Longueur en octets	= 32

7.4.2.6.8 Ecrire Fanions de programmation d'appareil de réseau

7.4.2.6.8.1 Aperçu du service

Ce service permet à l'utilisateur de demander une prise en compte spéciale d'un appareil lorsque le gestionnaire de réseau crée des programmes.

7.4.2.6.8.2 Paramètres de demande

Identifiant numérique	= 842
Identifiant supplémentaire	
Nom	= ID unique
Nom de type de données	= Identifiant unique

7.4.2.6.8.3 Paramètres de réponse

Identifiant numérique	= 842
Identifiant supplémentaire	
Nom	= ID unique
Nom de type de données	= Identifiant unique

7.4.2.6.8.4 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 842
Nom de variable	= Fanions de programmation
Nom de type de données	= Champ binaire

7.4.2.6.9 Lire Fanions de programmation d'appareil de réseau

7.4.2.6.9.1 Aperçu du service

Ce service lit les attributs de l'appareil de réseau dont le gestionnaire de réseau peut tenir compte lors de la création de programmes.

7.4.2.6.9.2 Paramètres de demande

Identifiant numérique	= 843
Identifiant supplémentaire	
Nom	= ID unique
Nom de type de données	= Identifiant unique

7.4.2.6.9.3 Paramètres de réponse

Identifiant numérique	= 843
Identifiant supplémentaire	
Nom	= ID unique
Nom de type de données	= Identifiant unique

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7.4.2.6.9.4 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 843
Nom de variable	= Fanions de programmation
Nom de type de données	= Champ binaire

7.4.2.6.10 Lire Contraintes du réseau

7.4.2.6.10.1 Aperçu du service

Ce service lit le réglage courant de la stratégie de gestion de réseau et le nombre de messages de demande/réponse par 10 s.

7.4.2.6.10.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 844
Nom de variable	= Contraintes du réseau
Nombre de champs	= 2
Liste de champs	
Nom de champ	= Fanions d'optimisation
Nom de type de données de champ	= Champ binaire
Nom de champ	= Nombre de paires de messages
Nom de type de données de champ	= Unsigned8

7.4.2.6.11 Ecrire Contraintes du réseau

7.4.2.6.11.1 Aperçu du service

Ce service écrit le réglage courant de la stratégie de gestion de réseau et le nombre de messages de demande / réponse par 10 s.

7.4.2.6.11.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 845
Nom de variable	= Contraintes du réseau
Nombre de champs	= 2
Liste de champs	
Nom de champ	= Fanions d'optimisation
Nom de type de données de champ	= Champ binaire
Nom de champ	= Nombre de paires de messages
Nom de type de données de champ	= Unsigned8

7.4.2.6.12 Lire statistiques réseau

7.4.2.6.12.1 Aperçu du service

Ce service lit les données statistiques globales de santé du réseau.

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7.4.2.6.12.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 846
Nom de variable	= Statistiques réseau
Nombre de champs	= 8
Liste de champs	
Nom de champ	= Débit
Nom de type de données de champ	= Float32
Nom de champ	= Utilisation
Nom de type de données de champ	= Float32
Nom de champ	= Disponibilité
Nom de type de données de champ	= Float32
Nom de champ	= Latence
Nom de type de données de champ	= Temps
Nom de champ	= Ecart type de latence
Nom de type de données de champ	= Temps
Nom de champ	= Taux d'erreurs sur les paquets
Nom de type de données de champ	= Float32
Nom de champ	= Paquets éliminés
Nom de type de données de champ	= Unsigned32
Nom de champ	= Echecs de rattachement
Nom de type de données de champ	= Unsigned32

7.4.2.6.13 Transférer liste de réseau à liste blanche

7.4.2.6.13.1 Aperçu du service

Ce service copie la liste de réseau vers la liste blanche.

7.4.2.6.13.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 847
Nom de variable	= Nombre
Nom de type de données	= Unsigned16

7.4.2.6.14 Générer clé

7.4.2.6.14.1 Aperçu du service

Ce service est utilisé par une application pour obtenir une clé aléatoire du gestionnaire de sécurité.

7.4.2.6.14.2 Paramètres de demande

Identifiant numérique	= 848
Identifiant supplémentaire	
Nom de champ	= Valeur
Type de données de champ	= Unsigned8

7.4.2.6.14.3 Paramètres de réponse

Identifiant numérique	= 848
Identifiant supplémentaire	

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Nom de champ	= Valeur
Type de données de champ	= Unsigned8

7.4.2.6.14.4 Modèle de variable de réponse

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 848
Nom de variable	= Clé
Nom de type de données	= Clé de sécurité

7.4.2.6.15 Lire clé de rattachement d'appareil

7.4.2.6.15.1 Aperçu du service

Cette commande lit une nouvelle clé de rattachement aléatoire pour l'appareil spécifié.

7.4.2.6.15.2 Paramètres de demande

Identifiant numérique	= 849
Identifiant supplémentaire	
Nom de champ	= Valeur
Type de données de champ	= Unsigned8
Nom	= ID unique
Nom de type de données	= Identifiant unique

7.4.2.6.15.3 Paramètres de réponse

Identifiant numérique	= 849
Identifiant supplémentaire	
Nom de champ	= Valeur
Type de données de champ	= Unsigned8
Nom	= ID unique
Nom de type de données	= Identifiant unique

7.4.2.6.15.4 Modèle de variable de réponse

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 849
Nom de variable	= Clé
Nom de type de données	= Clé de sécurité

7.4.2.6.16 Ecrire clé de rattachement d'appareil

7.4.2.6.16.1 Aperçu du service

Cette commande écrit la clé de rattachement spécifiée vers l'appareil identifié.

7.4.2.6.16.2 Modèle de variable

Identifiant numérique	= 850
Nom de variable	= Valeur
Nom de type de variable	= Identifiant unique
Nom de variable	= Clé
Nom de type de données	= Clé de sécurité

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7.4.2.6.17 Changer clé maintenant

7.4.2.6.17.1 Aperçu du service

Ce service demande au gestionnaire de sécurité de changer les clés (réseau, rattachement ou sessions) dans l'appareil spécifié.

7.4.2.6.17.2 Paramètres de demande

Identifiant numérique	= 851
Identifiant supplémentaire	
Nom de champ	= Valeur
Type de données de champ	= Unsigned8
Nom de champ	= Fanions de changement de clé
Type de données de champ	= Champ binaire
Nom de champ	= ID unique
Type de données de champ	= Identifiant unique

7.4.2.6.17.3 Paramètres de réponse

Identifiant numérique	= 851
Identifiant supplémentaire	
Nom de champ	= Valeur
Type de données de champ	= Unsigned8
Nom de champ	= Fanions de changement de clé
Type de données de champ	= Champ binaire
Nom de champ	= ID unique
Type de données de champ	= Identifiant unique

7.4.2.6.17.4 Modèle de variable de réponse

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 851
Nom de variable	= Changer l'heure
Nom de type de données	= Temps

7.4.2.6.18 Lire Points de consigne de péremption des données

7.4.2.6.18.1 Aperçu du service

Cette commande est utilisée par une application pour lire le temporisateur de données périmées et le point de consigne du compteur.

7.4.2.6.18.2 Modèle de variable

Identifiant numérique	= 852
Nom de variable	= Temporisateur de données périmées
Variable type Nom	= Float32
Nom de variable	= Point de consigne de péremption des données
Nom de type de données	= Unsigned8

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7.4.2.6.19 Ecrire Temporisateur de données périmées

7.4.2.6.19.1 Aperçu du service

Cette commande est utilisée par une application pour écrire le temporisateur de données périmées.

7.4.2.6.19.2 Modèle de variable

Identifiant numérique	= 853
Nom de variable	= Temporisateur de données périmées
Variable type Nom	= Float32

7.4.2.6.20 Ecrire Points de consigne de péremption des données

7.4.2.6.20.1 Aperçu du service

Cette commande est utilisée par une application pour écrire le point de consigne de péremption des données.

7.4.2.6.20.2 Modèle de variable

Identifiant numérique	= 854
Nom de variable	= Nombre de données périmées
Variable type Nom	= Unsigned8

7.4.2.6.21 Lire session étendue

7.4.2.6.21.1 Aperçu du service

Ce service lit les entrées dans la Table des sessions à partir d'une passerelle ou d'un gestionnaire de réseau.

7.4.2.6.21.2 Paramètres de demande

Identifiant numérique	= 855
Identifiant supplémentaire	
Nom	= Indice de session
Type de données	= Unsigned16

7.4.2.6.21.3 Paramètres de réponse

Identifiant numérique	= 855
Identifiant supplémentaire	
Nom	= Indice de session
Type de données	= Unsigned16

7.4.2.6.21.4 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 855
Nom de variable	= Session
Nombre de champs	= 6
Liste de champs	
Nom de champ	= Nombre de sessions
Nom de type de données de champ	= Unsigned8

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Nom de champ	= Type de session
Nom de type de données de champ	= Enumération
Nom de champ	= Surnom d'homologue
Nom de type de données de champ	= Unsigned16
Nom de champ	= Identifiant unique d'homologue
Nom de type de données de champ	= Identifiant unique
Nom de champ	= Compteur de nonces d'homologue
Nom de type de données de champ	= Unsigned32
Nom de champ	= Compteur de nonces d'appareil
Nom de type de données de champ	= Unsigned32

7.4.2.6.22 Lire réglages de suspension d'appareil

7.4.2.6.22.1 Aperçu du service

Cette commande lit les réglages courants de suspension à partir d'un appareil.

7.4.2.6.22.2 Modèle de variable

Identifiant numérique	= 856
Nom de variable	= Heure de suspension
Nom de type de variable	= Temps
Nom de variable	= Heure de reprise
Nom de type de données	= Temps

7.4.2.6.23 Lire niveau de sécurité annoncé

7.4.2.6.23.1 Aperçu du service

Cette commande est utilisée pour lire le niveau de sécurité pris en charge par le gestionnaire de réseau.

7.4.2.6.23.2 Modèle de variable

Identifiant numérique	= 857
Nom de variable	= Niveau de sécurité
Nom de type de variable	= Enumération

7.4.2.6.24 Réinitialiser statistiques de disponibilité

7.4.2.6.24.1 Aperçu du service

Cette commande donne à la passerelle l'instruction de réinitialiser les statistiques de disponibilité.

7.4.2.6.24.2 Modèle de variable

Identifiant numérique	= 858
Nom de variable	= ID unique
Nom de type de variable	= Identifiant unique

7.4.2.6.25 Lire statut d'annonce active

7.4.2.6.25.1 Aperçu du service

Cette commande renvoie les réglages d'annonce courants.

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7.4.2.6.25.2 Modèle de variable

Identifiant numérique	= 859
Nom de variable	= Temps de déconnexion d'annonce
Nom de type de variable	= Temps
Nom de variable	= Période d'annonce
Nom de type de variable	= Temps

7.4.2.6.26 Lire mode clé de rattachement

7.4.2.6.26.1 Aperçu du service

Cette commande lit le mode clé de rattachement en cours d'utilisation par le gestionnaire de réseau.

7.4.2.6.26.2 Modèle de variable

Identifiant numérique	= 860
Nom de variable	= Mode clé de rattachement
Nom de type de variable	= Enumération

7.4.2.6.27 Ecrire mode clé de rattachement

7.4.2.6.27.1 Aperçu du service

Cette commande écrit le mode clé de rattachement en cours d'utilisation par le gestionnaire de réseau.

7.4.2.6.27.2 Modèle de variable

Identifiant numérique	= 861
Nom de variable	= Mode clé de rattachement
Nom de type de variable	= Enumération

7.4.2.6.28 Lire Indicateur horaire par identifiant

7.4.2.6.28.1 Aperçu du service

Ce service lit l'indicateur horaire spécifié par l'identifiant par d'indicateur horaire.

7.4.2.6.28.2 Paramètres de demande

Identifiant numérique	= 862
Identifiant supplémentaire	
Nom	= Identifiant de calendrier
Type de données	= Unsigned8

7.4.2.6.28.3 Paramètres de réponse

Identifiant numérique	= 862
Identifiant supplémentaire	
Nom	= Identifiant de calendrier
Type de données	= Unsigned8

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7.4.2.6.28.4 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 862
Nom de variable	= Entrée de la Table des indicateurs horaires
Nombre de champs	= 5
Liste de champs	
Nom de champ	= Fanions de demande
Nom de type de données de champ	= Champ binaire
Nom de champ	= Domaine d'application
Nom de type de données de champ	= Enumération
Nom de champ	= Surnom
Nom de type de données de champ	= Unsigned16
Nom de champ	= Période
Nom de type de données de champ	= Temps
Nom de champ	= ID d'itinéraire
Nom de type de données de champ	= Unsigned8

7.4.2.7 Services de configuration de gestion réseau

7.4.2.7.1 Déconnecter appareil

7.4.2.7.1.1 Aperçu du service

Ce service permet au gestionnaire de réseau de faire sortir de force un appareil du réseau.

7.4.2.7.1.2 Paramètres de demande

CLASSE:	**Action qualifiée**
ATTRIBUTS:	
Identifiant numérique	= 960
Nom de variable	= Cause de la déconnexion
Nom de type de données	= Enumération

7.4.2.7.1.3 Paramètres de réponse

CLASSE:	**Action qualifiée**
ATTRIBUTS:	
Identifiant numérique	= 960
Nom de variable	= Cause de la déconnexion
Nom de type de données	= Enumération

7.4.2.7.2 Ecrire clé réseau

7.4.2.7.2.1 Aperçu du service

Ce service écrit la clé réseau dans un appareil de réseau.

7.4.2.7.2.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 961
Nom de variable	= Clé réseau
Nombre de champs	= 2
Liste de champs	

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Nom de variable	= Join_key
Nom de type de données	= Clé de sécurité
Nom de champ	= Heure de changement de clé
Nom de type de données de champ	= Unsigned40

7.4.2.7.3 Ecrire surnom d'appareil

7.4.2.7.3.1 Aperçu du service

Ce service écrit un surnom d'appareil de réseau.

7.4.2.7.3.2 Modèle de variable

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 962
Nom de variable	= Surnom d'appareil
Nom de type de données	= Unsigned16

7.4.2.7.4 Ecrire session

7.4.2.7.4.1 Aperçu du service

Ce service lit les paramètres de session indispensables pour établir une session entre l'appareil de destination (de cette demande) et l'appareil homologue spécifié dans la demande.

7.4.2.7.4.2 Modèle de variable de demande

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 963
Nom de variable	= Entrée de session
Nombre de champs	= 7
Nom de champ	= Session_type
Nom de type de données de champ	= Enumération
Nom de champ	= Peer_nickname
Nom de type de données de champ	= Unsigned16
Nom de champ	= Peer_unique_ID
Nom de type de données de champ	= Identifiant unique
Nom de champ	= Peer_nonce_counter
Nom de type de données de champ	= Unsigned32
Nom de champ	= Session_key
Nom de type de données de champ	= Clé de sécurité
Nom de champ	= Réservé
Nom de type de données de champ	= Unsigned8
Nom de champ	= Heure de changement de session
Nom de type de données de champ	= Unsigned40

7.4.2.7.4.3 Modèle de variable de réponse

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 963
Nom de variable	= Entrée de session
Nombre de champs	= 7

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Nom de champ = Session_type
Nom de type de données de champ = Enumération
Nom de champ = Peer_nickname
Nom de type de données de champ = Unsigned16
Nom de champ = Peer_unique_ID
Nom de type de données de champ = Identifiant unique
Nom de champ = Peer_nonce_counter
Nom de type de données de champ = Unsigned32
Nom de champ = Session_key
Nom de type de données de champ = Clé de sécurité
Nom de champ = Nombre de sessions
Nom de type de données de champ = Unsigned8
Nom de champ = Heure de changement de session
Nom de type de données de champ = Unsigned40

7.4.2.7.5 Supprimer session

7.4.2.7.5.1 Aperçu du service

Ce service supprime une session de bout en bout dans un appareil de réseau.

7.4.2.7.5.2 Paramètres de demande

CLASSE: **Action qualifiée**
ATTRIBUTS:
Identifiant numérique = 964
Nom de variable = Session_type
Nom de type de données = Enumération
Nom qualificatif = Peer_nickname
Nom de type de données = Unsigned16

7.4.2.7.5.3 Paramètres de réponse

CLASSE: **Action qualifiée**
ATTRIBUTS:
Identifiant numérique = 964
Nom de variable = Session_type
Nom de type de données = Enumération
Nom qualificatif = Peer_nickname
Nom de type de données = Unsigned16

7.4.2.7.5.4 Modèle de variable de réponse

CLASSE: **Variable simple**
ATTRIBUTS:
Identifiant numérique = 964
Nom de variable = Nombre de sessions
Nom de type de données = Unsigned8

7.4.2.7.6 Ecrire supertrame

7.4.2.7.6.1 Aperçu du service

Ce service écrit ou modifie une supertrame dans un appareil de réseau.

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7.4.2.7.6.2 Modèle de variable de demande

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 965
Nom de variable	= Entrée de supertrame
Nombre de champs	= 5
Nom de variable	= Superframe_ID
Nom de type de données de champ	= Unsigned8
Nom de champ	= Num_Slots
Nom de type de données de champ	= Unsigned16
Nom de variable	= Mode supertrame
Nom de type de données de champ	= Champ binaire
Nom de champ	= Réservé
Nom de type de données de champ	= Unsigned8
Nom de champ	= Heure de changement de supertrame
Nom de type de données de champ	= Unsigned40

7.4.2.7.6.3 Modèle de variable de réponse

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 965
Nom de variable	= Entrée de supertrame
Nombre de champs	= 5
Nom de variable	= Superframe_ID
Nom de type de données de champ	= Unsigned8
Nom de champ	= Num_Slots
Nom de type de données de champ	= Unsigned16
Nom de variable	= Mode supertrame
Nom de type de données de champ	= Champ binaire
Nom de champ	= Nombre de supertrames
Nom de type de données de champ	= Unsigned8
Nom de champ	= Heure de changement de supertrame
Nom de type de données de champ	= Unsigned40

7.4.2.7.7 Supprimer supertrame

7.4.2.7.7.1 Aperçu du service

Ce service supprime une supertrame dans un appareil de réseau.

7.4.2.7.7.2 Paramètres de demande

CLASSE:	**Action qualifiée**
ATTRIBUTS:	
Identifiant numérique	= 966
Nom de variable	= Superframe_ID
Nom de type de données	= Enumération

7.4.2.7.7.3 Paramètres de réponse

CLASSE:	**Action qualifiée**
ATTRIBUTS:	
Identifiant numérique	= 966
Nom de variable	= Superframe_ID

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Nom de type de données = Enumération

7.4.2.7.7.4 Modèle de variable de réponse

CLASSE: **Variable simple**
ATTRIBUTS:
Identifiant numérique = 966
Nom de champ = Nombre de supertrames
Nom de type de données de champ = Unsigned8

7.4.2.7.8 Ecrire liaison

7.4.2.7.8.1 Aperçu du service

Ce service ajoute une attribution de liaison à un appareil de réseau.

7.4.2.7.8.2 Modèle de variable de demande

CLASSE: **VARIABLE DE STRUCTURE**
ATTRIBUTS:
Identifiant numérique = 967
Nom de variable = Entrée de liaison
Nombre de champs = 6
Nom de variable = Superframe_ID
Nom de type de données de champ = Unsigned8
Nom de champ = Intervalle de temps
Nom de type de données de champ = Unsigned16
Nom de champ = Channel_Offset
Nom de type de données de champ = Unsigned8
Nom de champ = Voisin
Nom de type de données de champ = Unsigned16
Nom de champ = Options de liaison
Nom de type de données de champ = Champ binaire
Nom de champ = Link_type
Nom de type de données de champ = Enumération

7.4.2.7.8.3 Modèle de variable de réponse

CLASSE: **VARIABLE DE STRUCTURE**
ATTRIBUTS:
Identifiant numérique = 967
Nom de variable = Entrée de liaison
Nombre de champs = 7
Nom de variable = Superframe_ID
Nom de type de données de champ = Unsigned8
Nom de champ = Intervalle de temps
Nom de type de données de champ = Unsigned16
Nom de champ = Channel_Offset
Nom de type de données de champ = Unsigned8
Nom de champ = Voisin
Nom de type de données de champ = Unsigned16
Nom de champ = Options de liaison
Nom de type de données de champ = Champ binaire
Nom de champ = Link_type
Nom de type de données de champ = Enumération

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Nom de champ	= Compteur de liaisons
Nom de type de données de champ	= Unsigned16

7.4.2.7.9 Supprimer liaison

7.4.2.7.9.1 Aperçu du service

Ce service supprime une attribution de liaison dans un appareil de réseau.

7.4.2.7.9.2 Paramètres de demande

CLASSE:	**Action qualifiée**
ATTRIBUTS:	
Identifiant numérique	= 968
Nom de variable	= Superframe_ID
Nom de type de données	= Enumération
Nom qualificatif	= Intervalle de temps
Nom de type de données	= Unsigned16
Nom qualificatif	= Voisin
Nom de type de données	= Unsigned16

7.4.2.7.9.3 Paramètres de réponse

CLASSE:	**Action qualifiée**
ATTRIBUTS:	
Identifiant numérique	= 968
Nom de variable	= Superframe_ID
Nom de type de données	= Enumération
Nom qualificatif	= Intervalle de temps
Nom de type de données	= Unsigned16
Nom qualificatif	= Voisin
Nom de type de données	= Unsigned16

7.4.2.7.9.4 Modèle de variable de réponse

CLASSE:	**Variable simple**
ATTRIBUTS:	
Identifiant numérique	= 968
Nom de champ	= Compteur de liaisons
Nom de type de données de champ	= Unsigned16

7.4.2.7.10 Ecrire connexion de graphe

7.4.2.7.10.1 Aperçu du service

Ce service ajoute une attribution de connexion de graphe à un appareil de réseau.

7.4.2.7.10.2 Modèle de variable de demande

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 969
Nom de variable	= Entrée de connexion
Nombre de champs	= 2
Nom de champ	= Graph_ID
Nom de type de données de champ	= Unsigned16

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Nom de champ = Neighbor_nickname
Nom de type de données de champ = Unsigned16

7.4.2.7.10.3 Modèle de variable de réponse

CLASSE: **VARIABLE DE STRUCTURE**
ATTRIBUTS:
Identifiant numérique = 969
Nom de variable = Entrée de connexion
Nombre de champs = 3
Nom de champ = Graph_ID
Nom de type de données de champ = Unsigned16
Nom de champ = Neighbor_nickname
Nom de type de données de champ = Unsigned16
Nom de champ = Nombre de connexions
Nom de type de données de champ = Unsigned16

7.4.2.7.11 Supprimer connexion de graphe

7.4.2.7.11.1 Aperçu du service

Ce service supprime une affectation de connexion de graphe dans un appareil de réseau.

7.4.2.7.11.2 Paramètres de demande

CLASSE: **Action qualifiée**
ATTRIBUTS:
Identifiant numérique = 970
Nom de la variable = Graph_ID
Nom de type de données = Unsigned16
Nom qualificatif = Neighbor_nickname
Nom de type de données = Unsigned16

7.4.2.7.11.3 Paramètres de réponse

CLASSE: **Action qualifiée**
ATTRIBUTS:
Identifiant numérique = 970
Nom de la variable = Graph_ID
Nom de type de données = Unsigned16
Nom qualificatif = Neighbor_nickname
Nom de type de données = Unsigned16

7.4.2.7.11.4 CLASSE:

CLASSE: **Variable simple**
ATTRIBUTS:
Identifiant numérique = 970
Nom de champ = Nombre de connexions
Nom de type de données de champ = Unsigned16

7.4.2.7.12 Ecrire fanion d'attribut de voisin

7.4.2.7.12.1 Aperçu du service

Ce service établit les attributs d'un voisin pour un appareil de réseau.

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7.4.2.7.12.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 971
Sous-indice de variable	Absent
Nom de variable	= Attribut de voisin
Nombre de champs	= 2
Nom de champ	= Neighbor_nickname
Nom de type de données de champ	= Unsigned16
Nom de champ	= Fanions de voisins
Nom de type de données de champ	= Champ binaire

7.4.2.7.13 Ecrire suspendre réseau

7.4.2.7.13.1 Aperçu du service

Ce service place le réseau entier dans un état “silencieux”, sans transmissions. La commande peut être envoyée à tous les appareils sur le réseau ou à un appareil individuel en fonction de l'adressage utilisé.

7.4.2.7.13.2 Modèle de variable

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 972
Sous-indice de variable	Absent
Nom de variable	= Suspendre réseau
Nombre de champs	= 2
Nom de champ	= Heure de suspension
Nom de type de données de champ	= Unsigned40
Nom de champ	= Heure de reprise
Nom de type de données de champ	= Unsigned40

7.4.2.7.14 Ecrire indicateur horaire

7.4.2.7.14.1 Aperçu du service

Ce service ajoute un nouvel indicateur horaire à un appareil de réseau. L'appareil de réseau peut commencer à utiliser ce service après avoir traité cette commande.

7.4.2.7.14.2 Modèle de variable de demande

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 973
Nom de variable	= Entrée de la Table des indicateurs horaires
Nombre de champs	= 6
Nom de champ	= Timetable_ID
Nom de type de données de champ	= Unsigned8
Nom de champ	= Timetable_type
Nom de type de données de champ	= Champ binaire
Nom de champ	= Domaine d'application
Nom de type de données de champ	= Enumération
Nom de champ	= Peer_nickname
Nom de type de données de champ	= Unsigned16
Nom de champ	= Service_duration

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Nom de type de données de champ = Temps
Nom de champ = Route_ID
Nom de type de données de champ = Unsigned8

7.4.2.7.14.3 Modèle de variable de réponse

CLASSE: **VARIABLE DE STRUCTURE**
ATTRIBUTS:
Identifiant numérique = 973
Nom de variable = Entrée de la Table des indicateurs horaires
Nombre de champs = 7
Nom de champ = Timetable_ID
Nom de type de données de champ = Unsigned8
Nom de champ = Timetable_type
Nom de type de données de champ = Champ binaire
Nom de champ = Domaine d'application
Nom de type de données de champ = Enumération
Nom de champ = Peer_nickname
Nom de type de données de champ = Unsigned16
Nom de champ = Service_duration
Nom de type de données de champ = Temps
Nom de champ = Route_ID
Nom de type de données de champ = Unsigned8
Nom de champ = Nombre d'indicateurs horaires
Nom de type de données de champ = Unsigned8

7.4.2.7.15 Ecrire itinéraire

7.4.2.7.15.1 Aperçu du service

Ce service établit ou modifie un itinéraire pour un service particulier dans un appareil de réseau.

7.4.2.7.15.2 Modèle de variable de demande

CLASSE: **VARIABLE DE STRUCTURE**
ATTRIBUTS:
Identifiant numérique = 974
Nom de variable = Entrée d'itinéraire
Nombre de champs = 3
Nom de champ = Route_ID
Nom de type de données de champ = Unsigned8
Nom de champ = Destination_nickname
Nom de type de données de champ = Unsigned16
Nom de champ = Graph_ID
Nom de type de données de champ = Unsigned16

7.4.2.7.15.3 Modèle de variable

CLASSE: **VARIABLE DE STRUCTURE**
ATTRIBUTS:
Identifiant numérique = 974
Nom de variable = Entrée d'itinéraire
Nombre de champs = 4
Nom de champ = Route_ID

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Nom de type de données de champ	= Unsigned8
Nom de champ	= Destination_nickname
Nom de type de données de champ	= Unsigned16
Nom de champ	= Graph_ID
Nom de type de données de champ	= Unsigned16
Nom de champ	= Nombre d'itinéraires
Nom de type de données de champ	= Unsigned8

7.4.2.7.16 Supprimer itinéraire

7.4.2.7.16.1 Aperçu du service

Ce service supprime une entrée d'itinéraire dans un appareil de réseau.

7.4.2.7.16.2 Paramètres de demande

CLASSE:	**Action de variable simple**
ATTRIBUTS:	
Identifiant numérique	= 975
Nom de variable	= Route_ID
Nom de type de données	= Unsigned8

7.4.2.7.16.3 Paramètres de réponse

CLASSE:	**Action de variable simple**
ATTRIBUTS:	
Identifiant numérique	= 975
Nom de variable	= Route_ID
Nom de type de données	= Unsigned8

7.4.2.7.16.4 Modèle de variable de réponse

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 975
Nom de champ	= Nombre d'itinéraires
Nom de type de données de champ	= Unsigned8
Nom de champ	= Nombre d'itinéraires par source
Nom de type de données de champ	= Unsigned8

7.4.2.7.17 Ecrire itinéraire par source

7.4.2.7.17.1 Aperçu du service

Ce service écrit un itinéraire par source dans un appareil de réseau. Les adresses de diffusion ne sont pas des valeurs d'adresses légitimes dans cette demande et ne doivent pas être incluses dans des itinéraires par source ou dans les demandes ou les réponses pour cette commande.

7.4.2.7.17.2 Modèle de variable de demande

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 976
Nom de variable	= Entrée d'itinéraire par source
Nombre de champs	= 3
Liste de champs	

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Nom de champ	= Route_ID
Nom de type de données de champ	= Unsigned8
Nom de champ	= Nombre de sauts
Nom de type de données de champ	= Unsigned8
Nom de champ	= Liste des sauts
Nom de type de données de champ	= Matrice de sauts

CLASSE:	**Type de données**
ATTRIBUTS:	
Nom de type de données	= Matrice de sauts
Format	= MATRICE
Nombre d'éléments de matrice	= Valeur de nombre de sauts
Type de données d'élément de matrice	= Unsigned16

7.4.2.7.17.3 Modèle de variable de réponse

CLASSE:	**VARIABLE DE STRUCTURE**
ATTRIBUTS:	
Identifiant numérique	= 976
Nom de variable	= Entrée d'itinéraire par source
Nombre de champs	= 4
Liste de champs	
Nom de champ	= Route_ID
Nom de type de données de champ	= Unsigned8
Nom de champ	= Nombre de sauts
Nom de type de données de champ	= Unsigned8
Nom de champ	= Liste des sauts
Nom de type de données de champ	= Matrice de sauts
Nom de champ	= Nombre d'itinéraires par source
Nom de type de données de champ	= Unsigned8

7.4.2.7.18 Supprimer itinéraire par source

7.4.2.7.18.1 Aperçu du service

Ce service supprime une entrée d'itinéraire dans un appareil de réseau.

7.4.2.7.18.2 Paramètres de demande

CLASSE:	**Action de variable simple**
ATTRIBUTS:	
Identifiant numérique	= 977
Nom de variable	= Route_ID
Nom de type de données	= Unsigned8

7.4.2.7.18.3 Paramètres de réponse

CLASSE:	**Action de variable simple**
ATTRIBUTS:	
Identifiant numérique	= 977
Nom de variable	= Route_ID
Nom de type de données	= Unsigned8
Nom de variable	= Nombre d'itinéraires par source
Nom de type de données	= Unsigned8

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7.4.2.7.19 Mode Ecrire compteur de statuts

7.4.2.7.19.1 Aperçu du service

Ce service est utilisé pour configurer l'utilisation des compteurs de statuts de saturation ou des compteurs de débordement sur l'appareil.

7.4.2.7.19.2 Modèle de variable

Identifiant numérique	= 978
Nom de variable	= Mode compteur
Nom de type de variable	= Enumération

7.4.2.7.20 Ecrire niveau de sécurité pris en charge

7.4.2.7.20.1 Aperçu du service

Ce service autorise le gestionnaire de réseau à modifier le niveau de sécurité inclus dans les annonces générées par l'appareil.

7.4.2.7.20.2 Modèle de variable

Identifiant numérique	= 979
Nom de variable	= Niveau de sécurité
Nom de type de variable	= Enumération

7.4.3 AR

7.4.3.1 ASE de la relation d'applications

7.4.3.1.1 Vue d'ensemble

Les AR sont composés d'un ensemble de points d'extrémité de classes compatibles. Un point d'extrémité de chaque AR doit être de classe maître et l'autre extrémité de classe esclave. Chaque appareil peut avoir une seule instance d'AREP de classe esclave.

Un appareil peut utiliser plusieurs AREP de classe maître pour communiquer avec plusieurs AREP de classe esclave. L'utilisateur au niveau de l'AREP de classe maître fournit l'identification de l'AREP de classe esclave comme paramètre dans la primitive de demande.

7.4.3.1.2 AREP de classe maître

7.4.3.1.2.1 Modèle formel

ASE:			**ASE AR**
CLASSE:			Maître
ID de CLASSE:			Non utilisé
CLASSE PARENT:			Top
ATTRIBUTS:			
(m)	Attribut:		Address
SERVICES:			
1	(m)	OpsService:	Obtenir attribut d'AR
2	(m)	OpsService:	Etablir attribut d'AR

7.4.3.1.2.2 Attributs

Address
Cet attribut spécifie l'adresse réseau de l'appareil maître.

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7.4.3.1.3 AREP de classe esclave

7.4.3.1.3.1 Modèle formel

ASE:			**ASE AR**
CLASSE:			Esclave
ID de CLASSE:			Non utilisé
CLASSE PARENT:			Top
ATTRIBUTS:			
(m)	Couche physique de type		Sans fil
(m)	Attribut:		Surnom
(m)	Attribut:		Identifiant unique
SERVICES:			
1	(m)	OpsService:	Obtenir attribut d'AR
2	(m)	OpsService:	Etablir attribut d'AR

7.4.3.1.3.2 Attributs

Surnom
Cet attribut spécifie l'adresse réseau de l'appareil esclave. L'appareil répond uniquement à cette adresse dans une trame "Identifier" reçue en provenance d'un appareil maître.

Identifiant unique
Cet attribut est utilisé pour former l'adresse réseau de l'appareil esclave. L'appareil répond uniquement à cette adresse dans toutes les trames reçues en provenance d'un appareil maître. Une valeur de cet attribut avec des zéros partout doit être réservée comme adresse de diffusion.

7.4.3.1.4 Spécifications des services ASE pour la relation d'applications

7.4.3.1.4.1 Vue d'ensemble

Ce paragraphe contient la définition des services qui sont propres à cet ASE. Ces services sont les suivants:

- Obtenir attribut d'AR et
- Etablir attribut d'AR.

7.4.3.1.4.2 Service Obtenir attribut d'AR

7.4.3.1.4.2.1 Vue d'ensemble

Ce service confirmé est utilisé pour lire la valeur des attributs d'un AREP localement.

7.4.3.1.4.2.2 Paramètres de service

Les paramètres de service pour le service Obtenir attribut d'AR sont indiqués au Tableau 73.

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Tableau 73 – Paramètres du service Obtenir attribut d'AR

Nom de paramètre	Req	Cnf
Argument	M	
Index d'attribut	M	
Résultat (+)		S
Valeur		C
Résultat (-)		S
Statut		C
NOTE La méthode de corrélation entre la primitive de confirmation et la primitive de demande correspondante qui la précède est du ressort local.		

Argument
L'argument contient les paramètres de la demande de service.

Index d'attribut
Ce paramètre identifie l'attribut.

Résultat (+)
Ce paramètre de type sélection indique que la demande a réussi.

Valeur
Ce paramètre est envoyé avec la valeur de l'attribut demandé si la demande a réussi.

Résultat (-)
Ce paramètre de type sélection indique que la demande a échoué.

Statut
Si la demande a échoué, Statut est retourné en indiquant la raison de la défaillance. Les valeurs possibles sont: Indice d'attribut illicite, Valeur inconnue.

7.4.3.1.4.3 Service Etablir attribut d'AR

7.4.3.1.4.3.1 Vue d'ensemble

Ce service confirmé est utilisé pour définir la valeur actuelle des attributs d'un AREP localement.

7.4.3.1.4.3.2 Paramètres de service

Les paramètres de service pour le service Etablir attribut d'AR sont illustrés au Tableau 74.

Tableau 74 – Paramètres du service Etablir attribut d'AR

Nom de paramètre	Req	Cnf
Argument	M	
Index d'attribut	M	
Valeur	M	
Résultat		
Statut		M
NOTE La méthode de corrélation entre la primitive de confirmation et la primitive de demande correspondante qui la précède est du ressort local.		

Argument
L'argument contient les paramètres de la demande de service.

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Index d'attribut
Ce paramètre identifie l'attribut à mettre à jour.

Valeur
Ce paramètre contient la nouvelle valeur de l'attribut.

Statut
Comme résultat de la demande, Statut est retourné en indiquant OK ou la raison de la défaillance. Les valeurs possibles sont: OK, Indice d'attribut illicite, Valeur illicite.

7.4.3.2 Vacant

NOTE Afin de conserver la structure de la série de normes IEC 61158-6-x qui spécifie des AR supplémentaires, le présent paragraphe restera vide de manière à satisfaire au fait que la Partie 2 des Directives ISO/IEC exige qu'il n'y ait pas de paragraphes isolés.

7.4.4 Synthèse des classes

Ce paragraphe contient une synthèse des classes définies. Le Tableau 75 fournit une synthèse des classes.

Tableau 75 – Récapitulatif des classes

ASE	Classe
Appareil de terrain virtuel	VFD
Type de données	Type de données de longueur fixe
	Type de données chaîne
Variable	Variable simple
	Variable de structure

7.4.5 Services admis par rôle d'AREP

La syntaxe abstraite des unités de données de protocole d'application (APDU) est combinée à leur syntaxe de transfert; elle est spécifiée dans le Tableau 76 et dans le Tableau 77.

Tableau 76 – Services confirmés par la classe AREP

Services	Maître		Esclave	
	req	cnf	Ind	rsp
ASE VFD				
Identifier	X	X	X	X
ASE de Variable				
Service Read – tout	X	X	X	X
Service Write – tout	X	X	X	X

Tableau 77 – Services non confirmés de la classe AREP

Services	Esclave	Maître
	req	ind
ASE de Variable		
Rapport d'informations	X	X

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8 Spécification du protocole de la couche application – Eléments de type 20

8.1 Généralités

Le présent document spécifie le protocole de Couche Application sans fil de Type 20 en complément du protocole de Couche Application câblée de Type 20 spécifiée dans IEC 61158-6-20.

8.2 Syntaxe abstraite

La syntaxe abstraite des unités de données de protocole d'application (APDU) est combinée à leur syntaxe de transfert; elle est spécifiée en 8.3.

8.3 Syntaxe de transfert

8.3.1 Champs communs aux APDU

8.3.1.1 Champ "Numéro de commande"

Le numéro de commande est l'identifiant numérique des services Lire (7.4.2.2.3.3), Ecrire (7.4.2.2.3.4), Rapport d'informations (7.4.2.2.3.5) ou Action (7.4.2.3.4). Il identifie le type de service et l'objet dans l'esclave auquel il faut accéder ou l'action à accomplir. C'est un Numéro de commande étendu de type Unsigned16. Les commandes 0 à 255 sont remplies de zéros pour constituer le numéro de commande de 16 bits (par exemple, la Commande 9 est émise comme étant 0x0009). La Commande 31 est réservée et ne doit pas être utilisée dans la demande.

8.3.1.2 Champ "Nombre d'octets"

Ce champ représente le nombre d'octets dans l'ensemble des champs qui suivent ce champ. Le type de données de ce champ est Unsigned8 et sa valeur peut être de 0 à 255. Si la valeur de ce champ est zéro, il s'agit alors du dernier champ dans l'APDU.

8.3.1.3 Champ "Code de réponse"

Le champ "Code de réponse" est du type données Enumération et il indique soit l'achèvement réussi de la commande demandée, soit l'achèvement de la commande demandée avec un avertissement ou une erreur lors de l'exécution de la commande demandée, comme présenté au Tableau 78. Certaines valeurs dépendent de la valeur du champ de commande. Chaque structure d'APDU spécifique au service montre les valeurs de code de réponse attribuées au service en question. Un appareil se doit d'utiliser ces valeurs. L'appareil peut répondre avec une valeur non utilisée tant qu'elle indique un état qui n'est pas défini dans la présente norme

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Tableau 78 – Valeurs du code de réponse

Valeur	Classe	Définition
0	Succès	La commande (Lire ou Ecrire) a été exécutée correctement
1 – 127	Avertissement	La commande (Ecrire) a été exécutée avec l'écart décrit dans la réponse (par exemple, une valeur a été mise à la valeur licite la plus proche)
1 – 127	Erreur	L'exécution de la commande n'a pas été accomplie correctement et le code de réponse indique la raison (par exemple, l'appareil est en mode Ecrire protection en écriture)
1 – 127	Réservé	Un code peut être réservé à un usage futur par le protocole de la présente norme. Un appareil n'est pas autorisé à retourner une valeur réservée

Les valeurs de codes de réponse qui sont communes à toutes les commandes et le comportement de l'appareil répondeur pour ces codes sont spécifiées à l'Annexe E.

8.3.1.4 Statut de processus d'application

Ce champ est fourni par l'utilisateur de la FAL. Son type de données est un champ binaire d'un octet de longueur. Il n'est associé à l'achèvement d'aucune commande. Ce champ doit avoir au moins le statut suivant:

a) Configuration modifiée – une opération exécutée a changé la configuration de l'appareil, et

b) Encore plus de statuts disponibles – des informations supplémentaires sur le statut sont disponibles via une autre commande Lire.

Si "Configuration modifiée" est à '1', il convient que le client lise d'autres variables dans le serveur, s'il y a lieu et utilise ensuite le service "Réinitialiser fanion de configuration modifiée" pour réinitialiser ce bit de statut

Si "Encore plus de statuts disponibles" est à '1', il convient que le client utilise le service "Lire statut supplémentaire d'appareil" pour récupérer les informations qui ne sont pas incluses dans le champ "Statut de processus d'application".

8.3.1.5 Statut étendu

Ce champ indique l'état du VFD. Les valeurs possibles de ce paramètre sont indiquées au Tableau 79. Son type de données est un champ binaire d'un octet de longueur. Il n'est associé à l'achèvement d'aucune commande.

Tableau 79 – Valeurs de statut étendu

Code	Valeur	Description
0x01	Maintenance requise	Le VFD exige une maintenance, même s'il n'a pas mal fonctionné.
0x02	Alerte variable d'appareil	Une ou plusieurs des variables d'appareil sont dans un état Alarme ou Avertissement.
0x04	Panne d'énergie critique	La puissance disponible atteint un niveau faible critique; utilisé par les appareils qui fonctionnent avec un accumulateur d'énergie.

8.3.1.6 Champ "Valeur"

Le champ "Valeur" représente les données utilisateur qui sont transférées entre la couche application et son utilisateur. L'ALE l'assemble à partir de paramètres d'une primitive de service ou l'analyse en paramètres d'une primitive de service. Sa structure dépend du type d'APDU.

8.3.1.7 Formats de structures d'APDU

La couche application d'émission prépare une APDU afin de la transférer à la couche application de réception. À cet effet, elle utilise les paramètres issus des primitives de service. Il existe plusieurs formats d'unité APDU:

- APDU de demande de l'appareil maître à l'appareil esclave,
- réponse normale de l'appareil esclave à l'appareil maître et
- réponse d'erreur de commande de l'appareil esclave à l'appareil maître.

Les formats communs pour les structures d'APDU sont spécifiés en 8.3.2. Les formats pour les structures d'APDU spécifiques aux services sont spécifiés en 8.3.3, en 8.3.4, en 8.3.5 et 8.3.6.

Le champ "Numéro de commande" est inclus tant dans la demande que dans la réponse. Le demandeur n'est pas obligé de mémoriser l'APDU de demande pour l'associer à l'APDU de réponse.

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8.3.2 Structure commune aux APDU

8.3.2.1 APDU de demande de l'appareil maître à l'appareil esclave

Toutes les unités APDU possèdent une structure commune, représentée à la Figure 41.

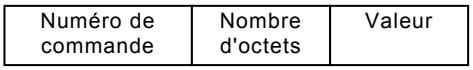

Figure 41 – Format d'APDU de demande du maître à l'esclave

Pour un service Lire, le champ "Valeur" est soit vide, soit un sous-indice de variable et pour un type de variable "matrice", il peut inclure un certain nombre d'éléments à lire. Pour un service Ecrire, le champ "Valeur" est un sous-indice de variable, suivi le cas échéant de la valeur qui a été inscrite dans les objets esclave identifiés par la commande. L'ALE l'assemble à partir des paramètres d'une primitive de service. Sa structure dépend du type d'APDU spécifique au service.

8.3.2.2 APDU de réponse normale de l'appareil esclave à l'appareil maître

La Figure 42 illustre le format des champs de couche application qui sont utilisés pour une réponse sans erreurs de l'esclave au maître.

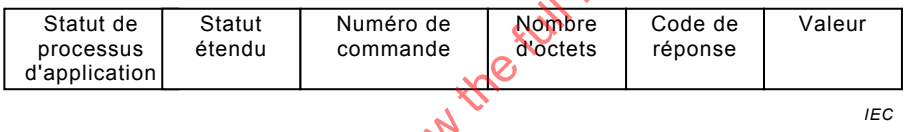

Figure 42 – Format d'APDU de réponse normale de l'esclave au maître

L'esclave envoie cette APDU en réponse à une demande du maître. La valeur du champ "Numéro de commande" dans cette APDU est identique à celle du champ "Numéro de commande" dans l'APDU de demande correspondante.

Le champ "Nombre d'octets" est le nombre d'octets dans le champ "Valeur" plus un. La valeur minimale du champ "Nombre d'octets" est un (1).

Si la réponse correspond à une demande de lecture, le champ de valeur est utilisé pour définir la valeur des objets qui sont lus sur l'appareil esclave. Si la réponse correspond à une demande d'écriture, ce champ est utilisé pour définir la valeur des objets qui ont été écrits dans l'appareil esclave. Dans la réponse à la demande Ecrire, il s'agit de la même valeur reçue dans la demande, à moins que la valeur reçue n'ait été interdite et que le serveur ait écrit une valeur différente. Dans ce cas, il s'agit de la valeur écrite dans l'appareil esclave.

Le maître doit émettre une seule commande à un seul esclave jusqu'à ce que l'esclave en question envoie la réponse ou que la demande dépasse son délai imparti et devienne non valide (voir 7.4.2.2.3.2 et 7.4.2.3.2).

8.3.2.3 APDU d'erreur de commande d'un appareil esclave vers l'appareil maître

La Figure 43 représente le format des champs de couche Application utilisés pour une réponse de l'esclave au maître en cas d'erreur lors de l'exécution de la commande. Il n'y a alors pas de champ "Valeur".

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Statut de processus d'application	Statut étendu	Numéro de commande	Nombre d'octets	Code de réponse

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Figure 43 – Format d'APDU de réponse en cas d'erreur de commande de l'esclave au maître

L'appareil répondeur envoie cette unité APDU en réponse à une demande du maître. La valeur du champ "Numéro de commande" dans cette APDU est identique à celle du champ "Numéro de commande" dans l'APDU de demande correspondante.

Le champ "Nombre d'octets" est mis à un (1).

La Commande 31 est réservée et toute réponse à une demande de Commande 31 doit être un code d'erreur "Commande non mise en œuvre".

8.3.2.4 APDU de rapport d'informations d'un appareil esclave vers l'appareil maître

L'édition de données et le rapport d'informations utilisent l'APDU de réponse définie en 8.3.2.2. L'édition est configurée pour utiliser l'un des numéros de commande (voir 8.3.3.33). D'autres numéros de commande de rapport d'informations sont spécifiés dans les paragraphes relatifs aux APDU spécifiques aux services.

8.3.2.5 Regroupement de commandes

La présente norme permet de transporter plusieurs commandes et données associées dans une seule APDU de demande et de réponse. Le regroupement de commandes est particulièrement utile pour lire les configurations des appareils. L''APDU de commandes regroupées est illustrée à la Figure 44. Le champ "Demande de Commande numéro n" est le même que l'APDU de demande illustré à la Figure 41. Le champ "Réponse de Commande numéro n" est le même que dans l'APDU de réponse illustrée à la Figure 42 et à la Figure 43, excepté que les champs "Statut de processus d'application" et "Statut étendu" sont utilisés une seule fois au début et ne font pas partie des champs "Réponse de Commande numéro 1 " à "Réponse de Commande numéro n".

Demande de commande n°1		Demande de Commande n° n

a) APDU de demande

Statut de processus d'application	Statut étendu	Réponse de commande n°1		Réponse de commande n°n

b) APDU de réponse

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Figure 44 – APDU de commandes regroupées

Si l'appareil a été configuré pour éditer plusieurs messages (voir 8.3.3.33), il peut les combiner en un seul message en utilisant le regroupement de commandes, excepté que "Message d'édition de données 0" ne doit jamais être regroupé.

Dans la mesure du possible, l'appareil de terrain conforme au Type 20 doit regrouper plusieurs "Messages d'édition de données" en instance en une seule transaction, en utilisant la demande de Rapport d'informations. Si les "Messages d'édition de données" ne rentrent pas dans une seule transaction, ils peuvent être envoyés dans des transactions distinctes.

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Les exigences générales pour regrouper des commandes sont les suivantes:

- Si un appareil reçoit une APDU de demande regroupée, il doit fournir une réponse à tous les champs "Commande" de la demande dans une seule APDU de réponse regroupée.
- Une commande avec un numéro dans la plage allant de 0x0300 à 0x03FF doit être regroupée uniquement avec une autre commande dans cette même plage.
- Une commande de lecture peut être regroupée avec une commande d'écriture.

  NOTE 1 La combinaison de commandes de lecture et d'écriture dans un même regroupement est admise, mais n'est pas recommandée.

- L'APDU de configuration de gestion de réseau (voir 8.3.6) ne doit être regroupée avec aucun autre type. La demande de configuration de gestion de réseau est une transaction acquittée contenant une commande d'écriture qui modifie le comportement du réseau.

  NOTE 2 Les commandes ne dépendent pas les unes des autres. Cela signifie que les commandes peuvent être regroupées. Par exemple, plusieurs commandes de lecture peuvent être regroupées en une seule transaction. Certaines restrictions peuvent être imposées dans les exigences relatives à des commandes spécifiques. Le protocole n'impose aucune autre restriction aux commandes. Une application hôte (utilisateur de la FAL), par exemple un étalonnage d'appareil, peut empêcher le regroupement de commandes.

8.3.3 Structures d'APDU spécifiques aux services d'application d'appareils

8.3.3.1 Unité PDU de couche FAL: Identifier

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.1.

8.3.3.2 Unité PDU de couche FAL: Lire variable primaire

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.2.

8.3.3.3 Unité PDU de couche FAL: Lire courant de boucle et pourcentage de la plage

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.3.

8.3.3.4 Unité PDU de couche FAL: Lire variables dynamiques et courant de boucle

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.4.

8.3.3.5 Unité PDU de couche FAL: Ecrire configuration de boucle

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.5.

8.3.3.6 Unité PDU de couche FAL: Lire configuration de boucle

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.6.

8.3.3.7 Unité PDU de couche FAL: Lire Classifications de familles de variables dynamiques

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.7.

8.3.3.8 Unité PDU de couche FAL: Lire variables d'appareil avec statut

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.8.

8.3.3.9 Unité PDU de couche FAL: Lire message

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.9.

8.3.3.10 Unité PDU de couche FAL: Lire marqueur, descripteur et date

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.10.

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8.3.3.11 Unité PDU de couche FAL: Lire informations de transducteur de variable primaire

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.11.

8.3.3.12 Unité PDU de couche FAL: Lire informations d'appareil

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.12.

8.3.3.13 Unité PDU de couche FAL: Lire numéro de montage final

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.13.

8.3.3.14 Unité PDU de couche FAL: Ecrire message

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.14.

8.3.3.15 Unité PDU de couche FAL: Ecrire marqueur, descripteur et date

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.15.

8.3.3.16 Unité PDU de couche FAL: Ecrire numéro de montage final

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.16.

8.3.3.17 Unité PDU de couche FAL: Lire Long_tag

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.17.

8.3.3.18 Unité PDU de couche FAL: Ecrire Long_tag

Cette commande est spécifiée dans l'IEC 61158-6-20:2014, 5.3.18.

8.3.3.19 Unité PDU de couche FAL: Réinitialiser fanions de configuration modifiée

8.3.3.19.1 Primitive de demande

La valeur de la commande est trente-huit (38); la valeur du champ "Nombre d'octets" est deux (2) et le champ "Valeur" est présenté au Tableau 80.

Tableau 80 – Champ "Valeur" de Réinitialiser fanions de configuration modifiée

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Compteur de modification de configuration	Nombre total de changements de configuration

8.3.3.19.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 80. Les valeurs des codes de réponse sont présentées au Tableau 81.

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Tableau 81 – Codes de réponse spécifiques à la commande Réinitialiser fanion de configuration modifiée

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
9	Erreur	Discordance du compteur des modifications de configuration
16	Erreur	Accès limité

8.3.3.19.3 Procédure au niveau de l'appareil répondeur

Un appareil de terrain doit contenir séparément des bits "Configuration modifiée" pour chaque maître primaire, maître secondaire et passerelle. Tous les bits "Configuration modifiée" doivent être mis à '1' lorsqu'un quelconque élément de configuration dans l'appareil de terrain a changé. Cette commande doit remettre à '0' le bit "Configuration modifiée" qui est associé à l'appareil maître émettant cette commande. Le bit en question doit rester à '0', jusqu'à ce qu'une autre modification soit apportée à la configuration de l'appareil. La valeur de ce bit doit être maintenue même en cas de coupure de l'alimentation en énergie ou de réinitialisation de l'appareil. Le bit "Configuration modifiée" de l'octet "Statut de processus d'application" pour l'appareil maître n'ayant pas émis cette commande n'est pas altéré par cette commande et reste à '1' jusqu'à ce que l'autre appareil maître émette cette commande.

Lorsqu'il reçoit cette commande, l'appareil doit comparer le "Compteur des modifications de configuration") reçu à la valeur courante de ce paramètre dans l'appareil. Si les valeurs ne concordent pas, l'appareil doit retourner l'information "Discordance des Compteurs de modifications de configuration" et ne pas réinitialiser le bit "Configuration modifiée".

8.3.3.20 Unité PDU de couche FAL: Effectuer autotest

8.3.3.20.1 Primitive de demande

La valeur de la commande est quarante et un (41); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.3.20.2 Primitive de réponse

Le champ "Valeur" de la réponse est vide. Les valeurs des codes de réponse sont présentées au Tableau 82.

Tableau 82 – Codes de réponse spécifiques à la commande Effectuer autotest

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
16	Erreur	Accès limité
32	Erreur	Occupé

8.3.3.20.3 Procédure au niveau de l'appareil répondeur

Cette commande déclenche la fonction d'autotest de l'appareil. L'exécution de cette commande peut prendre un temps relativement long. Au cours de l'autotest, l'appareil de terrain doit continuer à communiquer. Cependant, il lui est permis de répondre 'Occupé' à toutes les commandes reçues au cours de cette durée.

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Le courant de boucle peut ne pas refléter le processus alors que l'autotest s'exécute. Un maître ne doit ni générer de messages d'erreur parasites ni se déconnecter d'un appareil alors que l'autotest est en cours dans l'appareil en question.

8.3.3.21 Procédure au niveau de l'appareil répondeur

8.3.3.21.1 Primitive de demande

La valeur de la commande est quarante-deux (42); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.3.21.2 Primitive de réponse

Le champ "Valeur" de la réponse est vide. Les valeurs des codes de réponse sont présentées au Tableau 83.

Tableau 83 – Codes de réponse spécifiques à la commande Effectuer réinitialisation de l'appareil

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
16	Erreur	Accès limité
32	Erreur	Occupé

8.3.3.21.3 Procédure au niveau de l'appareil répondeur

L'appareil doit répondre à cette commande immédiatement et dans la limite du délai d'expiration de l'esclave et puis se réinitialiser lui-même. Cela équivaut à effectuer un cycle de mise hors puis sous tension de l'appareil.

L'exécution de cette commande peut prendre une durée relativement longue pour s'achever. L'appareil ne peut pas répondre à des commandes consécutives tant que la réinitialisation n'est pas achevée. L'appareil ne peut pas répondre tant qu'il est dans le processus de réinitialisation. Cela peut ressembler à une perte de communications avec l'appareil. Un maître ne doit ni générer de messages d'erreur parasites ni se déconnecter de l'appareil alors que la réinitialisation est en cours dans l'appareil en question.

8.3.3.22 Unité PDU de couche FAL: Lire statut d'appareil supplémentaire

8.3.3.22.1 Primitive de demande

La valeur de la commande est quarante-huit (48); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.3.22.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 84. Les valeurs des codes de réponse sont présentées au Tableau 85.

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Tableau 84 – Champ "Valeur" de Lire statut supplémentaire d'appareil

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Champ binaire (total de 6)	Statut spécifique à l'appareil 0	Statut spécifique au type d'appareil et au fabricant
6	Champ binaire	Statut étendu	Statut opérationnel étendu de l'appareil VFD
7	Champ binaire	Mode de fonctionnement d'appareil	Mode opérationnel de l'appareil
8	Champ binaire	Statut normalisé 0	Statut de l'appareil tel que spécifié au Tableau F.8
9	Champ binaire	Statut normalisé 1	Statut de l'appareil tel que spécifié au Tableau F.9
10	Champ binaire	Canal analogique saturé	Statut du canal analogique tel que spécifié au Tableau F.6
11	Champ binaire	Statut normalisé 2	Statut de l'appareil tel que spécifié au Tableau F.10
12	Champ binaire	Statut normalisé 3	Statut de l'appareil tel que spécifié au Tableau F.11
13	Champ binaire	Canal analogique fixé	Statut du canal analogique tel que spécifié au Tableau F.7
14	Champ binaire (1 à 11)	Statut spécifique à l'appareil 1	Statut spécifique au type d'appareil et au fabricant
NOTE Le Statut spécifique à l'appareil 0 et le Statut spécifique à l'appareil 1 peuvent être des types de données soit Champ binaire, soit Enumération.			

Tableau 85 – Codes de réponse spécifiques à la commande Lire statut supplémentaire d'appareil

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
8	Avertissement	Actualisation en cours
16	Erreur	Accès limité

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8.3.3.22.3 Procédure au niveau de l'appareil répondeur

Si l'appareil est capable de répondre à la demande, mais que les informations sur le statut sont en instance d'achèvement d'une commande qui requiert une durée relativement longue, la valeur du code de réponse "Actualisation en cours" doit être retournée. Il convient que le Client répète la demande après un délai.

Sinon, l'appareil doit répondre en indiquant 'Succès' et inclure dans la réponse tous les champs "Valeur" pris en charge par la mise en œuvre de la Commande 48 par l'appareil.

Les champs "Valeur de réponse" retournés sont tronqués après le dernier octet de statut pris en charge par l'appareil. Tous les appareils doivent prendre en charge au moins les octets 0 à 8, y compris "Statut étendu", "Mode de fonctionnement d'appareil" et "Statut normalisé 0". Si l'appareil prend en charge plusieurs canaux analogiques, les octets 9 à 13 doivent également être renvoyés.

8.3.3.23 Unité PDU de couche FAL: Réinitialiser "Encore plus de statuts disponibles"

8.3.3.23.1 Primitive de demande

La valeur de la commande est quarante-huit (48); la valeur du champ "Nombre d'octets" est neuf (9) à vingt-cinq (25) selon la mise en œuvre de l'appareil. Le champ "Valeur" est tel que présenté au Tableau 86.

Tableau 86 – Champ "Valeur" de Lire statut supplémentaire d'appareil

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Champ binaire (total de 6)	Statut spécifique à l'appareil 0	Statut spécifique au type d'appareil et au fabricant
6	Champ binaire	Statut étendu	Statut opérationnel étendu de l'appareil VFD
7	Champ binaire	Mode de fonctionnement d'appareil	Mode opérationnel de l'appareil
8	Champ binaire	Statut normalisé 0	Statut de l'appareil tel que spécifié au Tableau F.8
9	Champ binaire	Statut normalisé 1	Statut de l'appareil tel que spécifié au Tableau F.9
10	Champ binaire	Canal analogique saturé	Statut du canal analogique tel que spécifié au Tableau F.6
11	Champ binaire	Statut normalisé 2	Statut de l'appareil tel que spécifié au Tableau F.10
12	Champ binaire	Statut normalisé 3	Statut de l'appareil tel que spécifié au Tableau F.11
13	Champ binaire	Canal analogique fixé	Statut du canal analogique tel que spécifié au Tableau F.7
14	Champ binaire (1 à 11)	Statut spécifique à l'appareil 1	Statut spécifique au type d'appareil et au fabricant
NOTE Le Statut spécifique à l'appareil 0 et le Statut spécifique à l'appareil 1 peuvent être des types de données soit Champ binaire, soit Enumération.			

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8.3.3.23.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 86. Les valeurs des codes de réponse sont présentées au Tableau 87.

Tableau 87 – Codes de réponse spécifiques à la commande Lire statut supplémentaire d'appareil

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
8	Avertissement	Actualisation en cours
16	Erreur	Accès limité

8.3.3.23.3 Procédure au niveau de l'appareil répondeur

Si l'appareil est capable de répondre à la demande, mais que les informations sur le statut sont en instance d'achèvement d'une commande qui requiert une durée relativement longue,

la valeur du code de réponse "Actualisation en cours" doit être retournée. Il convient que le Client répète la demande après un délai.

Sinon, il doit comparer les valeurs reçues aux valeurs courantes contenues dans l'appareil. S'il y a une concordance exacte, le bit "Encore plus de statuts disponibles" correspondant à l'appareil demandeur (maître primaire, maître secondaire ou passerelle) doit être remis à '0'. S'il n'y a pas une concordance exacte ou si peu d'octets sont reçus, le bit "Encore plus de statuts disponibles" doit rester inchangé. Si la demande contient plus de champs "Valeur" que ceux pris en charge par l'appareil, ces champs supplémentaires doivent être ignorés. L'appareil doit toujours envoyer les valeurs courantes des champs "Valeur" dans la réponse.

Les champs "Valeur de réponse" retournés sont tronqués après le dernier octet de statut pris en charge par l'appareil. Tous les appareils doivent prendre en charge au moins les octets 0 à 8, y compris "Statut étendu", "Mode de fonctionnement d'appareil" et "Statut normalisé 0". Si l'appareil prend en charge plusieurs canaux analogiques, les octets 9 à 13 doivent également être renvoyés.

8.3.3.24 Unité PDU de couche FAL: Lire Informations de variables d'appareil

8.3.3.24.1 Primitive de demande

La valeur de la Commande est cinquante quatre (54); la valeur du champ "Nombre d'octets" est un (1). Le champ "Valeur" est tel que présenté au Tableau 88.

Tableau 88 – Champ "Valeur" de Lire Informations de variables d'appareil

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Code de variable	Variable pour laquelle des informations sont demandées

8.3.3.24.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 89. Les valeurs des codes de réponse sont présentées au Tableau 90.

Tableau 89 – Champ "Valeur" de réponse Lire Informations de variables d'appareil

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Code de variable	Code reçu dans la demande dans le champ "Valeur"
1	Unsigned24	Numéro de série de transducteur	Valeur de "Numéro de série du transducteur"
4	Enumération	Elément transducteur	Code pour les limites du transducteur et les unités d'intervalle de mesure minimal
5	Float32	Limite supérieure du transducteur	Valeur de la variable "Limite supérieure de transducteur"
9	Float32	Limite inférieure du transducteur	Valeur de la variable "Limite inférieure du transducteur"
13	Float32	Valeur d'amortissement	Constante d'amortissement pour la valeur du transducteur
17	Float32	Intervalle de mesure minimal	Valeur de la variable "intervalle de mesure minimal"
21	Enumération	Classification des variables d'appareil	Fonction accomplie par la variable d'appareil comme spécifié au Tableau F.5
22	Enumération	Famille de variables d'appareil	La famille d'appareils telle que spécifiée au Tableau F.4
23	Temps	Période d'actualisation	La période maximale entre actualisations de la variable d'appareil

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Tableau 90 – Codes de réponse spécifiques à la commande Lire Informations de variables d'appareil

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
16	Erreur	Accès limité
32	Erreur	Occupé

8.3.3.24.3 Procédure au niveau de l'appareil répondeur

S'il n'y a pas de transducteur pour la variable d'appareil sélectionnée, l'appareil doit mettre le numéro de série du transducteur à zéro, mettre les autres paramètres Float32 à "0x7F, 0xA0, 0x00, 0x00" et les paramètres d'unités de transducteur à "250" (non utilisé) lorsqu'ils ne sont pas applicables.

Si la classification de variable d'appareil n'est pas prise en charge par la variable d'appareil, l'appareil doit retourner "0" (non mis en œuvre). Si la famille de variables d'appareil n'est pas prise en charge par la variable d'appareil, l'appareil doit retourner "250" (non utilisé).

L'appareil doit actualiser la variable d'appareil au moins une fois dans l'intervalle indiqué par le champ "Période d'actualisation".

8.3.3.25 Unité PDU de couche FAL: Ecrire variable d'appareil

8.3.3.25.1 Primitive de demande

La valeur de la commande est soixante-dix-neuf (79); la valeur du champ "Nombre d'octets" est huit (8) et le champ "Valeur" est tel que présenté au Tableau 91.

Tableau 91 – Champ "Valeur" de Ecrire variable d'appareil

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Code de variable	Variable pour laquelle des valeurs doivent être écrites
1	Enumération	Commande de variable d'appareil	Commande devant être exécutée telle que spécifiée au Tableau F.3
2	Unité technique	Unité de variable d'appareil	Unité de mesure de la variable
3	Float32	Valeur de variable d'appareil	Valeur devant être écrite pour la variable
7	Champ binaire	Statut de variable d'appareil	Statut devant être écrit pour la variable

8.3.3.25.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 91. Les valeurs des codes de réponse sont présentées au Tableau 92.

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Tableau 92 – Codes de réponse spécifiques à la commande Ecrire variable d'appareil

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
8	Avertissement	Bit de statut de "Famille d'appareils" non mis
10	Erreur	Code non valide pour la variable d'appareil
16	Erreur	Accès limité
17	Erreur	Indice non valide pour la variable d'appareil; la variable d'appareil n'existe pas dans l'appareil
18	Erreur	Code d'unités non valide
19	Erreur	Indice de variable d'appareil non autorisé pour cette commande
32	Erreur	Occupé – une réponse différée n'a pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit

8.3.3.25.3 Procédure au niveau de l'appareil répondeur

La commande "Ecrire variable d'appareil" contrôle le fonctionnement de l'appareil en forçant la valeur de calcul ou en autorisant le fonctionnement normal. Pour les variables d'appareil calculées automatiquement par l'appareil de terrain, le fonctionnement normal doit reprendre lorsque l'appareil est mis hors tension puis de nouveau sous tension ou après réinitialisation de l'appareil.

Un appareil de terrain doit lancer une DR (réponse différée) si la variation de valeur de la variable d'appareil dépasse la limite du taux de variation. Cette DR doit se poursuivre jusqu'à ce qu'une nouvelle valeur puisse être obtenue. Pendant que la variable d'appareil reste forcée, le code de réponse 8 "Echec d'actualisation" doit être retourné à chaque fois que la valeur forcée est lue par un client. Cela indique au maître de détecter cet état. Le fait de forcer la valeur d'une variable d'appareil peut altérer les bits dans l'octet "Statut de processus d'application".

Il convient que l'application hôte n'utilise pas les bits de statut "Famille d'appareils" pour des variables d'appareil ne prenant pas en charge une famille d'appareils (ce qui signifie que dans ce cas l'appareil de terrain réinitialise toujours ces bits).

Le code d'unité de variable d'appareil reçu avec la commande n'altère pas les unités de variable d'appareil de l'appareil de terrain. La valeur de variable d'appareil doit être retournée dans les mêmes unités que celles reçues.

8.3.3.26 Lire résumé d'identité de sous-appareil de réseau

8.3.3.26.1 Primitive de demande

La valeur de la commande est quatre-vingt-quatre (84); la valeur du champ "Nombre d'octets" est deux (2) et le champ "Valeur" est vide.

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8.3.3.26.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 93. Les valeurs des codes de réponse sont présentées au Tableau 94.

Tableau 93 – Champ "Valeur" de Lire résumé d'identité de sous-appareil de réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Indice de sous-appareil	L'indice 0 renvoie l'identité du système d'E/S et il convient d'ignorer la carte et le canal dans les applications hôtes
2	Unsigned8	Carte d'E/S	
3	Unsigned8	Canal	
4	Unsigned16	ID de fabricant	
6	Unsigned16	Code de type d'appareil étendu	
8	Unsigned24	Identifiant d'appareil	
11	Unsigned8	Niveau de révision de commande universelle	
12	Latin-1	Marqueur long	À stocker dans l'appareil
44	Unsigned8	Révision de l'appareil	
45	Enumération	Profil d'appareil	Si le sous-appareil ne renvoie pas "Profil d'appareil" dans sa réponse à la Commande 0, le système d'E/S doit renvoyer "Appareil d'automatisation de processus"
46	Enumération	Etiquette Privée Code de distributeur	Voir l'IEC 61158-6-20:2014, Tableau 6

Tableau 94 – Codes de réponse spécifiques à la commande Lire résumé d'identité de sous-appareil de réseau

Valeur	Classe	Description
0	Succès	Pas d'erreur
1		Non défini
2	Erreur	Choix non valide
3		Non défini
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7		Non défini
8	Avertissement	ID en doublon
9 – 127		Non défini

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8.3.3.26.3 Procédure au niveau de l'appareil répondeur

L'appareil doit répondre avec l'heure interne à laquelle la demande a été reçue.

8.3.3.27 Unité PDU de couche FAL: Lire horloge temps réel

8.3.3.27.1 Primitive de demande

La valeur de la commande est quatre-vingt-dix (90); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.3.27.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 95. Les valeurs des codes de réponse sont présentées au Tableau 96.

Tableau 95 – Champ "Valeur" de Lire horloge temps réel

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Date	Date	Date courante
3	Temps	Heure courante	Heure du jour courante
7	Date	Dernier réglage de la date	Dernier réglage de date
10	Temps	Dernier réglage du temps	Dernier réglage du temps
14	Champ binaire	Fanions d'horloge temps réel	Fanions d'horloge temps réel, comme spécifié au Tableau F.18

Tableau 96 – Codes de réponse spécifiques à la commande Lire horloge temps réel

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil

8.3.3.27.3 Procédure au niveau de l'appareil répondeur

L'appareil doit répondre avec l'heure interne à laquelle la demande a été reçue. Si l'horloge n'a pas été réglée, la dernière heure réglée doit être initialisée à minuit (00:00) du 1er janvier 1900.

8.3.3.28 Unité PDU de couche FAL: Ecrire période d'édition de données

8.3.3.28.1 Primitive de demande

La valeur de la commande est cent trois (103); la valeur du champ "Nombre d'octets" est neuf (9) et le champ "Valeur" est tel que présenté au Tableau 97.

Tableau 97 – Champ "Valeur" de Ecrire période d'édition de données

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Réf. de message d'édition de données	Référence à un jeu d'édition de données dans toutes les demandes et réponses de lecture et d'écriture pour le jeu en question
1	Temps	Période d'actualisation	Durée entre deux éditions successives des données spécifiées, si les conditions de déclenchement dans la Commande 104 sont remplies
5	Temps	Période maximale d'actualisation	Durée entre deux éditions successives des données spécifiées, si les conditions de déclenchement dans la Commande 104 ne sont pas remplies
NOTE La valeur retournée dans les octets de données de réponse reflète la valeur effectivement utilisée par l'appareil.			

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8.3.3.28.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 97. Les valeurs des codes de réponse sont présentées au Tableau 98.

Tableau 98 – Codes de réponse spécifiques à la commande Ecrire période d'édition de données

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
8	Avertissement	Temps d'actualisation ajustés
9	Erreur	Code non valide pour la variable d'appareil
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit

8.3.3.28.3 Procédure au niveau de l'appareil répondeur

Cette demande sélectionne la période d'actualisation minimale et maximale d'un message d'édition de données. Le temps minimal doit être inférieur ou égal au temps maximal. Seules sont permises les valeurs suivantes du paramètre "Période d'actualisation":

0 100 s,
0 250 s,
0 500 s,
1 s,
2 s,
4 s,
8 s,
16 s,
32 s et
n'importe quelle valeur de 60 s à 3 600 s.

Les appareils de terrain doivent corriger à la valeur permise la plus proche les valeurs de réglage qui diffèrent de celles-ci et indiquer "Temps d'actualisation ajustés". La valeur par défaut du paramètre "Période d'actualisation" est de 60 s.

Si plusieurs messages d'édition de données sont activés et coïncident tous dans la limite du même temps, ils sont regroupés à l'aide de la Commande 78 pour former une seule APDU. Les messages d'édition de données ayant la plus haute priorité seront concaténés les premiers jusqu'au nombre maximal d'octets qu'autorise la couche de transport respective. Le message d'édition de données ayant le numéro de référence le plus bas a une plus haute priorité que le message d'édition de données ayant le numéro de référence le plus élevé. L'événement "Statut de processus d'application" a une plus faible priorité que les messages d'édition de données et une plus haute priorité que l'événement de Commande 48.

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8.3.3.29 Unité PDU de couche FAL: Ecrire déclencheur de l'édition de données

8.3.3.29.1 Primitive de demande

La valeur de la commande est cent quatre (104); la valeur du champ "Nombre d'octets" est huit (8) et le champ "Valeur" est tel que présenté au Tableau 99.

Tableau 99 – Champ "Valeur" de Ecrire déclencheur de l'édition de données

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Réf. de message d'édition de données	Référence à un jeu d'édition de données dans toutes les demandes et réponses de lecture et d'écriture pour le jeu en question
1	Enumération	Mode déclenchement	Code de sélection du mode déclenchement tel que spécifié au Tableau F.12
2	Enumération	Classification des variables d'appareil	Fonction accomplie par la variable d'appareil comme spécifié au Tableau F.5
3	Unité technique	Unité de variable d'appareil	Unité de mesure de la variable
4	Float32	Niveau de déclenchement	Fenêtre ou niveau utilisé(e) pour déclencher l'édition
NOTE La valeur retournée dans les octets de données de réponse reflète la valeur effectivement utilisée par l'appareil.			

8.3.3.29.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 99. Les valeurs des codes de réponse sont présentées au Tableau 100.

Tableau 100 – Codes de réponse spécifiques à la commande Ecrire déclencheur de l'édition de données

Valeur	Classe	Description
0	Succès	Pas d'erreur
3	Erreur	La valeur du paramètre devant être écrite est plus élevée que celle permise
4	Erreur	La valeur du paramètre devant être écrite est plus faible que celle permise
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
8	Avertissement	Mis à la valeur la plus proche possible
9	Erreur	"Réf. de message d'édition de données" non valide
11	Erreur	Classification non valide pour la variable d'appareil
12	Erreur	Code d'unités non valide
13	Erreur	Code de choix non valide pour le mode déclenchement d'édition de données
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit

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8.3.3.29.3 Procédure au niveau de l'appareil répondeur

Sauf configuration contraire par cette demande, le message d'édition de données doit supposer que le mode déclenchement est "Continu" et que la valeur de déclenchement est 0,00. De surcroît, si une commande spécifique à l'appareil est spécifiée comme la commande Editer, cette demande doit retourner "Accès limité" et utiliser la valeur par défaut de "Continu" pour le mode "déclenchement".

Les modes de déclenchement permettent de configurer l'appareil pour différer l'édition du message d'édition de données au-delà de la période d'actualisation spécifiée dans la Commande 103 (voir Tableau 97). Dans tous les cas, le message d'édition de données doit être déclenché en cas de dépassement du temps maximal d'actualisation indiqué dans la Commande 103 (voir Tableau 97). La source de déclenchement est spécifiée et est normalement la première valeur de processus retournée comme réponse à la commande, comme présenté au Tableau 101. Le numéro de commande pour le message d'édition de données est spécifié en 8.3.3.33.

Tableau 101 – Source de déclenchement de messages d'édition de données

Commande	Référence	Source de déclenchement
1	8.3.3.2	Valeur de variable primaire
2	8.3.3.3	Variable primaire en pourcentage de la plage
3	8.3.3.4	Variable primaire
9	8.3.3.8	Variable d'appareil pour intervalle de temps 0

En mode "fenêtrage", la valeur de déclenchement doit être un nombre positif; elle est la fenêtre symétrique autour de la dernière valeur communiquée. La Figure 45 illustre l'édition du message d'édition de données après dépassement de la fenêtre.

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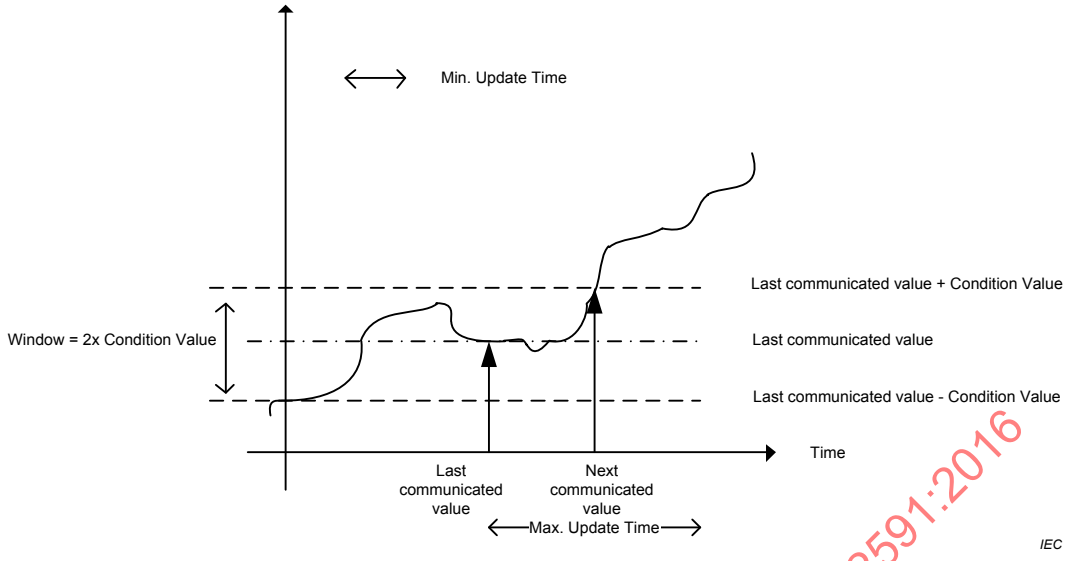

Anglais	Français
Min. Update Time	Temps minimal d'actualisation
Window = 2x Condition Value	Fenêtre = 2 fois la valeur de condition
Last communicated value	Dernière valeur communiquée
Next communicated value	Prochaine valeur communiquée
Max. Update Time	Temps maximal d'actualisation
Last communicated value + Condition Value	Dernière valeur communiquée + valeur de condition
Last communicated value – Condition Value	Dernière valeur communiquée – valeur de condition
Time	Temps

Figure 45 – Mode de déclenchement en fenêtrage

La Figure 46 illustre que même si la valeur ne dévie pas au-delà de la fenêtre, un "Message d'édition de données" est toujours édité en cas de dépassement de la "Période maximale d'actualisation".

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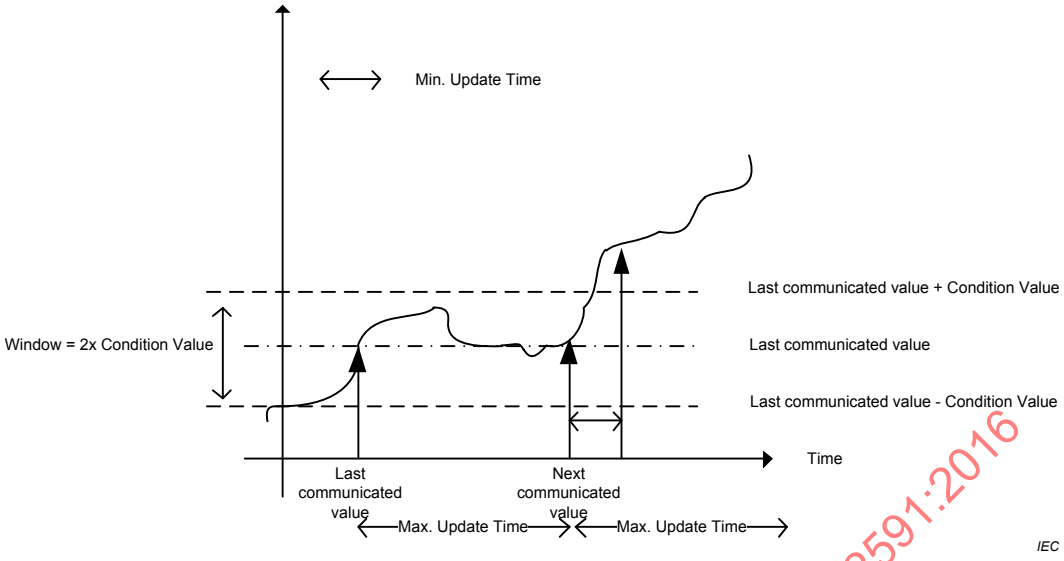

Anglais	Français
Min. Update Time	Temps minimal d'actualisation
Window = 2x Condition Value	Fenêtre = 2 fois la valeur de condition
Last communicated value	Dernière valeur communiquée
Next communicated value	Prochaine valeur communiquée
Max. Update Time	Temps maximal d'actualisation
Last communicated value + Condition Value	Dernière valeur communiquée + valeur de condition
Last communicated value – Condition Value	Dernière valeur communiquée – valeur de condition
Time	Temps

Figure 46 – Mode de déclenchement en fenêtrage avec expiration du délai maximal d'actualisation

En mode "Montée", le Message d'édition de données doit être édité lorsque la valeur source se situe au-dessus du seuil établi par la valeur de déclenchement. La Figure 47 illustre que le temps d'actualisation varie une fois la limite dépassée. Les messages d'édition de données sont édités à la fréquence indiquée par la Période d'actualisation tant que la valeur source reste au-dessus de la valeur de déclenchement. Si la valeur passe en dessous de la valeur de déclenchement, le temps d'actualisation doit être la période maximale d'actualisation.

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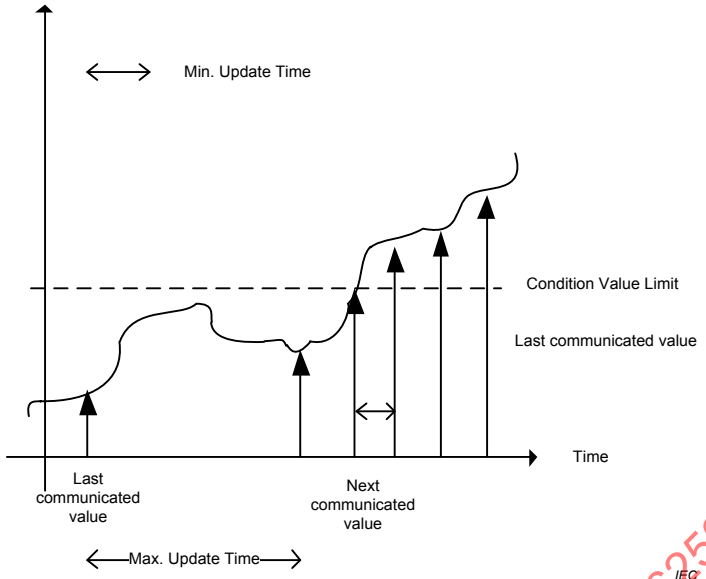

Anglais	Français
Min. Update Time	Temps minimal d'actualisation
Last communicated value	Dernière valeur communiquée
Next communicated value	Prochaine valeur communiquée
Max. Update Time	Temps maximal d'actualisation
Condition Value Limit	Limite de la valeur de condition
Time	Temps

Figure 47 – Mode de déclenchement en niveau

En mode "Descente" qui est similaire au mode "Montée", le Message d'édition de données doit être édité lorsque la valeur source passe en dessous du seuil établi par la valeur de déclenchement.

8.3.3.30 Unité PDU de couche FAL: Lire Configuration du mode "édition de données"

8.3.3.30.1 Primitive de demande

La valeur est cent cinq (105); la valeur du champ "Nombre d'octets"est zéro (0) ou un (1). Si la demande a un octet, le champ "Valeur" de la demande est présenté au Tableau 102.

Tableau 102 – Champ "Valeur" de la demande Lire Configuration du mode "édition de données"

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Réf. de message d'édition de données	Cela est utilisé pour se référer à un jeu d'édition de données dans toutes les demandes et réponses de lecture et d'écriture pour le jeu en question.Type de données

8.3.3.30.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 103. Les valeurs des codes de réponse sont présentées au Tableau 104.

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Tableau 103 – Champ "Valeur" de réponse Lire Configuration du mode "édition de données"

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Contrôle du mode "édition de données"	Code de contrôle de mode d'édition de données tel que spécifié au Tableau F.2
1	Unsigned8	Expansion du numéro de commande	31 (0x1F) ou LSB du numéro de commande d'édition de données – voir Note
2	Unsigned8	Code de variable d'appareil 0	Code de variable d'appareil attribué à l'intervalle de temps Slot 0
3	Unsigned8	Code de variable d'appareil 1	Code de variable d'appareil attribué à l'intervalle de temps Slot 1
4	Unsigned8	Code de variable d'appareil 2	Code de variable d'appareil attribué à l'intervalle de temps Slot 2
5	Unsigned8	Code de variable d'appareil 3	Code de variable d'appareil attribué à l'intervalle de temps Slot 3
6	Unsigned8	Code de variable d'appareil 4	Code de variable d'appareil attribué à l'intervalle de temps Slot 4
7	Unsigned8	Code de variable d'appareil 5	Code de variable d'appareil attribué à l'intervalle de temps Slot 5
8	Unsigned8	Code de variable d'appareil 6	Code de variable d'appareil attribué à l'intervalle de temps Slot 6
9	Unsigned8	Code de variable d'appareil 7	Code de variable d'appareil attribué à l'intervalle de temps Slot 7
10	Unsigned8	Réf. de message d'édition de données	Référence à un jeu d'édition de données dans toutes les demandes et réponses de lecture et d'écriture pour le jeu en question
11	Unsigned8	Nombre maximal d'édition de données	Nombre maximal de messages d'édition de données pris en charge par l'appareil
12	Unsigned16	Numéro de commande étendu	Nom de commande étendu (voir 8.3.2.2)
14	Temps	Période d'actualisation	Durée entre deux éditions successives des données spécifiées, si les conditions de déclenchement dans la Commande 104 sont remplies
18	Temps	Période maximale d'actualisation	Durée entre deux éditions successives des données spécifiées, si les conditions de déclenchement dans la Commande 104 ne sont pas remplies
22	Enumération	Mode déclenchement	Code de sélection du mode déclenchement tel que spécifié au Tableau F.12
23	Enumération	Classification des variables d'appareil	Fonction accomplie par la variable d'appareil comme spécifié au Tableau F.5
24	Unité technique	Unité de variable d'appareil	Unité de mesure de la variable
25	Float32	Niveau de déclenchement	Fenêtre ou niveau utilisé(e) pour déclencher l'édition
NOTE Si la demande a un octet, ce paramètre est mis à 31.			

Tableau 104 – Codes de réponse spécifiques à la commande Lire Configuration du mode "édition de données"

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
9	Erreur	"Réf. de message d'édition de données" non valide
32	Erreur	Occupé – une réponse différée n'a pu être lancée

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8.3.3.30.3 Procédure au niveau de l'appareil répondeur

Si l'appareil reçoit une demande sans octets de données, il doit retourner la configuration de Message d'édition de données "0" et le LSB du numéro de commande éditer doit être retourné dans un octet de données de réponse un (1).

Si un intervalle de temps n'est pas configuré pour émettre une variable d'appareil, l'intervalle de temps en question doit retourner "250" (non utilisé) comme code de la variable d'appareil. Si la Commande 9 est à éditer, ce code de variable Appareil pour l'intervalle de temps soit satisfaire aux exigences selon la Commande 9 (voir 8.3.3.8).

Si un appareil met en œuvre ce mode "édition de données", il doit prendre en charge au moins trois jeux d'édition de données, à savoir la valeur minimale de "Nombre maximal d'édition de données" doit être de trois (3).

8.3.3.31 Unité PDU de couche FAL: Purger réponses différées

8.3.3.31.1 Primitive de demande

La valeur de la commande est cent six (106); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.3.31.2 Primitive de réponse

Le champ "Valeur" de la réponse est vide. Les valeurs des codes de réponse sont présentées au Tableau 105.

Tableau 105 – Codes de réponse spécifiques à la commande Purger réponses différées

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
8	Avertissement	Procédure au niveau de l'appareil répondeur
16	Erreur	Accès limité
32	Erreur	Occupé

8.3.3.31.3 Procédure au niveau de l'appareil répondeur

Cette commande efface toutes les réponses différées en instance pour le maître qui a émis la commande. Les réponses différées en cours qui ne peuvent pas être interrompues ou abandonnées peuvent être achevées. Si tel est le cas, l'esclave doit répondre par "Toutes les réponses différées ont été purgées sauf réponses en cours".

Il convient que les appareils prennent en charge un minimum de deux tampons de DR (un pour chaque maître). Si un seul tampon de réponses DR est pris en charge, cette commande doit purger le tampon de DR même s'il est utilisé par l'autre maître qui n'a pas envoyé la demande de purge.

8.3.3.32 Unité PDU de couche FAL: Ecrire variables d'appareil d'édition de données

8.3.3.32.1 Primitive de demande

La valeur de la commande est cent sept (107); la valeur du champ "Nombre d'octets" est (5) ou (9) et le champ "Valeur" est tel que présenté au Tableau 106.

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Tableau 106 – Champ "Valeur" de Ecrire Configuration du mode d'édition de données

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Code de variable d'appareil 0	Code de variable d'appareil attribué à l'intervalle de temps Slot 0
1	Unsigned8	Code de variable d'appareil 1	Code de variable d'appareil attribué à l'intervalle de temps Slot 1
2	Unsigned8	Code de variable d'appareil 2	Code de variable d'appareil attribué à l'intervalle de temps Slot 2
3	Unsigned8	Code de variable d'appareil 3	Code de variable d'appareil attribué à l'intervalle de temps Slot 3
4	Unsigned8	Code de variable d'appareil 4	Code de variable d'appareil attribué à l'intervalle de temps Slot 4
5	Unsigned8	Code de variable d'appareil 5	Code de variable d'appareil attribué à l'intervalle de temps Slot 5
6	Unsigned8	Code de variable d'appareil 6	Code de variable d'appareil attribué à l'intervalle de temps Slot 6
7	Unsigned8	Code de variable d'appareil 7	Code de variable d'appareil attribué à l'intervalle de temps Slot 7
8	Unsigned8	Réf. de message d'édition de données	Référence à un jeu d'édition de données dans toutes les demandes et réponses de lecture et d'écriture pour le jeu en question
NOTE La valeur retournée dans les octets de données de réponse reflète la valeur effectivement utilisée par l'appareil.			

8.3.3.32.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 106. Les valeurs des codes de réponse sont présentées au Tableau 107.

Tableau 107 – Codes de réponse spécifiques à la commande Ecrire variable d'appareil d'édition de données

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
8	Avertissement	Accès limité
9	Erreur	"Réf. de message d'édition de données" non valide
16	Erreur	Accès limité

8.3.3.32.3 Procédure au niveau de l'appareil répondeur

Les codes des variables d'appareil reçus dans la demande doivent être utilisés par un appareil d'édition pour une Commande 9 ou 33 en mode "édition de données". Le maître doit toujours envoyer cinq (5) ou neuf (9) octets de données dans la demande. Si l'un des codes de variables d'appareil débutant par l'intervalle de temps 1 est '250' (non utilisé), la réponse de Commande 9 ou Commande 33 doit être tronquée à partir du premier intervalle de temps qui a une valeur '250' (non utilisé). Pour la Commande 33, seuls les quatre premiers intervalles de temps doivent être utilisés. Si la demande a seulement cinq (5) octets de données, le code de variable d'appareil pour les intervalles de temps 4 à 7 doit être mis à '250' (non utilisé).

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Si le mode "déclenchement" (voir Tableau 99) pour la "Réf. de message d'édition de données" dans cette demande est différent de zéro et que la classification de variables d'appareil de la source de déclenchement ne concorde pas avec le nouveau code de variable d'appareil attribué à l'intervalle de temps 0, la valeur provenant de cette demande doit être acceptée et le code de réponse "Conflit d'états d'édition de données" doit être retourné; l'appareil de terrain doit corriger la classification, les codes d'unité, régler le mode "déclenchement" pour éditer en continu à la période d'actualisation et jusqu'à ce qu'il reçoive une autre Commande 104.

8.3.3.33 Unité PDU de couche FAL: Ecrire Numéro de commande du mode "édition de données"

8.3.3.33.1 Primitive de demande

La valeur de la commande est cent huit (108); la valeur du champ "Nombre d'octets" est trois (3) comme présenté au Tableau 108 ou un (1) comme présenté au Tableau 109.

Tableau 108 – Champ "Valeur" de Ecrire numéro de commande du mode "édition de données"

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Numéro de commande d'édition	Numéro de commande codé sur 16 bits du message de réponse devant être transmis en mode "édition de données"
2	Unsigned8	Réf. de message d'édition de données	Référence à un jeu d'édition de données dans toutes les demandes et réponses de lecture et d'écriture pour le jeu en question
NOTE La valeur retournée dans les octets de données de réponse reflète la valeur effectivement utilisée par l'appareil.			

Tableau 109 – Champ "Valeur" de Ecrire numéro de commande du mode "édition de données"

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Numéro de commande d'édition	Numéro de commande codé sur 8 bits du message de réponse devant être transmis en mode "édition de données"
NOTE La valeur retournée dans les octets de données de réponse reflète la valeur effectivement utilisée par l'appareil.			

8.3.3.33.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 108 et au Tableau 109. Les valeurs des codes de réponse sont présentées au Tableau 110.

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Tableau 110 – Codes de réponse spécifiques à la commande Ecrire numéro de commande du mode "édition de données"

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
8	Avertissement	Accès limité
9	Erreur	"Réf. de message d'édition de données" non valide
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit

8.3.3.33.3 Procédure au niveau de l'appareil répondeur

Les valeurs permises pour le numéro de commande Editer sont {1, 2, 3, 9, 33 et 48}. Tous les appareils doivent prendre en charge toutes ces valeurs sauf 33. Si l'appareil met en œuvre la Commande facultative 33, il doit aussi prendre en charge cette valeur de numéro de commande Editer. Si un appareil de terrain reçoit un seul octet de données dans la demande, il doit supposer pour Réf. de message d'édition de données une valeur de '0'; et il doit traiter la demande comme un numéro de commande à un seul octet et répondre avec un seul octet dans la réponse.

Si le mode "déclenchement" (voir Tableau 99) pour le "Réf. de message d'édition de données" dans cette demande est différent de zéro et que la classification de variables d'appareil de la source de déclenchement ne concorde pas avec le numéro de commande indiqué dans la demande, la valeur provenant de cette demande doit être acceptée et le code de réponse "Conflit d'états d'édition de données" doit être retourné; l'appareil de terrain doit corriger la classification, les codes d'unité, régler le mode "déclenchement" pour éditer en continu à partir de la période d'actualisation et jusqu'à ce qu'il reçoive une autre Commande 104.

Après l'activation de l'édition (voir 8.3.3.34), l'appareil doit éditer la réponse à "Numéro de commande d'édition" en utilisant le service "Rapport d'informations"

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8.3.3.34 Unité PDU de couche FAL: Ecrire Contrôle de mode "édition de données"

8.3.3.34.1 Primitive de demande

La valeur de la commande est cent neuf (109); la valeur du champ "Nombre d'octets" est un (1) – le premier champ – ou deux (2) – les deux champs, comme présenté au Tableau 111.

Tableau 111 – Champ "Valeur"de Ecrire Contrôle de mode "édition de données"

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Contrôle du mode "édition de données"	Code de contrôle de mode d'édition de données tel que spécifié au Tableau F.2
1	Unsigned8	Réf. de message d'édition de données	Référence à un jeu d'édition de données dans toutes les demandes et réponses de lecture et d'écriture pour le jeu en question

8.3.3.34.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 111. Les valeurs des codes de réponse sont présentées au Tableau 112.

Tableau 112 – Codes de réponse spécifiques à la commande Ecrire Contrôle de mode "édition de données"

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
8	Avertissement	Période d'actualisation augmentée
9	Erreur	Largeur de bande insuffisante
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pas pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit

8.3.3.34.3 Procédure au niveau de l'appareil répondeur

Cette commande est utilisée pour activer ou désactiver le mode "édition de données" pour les appareils. Cette commande a une incidence sur le fonctionnement de la couche Liaison de données. Toutes les exigences de couche Liaison de données relatives à l'entrée et à la sortie du mode d'édition de données doivent être satisfaites.

Si la demande concerne l'activation de l'édition, l'appareil répondeur doit exécuter la procédure ci-après.

- Si l'appareil répondeur n'a pas la capacité actuellement programmée pour éditer le jeu de données spécifié pour "Réf. de message d'édition de données", il doit répondre par "Réponse différée déclenchée".
- L'appareil doit envoyer une demande "Unité PDU de couche FAL: Demander indicateur horaire" (voir 8.3.4.31.1) au gestionnaire de réseau pour éditer les données. Le gestionnaire de réseau est censé envoyer une réponse à "Unité PDU de couche FAL: Demander indicateur horaire" avec "Réponse différée déclenchée" et commencer à traiter la demande. Ensuite, le gestionnaire de réseau:
  - alloue les ressources réseau au service Edition;
  - si exigé, envoie une demande "Unité PDU de couche FAL: Ecrire supertrame" (voir 8.3.6.6.1) pour établir une supertrame; et
  - envoie une demande "Unité PDU de couche FAL: Ecrire Liaison" (voir 8.3.6.8.1) pour établir une liaison au sein de la supertrame.

NOTE 1 Le gestionnaire de réseau envoie aussi une demande aux autres appareils de réseau pour ajouter une supertrame et une liaison en vue de l'édition.

- Dans la plupart des cas, le gestionnaire de réseau établit des liaisons dans une supertrame existante pour satisfaire à cette demande. Une fois le réseau configuré, le gestionnaire de réseau retourne une réponse à "Unité PDU de couche FAL: Demander indicateur horaire" indiquant que la demande a été achevée.

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- Après réception de la réponse, l'appareil doit envoyer une réponse indiquant le succès.
- Si la réponse du gestionnaire de réseau à "Unité PDU de couche FAL: Demander indicateur horaire" indique que la demande ne peut pas être satisfaite, l'appareil doit répondre en indiquant "Largeur de bande insuffisante".
- Si l'appareil répondeur a une capacité suffisante actuellement programmée pour éditer le jeu de données spécifié dans "Message d'édition de données", l'appareil doit envoyer une réponse indiquant le succès.

Si la demande concerne la désactivation de l'édition, l'appareil répondeur doit exécuter la procédure ci-après

- L'appareil répondeur doit répondre par "Succès".
- L'appareil doit envoyer une demande "Unité PDU de couche FAL: Supprimer indicateur horaire" (voir 8.3.4.33.1) au gestionnaire de réseau. Le gestionnaire de réseau est censé démarrer le traitement de la demande. Ensuite, le gestionnaire de réseau:
  - libère les ressources réseau au profit du service Edition;
  - envoie la demande "Unité PDU de couche FAL: Supprimer liaison" (voir 8.3.6.9.1) pour retirer la liaison de la supertrame; et
  - si nécessaire, envoie la demande "Unité PDU de couche FAL: Supprimer supertrame" (voir 8.3.6.7.1) pour retirer la supertrame.

NOTE 2 Le gestionnaire de réseau envoie également une demande aux autres appareils de réseau pour supprimer la supertrame et la liaison utilisées pour l'édition.

- Une fois les ressources réseau libérées, le gestionnaire de réseau retourne une réponse à "Unité PDU de couche FAL: Demander indicateur horaire" indiquant que la demande a été menée à bien.

Si l'appareil n'a pas la capacité réseau requise pour l'édition, il doit mettre le bit "Capacité refusée" au statut "Normalisé" (voir 8.3.3.22.2 – commande 48).

S'il n'y a qu'un seul octet dans la demande, alors:

- Si l'appareil est construit conformément à la présente norme et que la valeur de ce champ n'est ni '0' ni '1', l'appareil doit répondre par "Nombre d'octets de données reçus trop faible";
- Sinon, l'appareil doit supposer que le Message d'édition de données '0' est en cours d'activation ou de désactivation pour l'édition.

8.3.3.35 Lire résumé de notification d'événement

8.3.3.35.1 Primitive de demande

La valeur de la commande est cent quinze (115); La valeur du champ "Nombre d'octets" est un (1) comme présenté au Tableau 113.

Tableau 113 – Champ "Valeur" de la demande Lire résumé de notification d'événement

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Réf. de numéro d'événement	Utilisé pour se référer à un jeu de données d'événement dans toutes les demandes et réponses de lecture et d'écriture pour le jeu en question.

8.3.3.35.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 114. Les valeurs des codes de réponse sont présentées au Tableau 115.

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Tableau 114 – Champ "Valeur" de réponse Lire résumé de notification d'événement

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Réf. de numéro d'événement	Référence à un jeu de données d'événement dans toutes les demandes et réponses de lecture et d'écriture pour le jeu en question
1	Unsigned8	Nombre maximal d'événements	Nombre maximal de messages de données d'événement pris en charge par l'appareil
2, bit 7	Champ binaire	Statut de l'événement	Statut d'événement tel que spécifié au Tableau F.14 – bits 7-4 au décalage d'octet 2
2, bit 3	Champ binaire	Contrôle de notification d'événement	Code de contrôle de notification d'événement tel que spécifié au Tableau F.13 – bits 3-0 au décalage d'octet 2
3	Temps	Heure d'occurrence de l'événement	Heure à laquelle le premier événement non acquitté a été déclenché; 0xFFFFFFFF si aucun événement en instance.
7	Temps	Délai de nouvelle tentative de notification d'événement	Heure de nouvelle tentative de notification d'événement
11	Temps	Temps maximal d'actualisation	Temps maximal d'actualisation
15	Temps	Intervalle antirebond d'événement	Intervalle antirebond d'événement
19	Champ binaire	Masque de statut de l'appareil	Bits inclus dans le statut de l'appareil
20	Matrice de champ binaire (1 à 26)	Masque d'événement	La concaténation du masque pour déclenchement sur les bits mis à '1' dans "Statut de processus d'application" et dans la réponse à la Commande 48

Tableau 115 – Codes de réponse spécifiques à la commande Lire résumé de notification d'événement

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil

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8.3.3.35.3 Procédure au niveau de l'appareil répondeur

Cette commande lit la configuration de la notification d'événement. Si l'appareil prend en charge moins de champs de statut que le nombre maximal de champs de statut décrits dans les réponses à la Commande 48 (voir Tableau 84), la réponse à cette demande doit inclure "Masque d'événement " pour les champs pris en charge par l'appareil.

8.3.3.36 Unité PDU de couche FAL: Ecrire Masque binaire de notification d'événement

8.3.3.36.1 Primitive de demande

La valeur de la commande est cent seize (116); la valeur du champ "Nombre d'octets" est trois (3) à vingt-huit (28) comme présenté au Tableau 116.

Tableau 116 – Champ "Valeur"de Ecrire Masque binaire de notification d'événement

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Réf. de numéro d'événement	Référence à un jeu de données d'événement dans toutes les demandes et réponses de lecture et d'écriture pour le jeu en question
1	Champ binaire	Masque de statut de l'appareil	Bits inclus dans le statut de l'appareil
2	Matrice de champ binaire (1 à 26)	Masque d'événement	La concaténation du masque pour déclenchement sur les bits mis à '1' dans "Statut de processus d'application" et dans la réponse à la Commande 48

8.3.3.36.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 116. Les valeurs des codes de réponse sont présentées au Tableau 117.

Tableau 117 – Codes de réponse spécifiques à la commande Ecrire Masque binaire de notification d'événement

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
16	Erreur	Accès limité

8.3.3.36.3 Procédure au niveau de l'appareil répondeur

Cette commande établit le masque d'événement qui est utilisé pour déclencher une notification d'événement. Pour chaque bit mis à '1' dans "Masque d'événement", toute modification de la valeur correspondante de "Statut de processus d'application" ou de réponse à la Commande 48 déclenche une notification d'événement. Si le nombre de champs "Masque d'événement" dans la demande est inférieur à celui des champs "Masque d'événement" pris en charge par l'appareil, les bits de masque non spécifiés doivent être considérés comme étant à '0'.

L'appareil doit conserver le masque d'événement suite à une réinitialisation de l'appareil, à un autotest ou à une mise hors tension puis de nouveau sous tension.

8.3.3.37 Unité PDU de couche FAL: Ecrire temporisation de notification d'événement

8.3.3.37.1 Primitive de demande

La valeur de la commande est cent dix-sept (117); la valeur du champ "Nombre d'octets" est treize (13) et le champ "Valeur" est tel que présenté au Tableau 118.

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Tableau 118 – Champ "Valeur" de Ecrire temporisation de notification d'événement

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Réf. de numéro d'événement	Référence à un jeu de données d'événement dans toutes les demandes et réponses de lecture et d'écriture pour le jeu en question
1	Temps	Délai de nouvelle tentative de notification d'événement	Heure de nouvelle tentative de notification d'événement
5	Temps	Temps maximal d'actualisation	Temps maximal d'actualisation
9	Temps	Intervalle antirebond d'événement	Intervalle antirebond d'événement
NOTE La valeur retournée dans les octets de données de réponse reflète la valeur effectivement utilisée par l'appareil.			

8.3.3.37.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 118. Les valeurs des codes de réponse sont présentées au Tableau 119.

Tableau 119 – Codes de réponse spécifiques à la commande Ecrire temporisation de notification d'événement

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
8	Avertissement	Temps d'actualisation ou intervalle antirebond ajusté
9	Erreur	Demande non valide de temporisation de notification d'événement
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pas pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit

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8.3.3.37.3 Procédure au niveau de l'appareil répondeur

Cette commande fixe les paramètres de temporisation pour la notification d'événement. Si le temps de nouvelle tentative de notification d'événement n'est pas inférieur ou égal au temps maximal d'actualisation, l'appareil doit le réajuster. S'il y a lieu, les appareils doivent corriger les valeurs de temporisation reçue dans la demande et répondre par "temps d'actualisation ou intervalle antirebond ajusté".

L'intervalle antirebond d'événement établit la durée minimale sur laquelle le bit de statut doit rester changé (à savoir, le temps pendant lequel l'événement doit persister) dans un appareil avant qu'une notification d'événement ne soit envoyée. L'appareil doit effectuer un balayage pour rechercher de possibles événements au moins deux fois au cours d'un même intervalle antirebond d'événement.

Si aucun événement n'a été généré pendant un temps maximal d'actualisation, l'appareil doit éditer la réponse de la Commande 119 une fois à l'attention de la passerelle en utilisant la demande "Rapport d'informations".

L'appareil doit conserver les paramètres de temporisation de la notification d'événement suite à une réinitialisation de l'appareil, à un autotest ou à une mise hors tension puis de nouveau sous tension.

8.3.3.38 Unité PDU de couche FAL: Ecrire contrôle de notification d'événement

8.3.3.38.1 Primitive de demande

La valeur de la commande est cent dix-huit (118). La valeur du champ "Nombre d'octets" est deux (2) comme présenté au Tableau 120.

Tableau 120 – Champ "Valeur" de Ecrire contrôle de notification d'événement

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Réf. de numéro d'événement	Référence à un jeu de données d'événement dans toutes les demandes et réponses de lecture et d'écriture pour le jeu en question
1	Champ binaire	Contrôle de notification d'événement	Code de contrôle de notification d'événement tel que spécifié au Tableau F.13

8.3.3.38.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 120. Les valeurs des codes de réponse sont présentées au Tableau 121.

Tableau 121 – Codes de réponse spécifiques à la commande Ecrire contrôle de notification d'événement

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
8	Avertissement	Temps d'actualisation ajustés
9	Erreur	Demande non valide de temporisation de notification d'événement
14	Avertissement	Temps d'actualisation incertain autorisé uniquement en l'absence de connexion au réseau
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pas pu être lancée
33	Erreur	Réponse différée (DR) déclenchée – autorisé uniquement lors de l'activation d'événements dans un appareil connecté à un réseau conforme à la présente norme
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit

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8.3.3.38.3 Procédure au niveau de l'appareil répondeur

Cette commande est utilisée pour activer ou désactiver la notification d'événement. Si un appareil de terrain conforme au Type 20 rejoint le réseau et s'il lui est refusé la capacité requise pour la notification d'événement, il doit mettre le bit 'Capacité refusée' au "Statut normalisé" 3 (voir Tableau F.11). La capacité peut être refusée en raison de demandes d'édition de données ou de notification d'événement.

L'appareil doit conserver le contrôle du mode de notification d'événement suite à une réinitialisation de l'appareil, à un autotest ou à une mise hors tension puis de nouveau sous tension.

8.3.3.39 Unité PDU de couche FAL: Ecrire Acquittement de notification d'événement

8.3.3.39.1 Primitive de demande

La valeur de la commande est cent dix-neuf (119); la valeur du champ "Nombre d'octets" est soit un (1), soit huit (8) à trente-trois (33) comme présenté au Tableau 122. S'il n'y a qu'un seul octet, celui-ci doit être "Réf. de numéro d'événement".

Tableau 122 – Champ "Valeur" de Ecrire Acquittement de notification d'événement

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Réf. de numéro d'événement	Référence à un jeu de données d'événement dans toutes les demandes et réponses de lecture et d'écriture pour le jeu en question
1	Temps	Heure d'occurrence de l'événement	Heure à laquelle le premier événement non acquitté a été déclenché; '1' lorsque aucun événement n'est en instance
5	Unsigned16	Compteur de modification de configuration	Compteur de modification de configuration
7	Champ binaire	Statut de processus d'application	Statut de processus d'application (voir 8.3.1.4)
8	Matrice de champ binaire (1 à 25)	Statut supplémentaire d'appareil	Données de la Commande 48, voir Note
NOTE Contient des données verrouillées et peut ne pas concorder avec les données de réponse courantes de la Commande 48.			

8.3.3.39.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 122. Les valeurs des codes de réponse sont présentées au Tableau 123.

Tableau 123 – Codes de réponse spécifiques à la commande Ecrire Acquittement de notification d'événement

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible; généré uniquement si le numéro d'événement ne figure pas dans les données de la demande
6	Erreur	Erreur de commande spécifique à l'appareil
8	Avertissement	Tous les événements n'ont pas été libérés
16	Erreur	Accès limité

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8.3.3.39.3 Procédure au niveau de l'appareil répondeur

Cette commande est utilisée pour acquitter la notification d'événement. L'appareil doit comparer les valeurs de paramètres dans l'acquittement reçu aux valeurs courantes de ces mêmes paramètres au niveau de l'appareil "Heure d'occurrence de l'événement", "Compteur de modifications de configuration", "Statut de processus d'application" et "Statut supplémentaire d'appareil". Si toutes les valeurs de paramètres sont égales, l'appareil doit répondre par "Succès" et mettre les bits de Statut d'événement (voir Tableau 114) à '0'. Sachant qu'il peut y avoir plusieurs transitions de bits horodatées, la commande doit seulement effacer la plus ancienne. Si tous les bits ne sont pas mis à '0', l'appareil doit répondre par "Tous les événements n'ont pas été libérés". Il s'agit certes d'une commande d'écriture, mais elle ne doit toutefois être affectée par aucun mécanisme de protection en écriture. Il est essentiel que les notifications d'événements puissent être à tout moment libérées.

La commande est tronquée après le dernier octet reçu lors de l'établissement du masque d'événements (voir la Commande 116 en 8.3.3.36). Si des octets au-delà de ceux fournis dans la Commande 116 sont reçus dans cette demande de commande, ils doivent être ignorés et ne doivent pas être retournés dans la réponse de commande. Les valeurs les plus récentes du "Statut de processus d'application", du "Compteur des modifications de configuration" et des octets de réponse à la Commande 48 sont toujours inclus dans la Commande 119.

Cette commande peut être émise avec uniquement la "Réf. de numéro d'événement" dans les données de demande. Si cela se produit, l'appareil doit retourner les données d'événement verrouillées courantes comme présenté au Tableau 122 et ne doit pas mettre les bits "Statut d'événement" à '0'.

L'appareil doit stocker au moins trois (3) messages de réponse (l'événement courant édité en utilisant la Commande 119 et 2 autres qui sont en tampon). Il est fortement conseillé que cinq (5) transitions soient en tampon. Il n'est pas nécessaire de les sauvegarder en cas de mise hors puis sous tension.

8.3.4 Structures d'APDU spécifiques aux services de gestion de couche

8.3.4.1 Unité PDU de couche FAL: Ecrire Join_key

8.3.4.1.1 Primitive de demande

La valeur de la commande est sept cent soixante-huit (768); la valeur du champ "Nombre d'octets" est un (1) et le champ "Valeur" est présenté au Tableau 124.

Tableau 124 – Champ "Valeur" de Ecrire Join_key

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Clé de sécurité	Join_key	Il s'agit d'une clé réseau de 128 bits utilisée pour la sécurité.

8.3.4.1.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 124. Les valeurs des codes de réponse sont présentées au Tableau 125.

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Tableau 125 – Codes de réponse spécifiques à la commande Ecrire Join_key

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit
65	Erreur	Echec du changement de clé

8.3.4.1.3 Procédure au niveau de l'appareil répondeur

Cette commande modifie la Join_key des appareils. La commande peut être émise par le gestionnaire de réseau ou être saisie via un outil de maintenance local (par exemple un terminal portatif). Cette commande doit être acceptée à tout moment si elle est reçue du gestionnaire de réseau ou via le port de maintenance local. Si elle est reçue de toute autre source, l'appareil doit répondre par "Accès limité".

8.3.4.2 Unité PDU de couche FAL: Lire statut de rattachement

8.3.4.2.1 Primitive de demande

La valeur de la commande est sept cent soixante-neuf (769); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.2.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 126. Les valeurs des codes de réponse sont présentées au Tableau 127.

Tableau 126 – Champ "Valeur" de Lire statut de rattachement

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Mode sans fil	Mode sans fil tel que spécifié au Tableau F.27; les quatre bits de poids fort doivent être mis à zéro.
1	Champ binaire	Statut de rattachement	Cette énumération de 2 octets indique le statut de rattachement tel que spécifié au Tableau F.28
3	Unsigned8	Voisins	Nombre de voisins disponibles. Le nombre de voisins détectés par l'appareil.
4	Unsigned8	Paquets d'annonce	Nombre de paquets d'annonce reçus
5	Unsigned8	Max_join_retries	Nombre maximal de tentatives de rattachement; Un trop grand nombre de tentatives de rattachement amène l'appareil à considérer que le rattachement a échoué.
6	Temps	Join_rsp_time	Durée depuis que la dernière demande de rattachement a été envoyée
10	Temps	Temps de recherche	Durée d'écoute pour détecter la première annonce

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Tableau 127 – Codes de réponse spécifiques à la commande Lire statut de rattachement

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil

8.3.4.2.3 Procédure au niveau de l'appareil répondeur

Cette commande permet à un système hôte ou à un terminal portatif de surveiller un appareil de terrain à mesure qu'il franchit les étapes de transition du processus de rattachement conformément à l'Article A.2. Si l'appareil ne peut pas rejoindre le réseau, la réponse à cette commande fournit une assistance au diagnostic à un technicien en instrumentation ou à un chargé d'entretien.

8.3.4.3 Unité PDU de couche FAL: Ecrire Active_search_shed_time

8.3.4.3.1 Primitive de demande

La valeur de la commande est sept cent soixante-dix (770); la valeur du champ "Nombre d'octets" est quatre (4) et le champ "Valeur" est tel que présenté au Tableau 128.

Tableau 128 – Champ "Valeur" de la demande Ecrire Active_search_shed_time

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Temps	Active_search_shed_time (temps de renforcement de recherche active)	Durée pendant laquelle la recherche active est activée au cours de la procédure de rattachement

8.3.4.3.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 129. Les valeurs des codes de réponse sont présentées au Tableau 130.

Tableau 129 – Champ "Valeur" de réponse Ecrire Active_search_shed_time

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Temps	Active_search_shed_time (temps de renforcement de recherche active)	Durée pendant laquelle la recherche active est activée au cours de la procédure de rattachement
4	Temps	Advertise_time	Intervalle auquel les DLPDU d'annonce sont émises
8	Unsigned8	Voisins	Nombre de voisins effectuant des annonces en plus de cet appareil

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Tableau 130 – Codes de réponse spécifiques à la commande Ecrire Active_search_shed_time

Valeur	Classe	Description
0	Succès	Pas d'erreur
3	Erreur	Paramètre passé plus grand que permis
4	Erreur	Paramètre passé plus petit que permis
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
8	Avertissement	Mis à la valeur la plus proche possible
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit
65	Erreur	Demande rejetée (par exemple opérateur neutralisé)

8.3.4.3.3 Procédure au niveau de l'appareil répondeur

Cette commande demande une recherche active et rapide voir A.2.3.2. En général, elle est reçue localement par un appareil de réseau à partir d'un outil de maintenance local (par exemple, un terminal portatif); elle est ensuite propagée vers le gestionnaire de réseau. Le gestionnaire de réseau est censé configurer ou activer une annonce rapide de l'appareil et au niveau d'un ou plusieurs de ses voisins.

8.3.4.4 Unité PDU de couche FAL: Ecrire Configuration du mode de rattachement

8.3.4.4.1 Primitive de demande

La valeur de la commande est sept cent soixante et onze (771); la valeur du champ "Nombre d'octets" est six (6) et le champ "Valeur" est présenté au Tableau 131.

Tableau 131 – Champ "Valeur" de Ecrire configuration du mode de rattachement

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Mode de rattachement	Le mode de rattachement tel que spécifié au Tableau F.36
1	Temps	Active_search_shed_time (temps de renforcement de recherche active)	Durée pendant laquelle la recherche active est activée au cours de la procédure de rattachement
5	Unsigned8	max_join_retries	Nombre maximal de nouvelles tentatives de rattachement

8.3.4.4.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 131. Les valeurs des codes de réponse sont présentées au Tableau 132.

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Tableau 132 – Codes de réponse spécifiques à la commande Ecrire configuration du mode de rattachement

Valeur	Classe	Description
0	Succès	Pas d'erreur
3	Erreur	Paramètre passé plus grand que permis
4	Erreur	Paramètre passé plus petit que permis
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
8	Avertissement	Mis à la valeur la plus proche possible
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit
65	Erreur	Demande rejetée

8.3.4.4.3 Procédure au niveau de l'appareil répondeur

Cette commande permet à un système hôte ou terminal portatif de forcer un appareil de terrain à entrer en mode de rattachement actif. L'appareil doit rester en mode de recherche active pendant au moins le temps "Active_search_shed_time" (voir A.2.3.2). Ce temps écoulé, l'appareil peut entrer en mode Sommeil profond ou Puissance ultra faible.

8.3.4.5 Unité PDU de couche FAL: Lire configuration du mode de rattachement

8.3.4.5.1 Primitive de demande

La valeur de la commande est sept cent soixante-douze (772); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.5.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 133. Les valeurs des codes de réponse sont présentées au Tableau 134.

Tableau 133 – Champ "Valeur" de réponse Lire configuration du mode de rattachement

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Mode de rattachement	Le mode de rattachement tel que spécifié au Tableau F.36
1	Temps	Active_search_shed_time (temps de renforcement de recherche active)	Durée pendant laquelle la recherche active est activée au cours de la procédure de rattachement
5	Unsigned8	max_join_retries	Nombre maximal de nouvelles tentatives de rattachement

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Tableau 134 – Codes de réponse spécifiques à la commande Lire configuration du mode de rattachement

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée

8.3.4.5.3 Procédure au niveau de l'appareil répondeur

Cette commande lit le mode "Rattachement" et le temps "Active_search_shed_time".

8.3.4.6 Unité PDU de couche FAL: Ecrire Network_ID

8.3.4.6.1 Primitive de demande

La valeur de la commande est sept cent soixante-treize (773); la valeur du champ "Nombre d'octets" est deux (2) et le champ "Valeur" est présenté au Tableau 135.

Tableau 135 – Champ "Valeur" de Ecrire Network_ID

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	network_ID	Identifiant de réseau, comme défini en 3.2.72

8.3.4.6.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 136. Les valeurs des codes de réponse sont présentées au Tableau 137.

Tableau 136 – Champ "Valeur" de réponse de Ecrire Network_ID value field

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Nouveau Network_ID	Il s'agit du nouvel identifiant, comme défini en 3.2.72
2	Unsigned16	Network_ID courant	Il s'agit de l'identifiant courant, comme défini en 3.2.72

Tableau 137 – Codes de réponse spécifiques à la commande Ecrire "Network_ID "

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
8	Avertissement	Changement de Network_ID en instance; une nouvelle valeur doit être utilisée pour le rattachement suivant ou au redémarrage du réseau.
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit
65	Erreur	Network_ID non valide

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8.3.4.6.3 Procédure au niveau de l'appareil répondeur

Cette commande configure l'appareil pour reconnaître le Network_ID correct. Si cette commande n'a pas été émise par le gestionnaire de réseau ou via le port de maintenance, l'appareil doit répondre par "Accès limité".

Si l'appareil n'est pas connecté au réseau, le Network_ID est immédiatement changé. Il convient que l'appareil entre en mode d'économie d'énergie et attende la commande de configuration du mode de rattachement avant de commencer à rechercher activement le réseau.

Sinon, le nouveau Network_ID doit être utilisé pour le prochain processus de rattachement.

8.3.4.7 Unité PDU de couche FAL: Lire Network_ID

8.3.4.7.1 Primitive de demande

La valeur de la commande est sept cent soixante-quatorze (774); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.7.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 138. Les valeurs des codes de réponse sont présentées au Tableau 139.

Tableau 138 – Champ "Valeur" de Lire "Network_ID "

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Nouveau Network_ID	Nouvel identifiant de réseau, comme défini en 3.2.72
2	Unsigned16	Network_ID courant	Identifiant de réseau courant, comme défini en 3.2.72

Tableau 139 – Codes de réponse spécifiques à la commande Lire "Network_ID "

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
8	Avertissement	Changement d'identifiant de réseau en instance
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée

8.3.4.7.3 Procédure au niveau de l'appareil répondeur

Cette commande lit la valeur de réglage courante du Network_ID dans l'appareil.

8.3.4.8 Unité PDU de couche FAL: Ecrire Network_tag

8.3.4.8.1 Primitive de demande

La valeur de la commande est sept cent soixante-quinze (775); la valeur du champ "Nombre d'octets" est trente-deux (32) et le champ "Valeur" est présenté au Tableau 140.

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Tableau 140 – Champ "Valeur" de Ecrire "Network_tag"

Décalage d'octet	Type de données	Nom de paramètre	Description
0 – 31	Latin-1	Network_tag	Marqueur long devant être stocké dans l'appareil

8.3.4.8.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 140. Les valeurs des codes de réponse sont présentées au Tableau 141.

Tableau 141 – Codes de réponse spécifiques à la commande Ecrire "Network_tag"

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit

8.3.4.8.3 Procédure au niveau de l'appareil répondeur

Cette commande lit le marqueur pour le réseau. Le Network_tag est un proxy pour le Network_ID et, de ce fait, le réseau peut être identifié sous une forme textuelle au niveau de l'application.

8.3.4.9 Unité PDU de couche FAL: Lire Network_tag

8.3.4.9.1 Primitive de demande

La valeur de la commande est sept cent soixante-seize (776); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.9.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 142. Les valeurs des codes de réponse sont présentées au Tableau 143.

Tableau 142 – Champ "Valeur" de réponse Lire "Network_tag"

Décalage d'octet	Type de données	Nom de paramètre	Description
0 – 31	Latin-1	Long_tag	Marqueur long stocké dans l'appareil

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Tableau 143 – Codes de réponse spécifiques à la commande Lire "Network_tag"

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
16	Erreur	Accès limité
32	Erreur	Occupé

8.3.4.10 Unité PDU de couche FAL: Lire capacités de l'appareil sans fil

8.3.4.10.1 Primitive de demande

La valeur de la commande est sept cent soixante-dix-sept (777); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.10.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 144. Les valeurs des codes de réponse sont présentées au Tableau 145.

Tableau 144 – Champ "Valeur" de Lire capacités de l'appareil sans fil

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Power source (source d'alimentation)	Les 4 bits de poids fort (7-4) représentent la capacité de l'appareil sans fil, comme spécifié au Tableau F.39 Les 4 bits de poids faibles (3-0) représentent la source d'énergie, comme spécifié au Tableau F.20
1	Float32	Débit de crête des paquets	Valeur crête du nombre de paquets par seconde
5	Temps	Durée de charge	Durée à la charge de crête des paquets avant consommation d'énergie
9	Temps	Temps de récupération	Temps pour récupérer après consommation de l'énergie
13	Integer8	Niveau de signal reçu correct	Seuil de niveau de signal reçu (en dB) pour une 'bonne' connexion
14	Temps	Min Keep_alive_time	Keep_alive_time minimal requis
18	Unsigned16	Nombre de voisins	Nombre maximal de voisins
20	Unsigned16	Tampon de paquets	Nombre maximal de tampons de paquets

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Tableau 145 – Codes de réponse spécifiques à la commande Lire capacités de l'appareil sans fil

Valeur	Classe	Description
0	Succès	Pas d'erreur
16	Erreur	Accès limité

8.3.4.10.3 Procédure au niveau de l'appareil répondeur

Cette PDU est utilisée par le gestionnaire de réseau pour déterminer des caractéristiques opérationnelles d'un appareil de réseau. Le gestionnaire de réseau est censé utiliser le débit de crête des paquets et le temps de récupération pour prendre en charge des appareils rechargeables ou récupérateurs d'énergie.

Les appareils alimentés par batterie d'accumulateurs doivent pouvoir supporter le débit de crête des paquets pendant la durée de vie spécifiée pour l'appareil. La durée de charge doit être d'une heure au moins. Si ce paramètre n'est pas applicable, sa valeur doit être mise à vingt-quatre heures.

Alors que l'appareil récupère après une consommation d'énergie, il doit pouvoir acheminer un paquet par seconde. Si ce paramètre n'est pas applicable, sa valeur doit être mise à zéro.

8.3.4.11 Unité PDU de couche FAL: Lire durée de vie de la batterie

8.3.4.11.1 Primitive de demande

La valeur de la commande est sept cent soixante-dix-huit (778); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.11.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 146. Les valeurs des codes de réponse sont présentées au Tableau 147.

Tableau 146 – Champ "Valeur" de réponse Lire durée de vie de la batterie

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Durée de vie de la batterie	Durée de vie restante de la batterie en jours

Tableau 147 – Codes de réponse spécifiques à la commande Lire durée de vie de la batterie

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
32	Erreur	Occupé

8.3.4.11.3 Procédure au niveau de l'appareil répondeur

Cette PDU est utilisée par l'état courant de la batterie dans un appareil de réseau. Si l'appareil n'a ni batterie ni autre composant d'accumulation d'énergie, l'appareil peut retourner 0xFFFF comme étant la valeur de la durée de vie de la batterie.

Une analyse de conception méticuleuse des performances à long terme des batteries est recommandée pour mettre correctement en œuvre cette commande.

8.3.4.12 Unité PDU de couche FAL: Rendre compte de la santé de l'appareil

8.3.4.12.1 Primitive de demande

Il n'y a aucune primitive de demande pour cette commande.

8.3.4.12.2 Primitive de réponse

La valeur de la commande est sept cent soixante-dix-neuf (779); Le champ "Valeur" de la réponse est présenté au Tableau 148. Les valeurs des codes de réponse sont présentées au Tableau 149.

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Tableau 148 – Champ "Valeur" de Réponse Rendre compte de la santé de l'appareil

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Paquets générés	Nombre de paquets générés par cet appareil
2	Unsigned16	Paquets terminés	Nombre de paquets terminés par cet appareil
4	Unsigned8	Défaillances MIC de la DLL	Nombre de défaillances MIC de la DLL détectées
5	Unsigned8	Défaillances MIC de la couche NL	Nombre de défaillances détectées relatives au MIC (de session) de la couche NL
6	Enumération	Statut d'énergie	Statut d'énergie tel que spécifié au Tableau F.33
7	Unsigned8	Erreurs de CRC	Nombre d'erreurs de CRC détectées
8	Unsigned8	Paquets manqués	Nombre de paquets détectés comme absents
9	Unsigned8	File d'attente maximale de tampon	Longueur de la file d'attente maximale de tampon depuis la dernière publication du rapport
10	Float32	File d'attente moyenne de tampon	Longueur de la file d'attente moyenne de tampon dans le temps (moyenne glissante)
14	Temps	Latence moyenne	Latence moyenne de tous les paquets en provenance de la passerelle et du gestionnaire de réseau depuis le dernier rattachement
18	Temps	Variance de la latence	Variance de la latence de tous les paquets provenant de la passerelle et du gestionnaire de réseau depuis le dernier rattachement
22	Unsigned32	Paquets reçus	Nombre de paquets reçus
26	Unsigned32	Paquets en retard ou perdus	Nombre de paquets en retard ou perdus
30	Unsigned8	Session inconnue	Nombre de paquets avec session inconnue

Tableau 149 – Codes de réponse spécifiques à la commande Rendre compte de la santé de l'appareil

Valeur	Classe	Description
0	Succès	Pas d'erreur
16	Erreur	Accès limité

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8.3.4.12.3 Procédure au niveau de l'appareil répondeur

Cette PDU est utilisée par l'appareil de terrain pour éditer des compteurs relatifs aux communications comme "Rapport d'informations". Ces compteurs doivent uniquement être réinitialisés juste avant que l'appareil ne rejoigne le réseau. Ensuite, les compteurs doivent être incrémentés et repasser par zéro après dépassement de capacité. La valeur de "Paquets manqués" est incrémentée pour chaque zéro dans l'historique du compteur de Nonces qui est en soupassement de capacité.

Cette commande doit être rejetée avec un code de réponse d'accès limité si l'appareil n'est pas rattaché au réseau.

L'appareil doit éditer le rapport de santé de l'appareil en utilisant le niveau de priorité "Commande" en tant que rapport d'informations.

8.3.4.13 Unité PDU de couche FAL: Lire liste de santé des voisins

8.3.4.13.1 Primitive de demande

La valeur de la commande est sept cent quatre-vingts (780); la valeur du champ "Nombre d'octets" est deux (2) et le champ "Valeur" est présenté au Tableau 150.

Tableau 150 – Champ "Valeur" de la demande Lire liste de santé des voisins

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Indice de Table	Indice de la Table des voisins
1	Unsigned8	Nombre d'entrées	Nombre d'entrées de voisins devant être lues

8.3.4.13.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 151. Les valeurs des codes de réponse sont présentées au Tableau 152.

Tableau 151 – Champ "Valeur" de la réponse Lire liste de santé des voisins

Décalage d'octet[a]	Type de données	Nom de paramètre	Description
0	Unsigned8	Indice de Table	Indice de la Table des voisins
1	Unsigned8	Nombre d'entrées	Nombre d'entrées de voisins contenues dans la réponse
2	Unsigned8	Nombre de voisins	Nombre total de voisins reliés ou non dans la Table des voisins
3	Unsigned16	Neighbor_nickname	Surnom du voisin comme défini en 3.2.74
5	Champ binaire	Fanions de voisins	Fanions de voisins, comme spécifié au Tableau F.34
6	Integer8	Average_RSL (niveau moyen de signal reçu)	Niveau moyen de signal reçu (en dBm) depuis le dernier rapport
7	Unsigned16	Packets_transmitted (paquets émis)	Nombre de paquets émis vers ce voisin
9	Unsigned16	Missed_ACK_packets (paquets ACQ manqués)	Emission échouée vers ce voisin nombre de paquets attendant un ACQ et aucun reçu
11	Unsigned16	Packets_received (paquets reçus)	Nombre de paquets reçus de ce voisin
13..			

[a] Les champs dans les octets 3 à 12 sont répétés autant de fois que la valeur de "Nombre de voisins".

Tableau 152 – Codes de réponse spécifiques à la commande Lire liste de santé des voisins

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
8	Avertissement	Mis à la valeur la plus proche possible
16	Erreur	Accès limité

8.3.4.13.3 Procédure au niveau de l'appareil répondeur

Cette commande lit les entrées de la Table des voisins à partir de l'appareil de réseau. Les voisins avec des liaisons à l'appareil sont attendus au début de la liste et ceux sans liaisons le sont à la fin de la liste. La Table des voisins est une liste dont des entrées sont supprimées lorsqu'un voisin arrête la communication, ou ajoutées lorsqu'un nouveau voisin est détecté. L'indice de la Table et le compte d'entrées changent suite à l'addition ou à la suppression d'un voisin. Par conséquent, si le(s) paramètre(s) de la demande ne sont pas valides,

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l'appareil doit répondre au moyen de la valeur valide la plus proche du/des paramètre(s) et envoyer le code de réponse "mis à la valeur la plus proche possible".

L'appareil doit envoyer cette réponse à une demande de lecture. L'appareil doit éditer la liste de santé des voisins en utilisant le niveau de priorité "Commande" en tant que rapport d'informations. La période d'édition est fixée en configurant l'heure de "Rapport de santé" au moyen de la Commande 795 (voir 8.3.4.27).

Les compteurs de paquets doivent uniquement être réinitialisés juste avant que l'appareil ne rejoigne le réseau. Ensuite, les compteurs doivent être incrémentés et repasser par zéro après dépassement de capacité.

Cette PDU est également utilisée par l'appareil de terrain pour éditer la santé des voisins comme "Rapport d'informations".

8.3.4.14 Unité PDU de couche FAL: Lire surnom d'appareil

8.3.4.14.1 Primitive de demande

La valeur de la commande est sept cent quatre-vingt-un (781); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.14.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 153. Les valeurs des codes de réponse sont présentées au Tableau 154.

Tableau 153 – Champ "Valeur" de réponse Lire surnom d'appareil

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Surnom d'appareil	Surnom de l'appareil comme défini en 3.2.74

Tableau 154 – Codes de réponse spécifiques à la commande Lire surnom d'appareil

Valeur	Classe	Description
0	Succès	Pas d'erreur
16	Erreur	Accès limité

8.3.4.14.3 Procédure au niveau de l'appareil répondeur

Cette commande lit un surnom d'appareil de réseau (adresse courte).

8.3.4.15 Unité PDU de couche FAL: Lire liste de sessions

8.3.4.15.1 Primitive de demande

La valeur de la commande est sept cent quatre-vingt-deux (782); la valeur du champ "Nombre d'octets" est deux (2) et le champ "Valeur" est présenté au Tableau 155.

Tableau 155 – Champ "Valeur" de demande Lire liste de sessions

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Indice de Table	Indice de la Table des sessions
1	Unsigned8	Nombre d'entrées	Nombre d'entrées de sessions à lire (doit être mis à 1)

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8.3.4.15.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 156. Les valeurs des codes de réponse sont présentées au Tableau 157.

Tableau 156 – Champ "Valeur" de réponse Lire liste de sessions

Décalage d'octet[a]	Type de données	Nom de paramètre	Description
0	Unsigned8	Indice de Table	Indice de la Table des sessions
1	Unsigned8	Nombre d'entrées	Nombre d'entrées de sessions contenues dans la réponse
2	Unsigned8	Session count	Nombre total de sessions actives
3	Enumération	Session_type	Session_type comme spécifié au Tableau F.24
4	Unsigned16	Peer_nickname	Surnom de l'appareil du correspondant
6	Identifiant unique	Peer_unique_ID (identifiant unique d'homologue)	ID propre à l'appareil du correspondant, comme défini en 3.2.105
11	Unsigned32	Peer_nonce_counter (compteur de nonces de l'appareil homologue)	Valeur la plus élevée du compteur de nonces reçue de l'appareil du correspondant
15	Unsigned32	My_nonce_counter	Compteur de nonces pour les paquets fournis par l'appareil
19..			

[a] Les champs dans les octets 3 à 18 sont répétés autant de fois que la valeur du nombre de sessions.

Tableau 157 – Codes de réponse spécifiques à la commande Lire liste de sessions

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
8	Avertissement	Mis à la valeur la plus proche possible
16	Erreur	Accès limité

8.3.4.15.3 Procédure au niveau de l'appareil répondeur

Cette commande lit les entrées de la Table des sessions à partir de l'appareil de réseau. La Table des sessions est une liste dont les entrées sont supprimées ou ajoutées. L'indice des sessions et le compte d'entrées changent suite à l'addition ou à la suppression d'une session. Par conséquent, si le(s) paramètre(s) de la demande ne sont pas valides, l'appareil doit répondre au moyen de la valeur valide la plus proche du/des paramètre(s) et envoyer le code de réponse "mis à la valeur la plus proche possible".

8.3.4.16 Unité PDU de couche FAL: Liste de supertrames

8.3.4.16.1 Primitive de demande

La valeur de la commande est sept cent quatre-vingt-trois (783); la valeur du champ "Nombre d'octets" est deux (2) et le champ "Valeur" est présenté au Tableau 158.

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Tableau 158 – Champ "Valeur" de demande Lire liste de supertrames

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Indice de Table	Indice de la Table des supertrames
1	Unsigned8	Nombre d'entrées	Nombre d'entrées de supertrames à lire (doit être mis à 1)

8.3.4.16.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 159. Les valeurs des codes de réponse sont présentées au Tableau 160.

Tableau 159 – Champ "Valeur" de réponse Lire liste de supertrames

Décalage d'octet[a]	Type de données	Nom de paramètre	Description
0	Unsigned8	Indice de Table	Indice de la Table des supertrames
1	Unsigned8	Nombre d'entrées	Nombre d'entrées de supertrames contenues dans la réponse
2	Unsigned8	Nombre de supertrames	Nombre total de supertrames actives
3	Unsigned8	Superframe_ID	Numéro d'identification attribué à la supertrame
4	Unsigned16	Num_Slots	Nombre d'intervalles de temps dans cette supertrame, c'est-à-dire la taille de la supertrame
6	Champ binaire	Mode Supertrame	Fanions de mode supertrame tels que spécifiés au Tableau F.23
7..			

[a] Les champs dans les octets 3 à 6 sont répétés autant de fois que la valeur de "Nombre de supertrames".

Tableau 160 – Codes de réponse spécifiques à la commande Lire liste de supertrames

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Section non valide
5	Erreur	Nombre d'octets de données reçus trop faible
8	Avertissement	Mis à la valeur la plus proche possible
16	Erreur	Accès limité

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8.3.4.16.3 Procédure au niveau de l'appareil répondeur

Cette commande lit les entrées de la Table des supertrames à partir de l'appareil de réseau. La Table des supertrames est une liste dont les entrées sont supprimées ou ajoutées. L'indice des supertrames et le compte d'entrées changent suite à l'addition ou à la suppression d'une supertrame. Par conséquent, si le(s) paramètre(s) de la demande ne sont pas valides, l'appareil doit répondre au moyen de la valeur valide la plus proche du/des paramètre(s) et envoyer le code de réponse "mis à la valeur la plus proche possible".

8.3.4.17 Unité PDU de couche FAL: Lire liste de liaisons

8.3.4.17.1 Primitive de demande

La valeur de la commande est sept cent quatre-vingt-quatre (784); la valeur du champ "Nombre d'octets" est trois (3) et le champ "Valeur" est présenté au Tableau 161.

Tableau 161 – Champ "Valeur" de demande Lire liste de liaisons

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Indice de Table	Indice de la Table des liaisons
2	Unsigned8	Nombre d'entrées	Nombre d'entrées de liaisons à lire (doit être mis à 1)

8.3.4.17.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 162. Les valeurs des codes de réponse sont présentées au Tableau 163.

Tableau 162 – Champ "Valeur" de réponse Lire liste de liaisons

Décalage d'octet[a]	Type de données	Nom de paramètre	Description
0	Unsigned16	Indice de Table	Indice de la Table des liaisons
2	Unsigned8	Nombre d'entrées	Nombre d'entrées de liaisons contenues dans la réponse
3	Unsigned16	Compteur de liaisons	Nombre total de liaisons actives
5	Unsigned8	Link_ID	Numéro d'identification attribué à cette liaison
6	Unsigned16	intervalle de temps	Nombre d'intervalles de temps dans la supertrame attribué à cette liaison
8	Unsigned8	Channel_Offset	Décalage initial du canal de saut de fréquence
9	Unsigned16	Neighbor_nickname	Surnom du voisin pour cette liaison, ou bien 0xFFFF si liaison de diffusion
11	Champ binaire	Options des liaisons	Options de liaisons telles que spécifiées au Tableau F.22
12	Enumération	Link_type	Link_type comme spécifié au Tableau F.21
13..			

[a] Les champs dans les octets 5 à 12 sont répétés autant de fois que la valeur de "Compteur de liaisons".

Tableau 163 – Codes de réponse spécifiques à la commande Lire liste de liaisons

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
8	Avertissement	Mis à la valeur la plus proche possible
16	Erreur	Accès limité

8.3.4.17.3 Procédure au niveau de l'appareil répondeur

Cette commande lit les entrées de la Table des liaisons à partir de l'appareil de réseau. La Table des liaisons est une liste dont les entrées sont supprimées ou ajoutées. L'indice des liaisons et le compte d'entrées changent suite à l'addition ou à la suppression d'une liaison. Par conséquent, si le(s) paramètre(s) de la demande ne sont pas valides, l'appareil doit répondre au moyen de la valeur valide la plus proche du/des paramètre(s) et envoyer le code de réponse "mis à la valeur la plus proche possible".

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8.3.4.18 Unité PDU de couche FAL: Lire liste de graphes

8.3.4.18.1 Primitive de demande

La valeur de la commande est sept cent quatre-vingt-cinq (785); la valeur du champ "Nombre d'octets" est un (1) et le champ "Valeur" est présenté au Tableau 164.

Tableau 164 – Champ "Valeur" de demande Lire liste de graphes

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Indice de Table	Indice de la Table des graphes

8.3.4.18.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 165. Les valeurs des codes de réponse sont présentées au Tableau 166.

Tableau 165 – Champ "Valeur" de réponse Lire liste de graphes

Décalage d'octet[a]	Type de données	Nom de paramètre	Description
0	Unsigned8	Indice de Table	Indice de la Table des graphes
1	Unsigned8	Nombre de graphes	Nombre total de graphes actuellement configurés
2	Unsigned16	Graph_ID	Numéro d'identification attribué à ce graphe
4	Unsigned8	Nombre de voisins	Nombre de voisins spécifiés pour ce Graph_ID
5	Unsigned16	Neighbor_nickname	Surnom de voisin pour ce graphe
7..			

[a] Les champs dans les octets 5 à 6 sont répétés autant de fois que la valeur de "Nombre de voisins".

Tableau 166 – Codes de réponse spécifiques à la commande Lire liste de graphes

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
8	Avertissement	Mis à la valeur la plus proche possible
16	Erreur	Accès limité

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8.3.4.18.3 Procédure au niveau de l'appareil répondeur

Cette commande lit un élément dans la Table des graphes à partir de l'appareil de réseau. L'indice sert uniquement de référence et le graphe référencé peut changer si un graphe placé avant lui sur la liste est supprimé. Par conséquent, si le(s) paramètre(s) de la demande ne sont pas valides, l'appareil doit répondre au moyen de la valeur valide la plus proche du paramètre et envoyer le code de réponse "mis à la valeur la plus proche possible".

8.3.4.19 Unité PDU de couche FAL: Lire fanion d'attribut de voisin

8.3.4.19.1 Primitive de demande

La valeur de la commande est sept cent quatre-vingt-six (786); la valeur du champ "Nombre d'octets" est deux (2) et le champ "Valeur" est présenté au Tableau 167.

Tableau 167 – Champ "Valeur" de demande Lire fanion d'attribut de voisin

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Neighbor_nickname	Surnom du voisin comme défini en 3.2.74

8.3.4.19.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 168. Les valeurs des codes de réponse sont présentées au Tableau 169.

Tableau 168 – Champ "Valeur" de réponse Lire fanion d'attribut de voisin

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Neighbor_nickname	Surnom du voisin comme défini en 3.2.74
2	Champ binaire	Fanions de voisins	Attributs de voisins, comme spécifié au Tableau F.34

Tableau 169 – Codes de réponse spécifiques à la commande Lire fanion d'attribut de voisin

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
16	Erreur	Accès limité
65	Erreur	Neighbor_nickname inconnu

8.3.4.19.3 Procédure au niveau de l'appareil répondeur

Cette commande lit les attributs d'un voisin à partir de l'appareil de réseau.

8.3.4.20 Unité PDU de couche FAL: Lire niveau de signal du voisin

8.3.4.20.1 Primitive de demande

La valeur de la commande est sept cent quatre-vingt-sept (787); la valeur du champ "Nombre d'octets" est deux (2) et le champ "Valeur" est présenté au Tableau 170.

Tableau 170 – Champ "Valeur" de demande Lire niveau de signal du voisin

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Indice de Table	Indice de la Table des voisins
1	Unsigned8	Nombre d'entrées	Nombre d'entrées de voisins devant être lues

8.3.4.20.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 171. Les valeurs des codes de réponse sont présentées au Tableau 172.

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Tableau 171 – Champ "Valeur" de réponse Lire niveau de signal du voisin

Décalage d'octet[a]	Type de données	Nom de paramètre	Description
0	Unsigned8	Indice de Table	Indice de la Table des voisins
1	Unsigned8	Nombre d'entrées	Nombre d'entrées de voisins contenues dans la réponse
2	Unsigned8	Nombre de voisins	Nombre total de voisins
3	Unsigned16	Neighbor_nickname	Surnom du voisin comme défini en 3.2.74
5	Integer8	Average_RSL (niveau moyen de signal reçu)	Niveau moyen de signal reçu (en dBm) de voisin
6..			

[a] Les champs dans les octets 3 à 5 sont répétés autant de fois que la valeur de "Nombre de voisins".

Tableau 172 – Codes de réponse spécifiques à la commande Lire niveau de signal du voisin

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Nombre d'octets de données reçus trop faible
8	Avertissement	Mis à la valeur la plus proche possible
16	Erreur	Accès limité

8.3.4.20.3 Procédure au niveau de l'appareil répondeur

Cette commande lit le niveau de signal de la Table des voisins à partir de l'appareil de réseau. La Table des voisins est une liste dont des entrées sont supprimées lorsqu'un voisin arrête la communication, ou ajoutées lorsqu'un nouveau voisin est détecté. L'indice de la Table et le compte d'entrées changent suite à l'addition ou à la suppression d'un voisin. Par conséquent, si le(s) paramètre(s) de la demande ne sont pas valides, l'appareil doit répondre au moyen de la valeur valide la plus proche du/des paramètre(s) et envoyer le code de réponse "mis à la valeur la plus proche possible". Cette liste inclut tous les voisins.

L'appareil doit envoyer cette réponse à une demande de lecture. En outre, l'appareil doit éditer le niveau de signal du voisin en utilisant le niveau de priorité "Commande" en tant que rapport d'informations. Les voisins transmis de cette manière sont les voisins découverts, mais non reliés. La période d'édition est fixée en configurant l'heure de "Rapport de santé" au moyen de la Commande 795 (voir 8.3.4.27).

8.3.4.21 Unité PDU de couche FAL: Rendre compte d'alarme de trajet défaillant

8.3.4.21.1 Primitive de demande

Il n'y a aucune primitive de demande pour ce service. La valeur de la commande est sept cent quatre-vingt-huit (788).

8.3.4.21.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 173. Les valeurs des codes de réponse sont présentées au Tableau 174.

Tableau 173 – Champ "Valeur" de réponse Rendre compte d'alarme de trajet défaillant

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Neighbor_nickname	Surnom du voisin comme défini en 3.2.74

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Tableau 174 – Codes de réponse spécifiques à la commande Rendre compte de d'alarme de trajet défaillant

Valeur	Classe	Description
0	Succès	Pas d'erreur
16	Erreur	Accès limité

8.3.4.21.3 Procédure au niveau de l'appareil répondeur

Si l'appareil ne peut pas communiquer avec l'un de ses voisins pendant un temps dépassant Path_fail_time, il doit éditer la réponse d'alarme de trajet défaillant en utilisant la priorité de niveau "Commande" en tant que rapport d'informations. Le temps Path_fail_time est configuré par la Commande 795 (voir 8.3.4.27).

8.3.4.22 Unité PDU de couche FAL: Rendre compte de réponse d'alarme d'itinéraire par source défaillant

8.3.4.22.1 Primitive de demande

Il n'y a aucune primitive de demande pour ce service. La valeur de la commande est sept cent quatre-vingt-neuf (789).

8.3.4.22.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 175. Les valeurs des codes de réponse sont présentées au Tableau 176.

Tableau 175 – Champ "Valeur" de réponse Rendre compte d'alarme d'itinéraire par source défaillant

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Voisin injoignable	Surnom de voisin injoignable dans l'itinéraire par source
2	Unsigned32	NL_MIC	MIC de la couche réseau issu de la NPDU qui a échoué au routage

Tableau 176 – Codes de réponse spécifiques à la commande Rendre compte d'alarme d'itinéraire par source défaillant

Valeur	Classe	Description
0	Succès	Pas d'erreur
16	Erreur	Accès limité

8.3.4.22.3 Procédure au niveau de l'appareil répondeur

Si l'appareil détecte une défaillance d'itinéraire par source, il doit éditer la réponse d'alarme d'itinéraire par source défaillant en utilisant la priorité de niveau "Commande" en tant que rapport d'informations.

8.3.4.23 Unité PDU de couche FAL: Rendre compte de réponse d'alarme d'itinéraire par graphe défaillant

8.3.4.23.1 Primitive de demande

Il n'y a aucune primitive de demande pour ce service. La valeur de la commande est sept cent quatre-vingt-dix (790).

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8.3.4.23.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 177. Les valeurs des codes de réponse sont présentées au Tableau 178.

Tableau 177 – Champ "Valeur" de réponse Rendre compte d'alarme d'itinéraire par graphe défaillant

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Graph_ID	Graph_ID de l'itinéraire défaillant

Tableau 178 – Codes de réponse spécifiques à la commande Rendre compte d'alarme d'itinéraire par graphe défaillant

Valeur	Classe	Description
0	Succès	Pas d'erreur
16	Erreur	Accès limité

8.3.4.23.3 Procédure au niveau de l'appareil répondeur

Si l'appareil détecte une défaillance d'itinéraire par graphe, il doit éditer la réponse d'alarme d'itinéraire par graphe défaillant en utilisant la priorité de niveau "Commande" en tant que rapport d'informations.

8.3.4.24 Unité PDU de couche FAL: Rendre compte de réponse d'alarme de couche transport défaillante

8.3.4.24.1 Primitive de demande

Il n'y a aucune primitive de demande pour ce service. La valeur de la commande est sept cent quatre-vingt-onze (791).

8.3.4.24.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 179. Les valeurs des codes de réponse sont présentées au Tableau 180.

Tableau 179 – Champ "Valeur" de réponse Rendre compte d'alarme de couche de transport défaillante

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Homologue injoignable	Surnom d'un homologue injoignable dans la couche de transport de bout en bout

Tableau 180 – Codes de réponse spécifiques à la commande Rendre compte de réponse d'alarme de couche de transport défaillante

Valeur	Classe	Description
0	Succès	Pas d'erreur
16	Erreur	Accès limité

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8.3.4.24.3 Procédure au niveau de l'appareil répondeur

Si l'appareil détecte une défaillance de session, il doit éditer la réponse d'alarme de connexion de couche transport défaillante en utilisant la priorité de niveau "Commande" en tant que rapport d'informations.

8.3.4.25 Unité PDU de couche FAL: Ecrire mapping de temps TUC

8.3.4.25.1 Primitive de demande

La valeur de la commande est sept cent quatre-vingt-treize (793); la valeur du champ "Nombre d'octets" est sept (7) et le champ "Valeur" est présenté au Tableau 181.

Tableau 181 – Champ "Valeur" de Ecrire mapping de temps TUC

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Date	Date	Date
3	Temps	Heure de la journée	Heure de la journée

8.3.4.25.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 181. Les valeurs des codes de réponse sont présentées au Tableau 182.

Tableau 182 – Codes de réponse spécifiques à la commande Ecrire mapping de temps TUC

Valeur	Classe	Description
0	Succès	Pas d'erreur
3	Erreur	Paramètre passé trop grand
5	Erreur	Nombre d'octets de données reçus trop faible
9	Erreur	Code de données non valide détecté
16	Erreur	Accès limité

8.3.4.25.3 Procédure au niveau de l'appareil répondeur

Cette commande établit la date et l'heure reçues dans la demande en tant qu'instance temporelle du moment auquel l'ASN zéro a débuté. La date et l'heure dans la demande peuvent être le temps TUC ou le temps local ou n'importe quel autre temps utilisé par le demandeur. Si cette commande n'a pas été émise par le gestionnaire de réseau, l'appareil doit répondre par Accès limité.

8.3.4.26 Unité PDU de couche FAL: Lire mapping de temps TUC

8.3.4.26.1 Primitive de demande

La valeur de la commande est sept cent quatre-vingt-quatorze (794); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.26.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 183. Les valeurs des codes de réponse sont présentées au Tableau 184.

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Tableau 183 – Champ "Valeur" de réponse Lire mapping de temps TUC

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Date	Date	Date
3	Temps	Heure de la journée	Heure de la journée

Tableau 184 – Codes de réponse spécifiques à la commande Lire mapping de temps TUC

Valeur	Classe	Description
0	Succès	Pas d'erreur
16	Erreur	Accès limité

8.3.4.26.3 Procédure au niveau de l'appareil répondeur

Cette commande lit le temps auquel l'ASN zéro a débuté, comme réglé dans l'appareil de réseau.

8.3.4.27 Unité PDU de couche FAL: Ecrire intervalle de temps

8.3.4.27.1 Primitive de demande

La valeur de la commande est sept cent quatre-vingt-quinze (795); la valeur du champ "Nombre d'octets" est cinq (5) et le champ "Valeur" est présenté au Tableau 185.

Tableau 185 – Champ "Valeur" de Ecrire intervalle de temps

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Timer_type	Type de temporisateur comme spécifié au Tableau F.19
1	Unsigned32	Intervalle	Intervalle de temporisateur en ms

8.3.4.27.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 185. Les valeurs des codes de réponse sont présentées au Tableau 186.

Tableau 186 – Codes de réponse spécifiques à la commande Ecrire intervalle de temps

Valeur	Classe	Description
0	Succès	Pas d'erreur
3	Erreur	Paramètre passé plus grand que permis par l'appareil
4	Erreur	Paramètre passé plus petit que permis par l'appareil
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
8	Avertissement	Mis à la valeur la plus proche possible
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit
65	Erreur	Timer_type non valide

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8.3.4.27.3 Procédure au niveau de l'appareil répondeur

Cette commande établit la durée pour le temporisateur spécifié par le Timer_type dans un appareil de réseau.

8.3.4.28 Unité PDU de couche FAL: Lire intervalle de temps

8.3.4.28.1 Primitive de demande

La valeur de la commande est sept cent quatre-vingt-seize (796); la valeur du champ "Nombre d'octets" est un (1) et le champ "Valeur" est présenté au Tableau 187.

Tableau 187 – Champ "Valeur" de demande Lire intervalle de temps

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Timer_type	Type de temporisateur comme spécifié au Tableau F.19

8.3.4.28.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 188. Les valeurs des codes de réponse sont présentées au Tableau 189.

Tableau 188 – Champ "Valeur" de réponse Lire intervalle de temps

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Timer_type	Type de temporisateur comme spécifié au Tableau F.19
1	Unsigned32	Intervalle	Intervalle de temporisateur en ms

Tableau 189 – Codes de réponse spécifiques à la commande Lire intervalle de temps

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée
65	Erreur	Timer_type non valide

8.3.4.28.3 Procédure au niveau de l'appareil répondeur

Cette commande lit la durée pour le temporisateur spécifié par le Timer_type dans un appareil de réseau.

8.3.4.29 Unité PDU de couche FAL: Ecrire puissance de sortie radio

8.3.4.29.1 Primitive de demande

La valeur de la commande est sept cent quatre-vingt-dix-sept (797); la valeur du champ "Nombre d'octets" est un (1) et le champ "Valeur" est présenté au Tableau 190.

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Tableau 190 – Champ "Valeur" de Ecrire sortie de puissance radio

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Integer8	Puissance de sortie	Puissance d'émission en dBm

8.3.4.29.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 190. Les valeurs des codes de réponse sont présentées au Tableau 191.

Tableau 191 – Codes de réponse spécifiques à la commande Ecrire sortie de puissance radio

Valeur	Classe	Description
0	Succès	Pas d'erreur
3	Erreur	Paramètre passé plus grand que permis
4	Erreur	Paramètre passé plus petit que permis
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
8	Avertissement	Mis à la valeur la plus proche possible
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit

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8.3.4.29.3 Procédure au niveau de l'appareil répondeur

Cette commande établit la puissance de sortie radio pour un appareil ou une passerelle. Si l'appareil ne peut pas accepter la valeur exacte envoyée depuis l'application, il doit l'établir à la valeur la plus proche possible et répondre par "Mis à la valeur la plus proche possible". Chaque appareil doit supporter au moins les valeurs suivantes -10 dBm, 0 dBm et 10 dBm. Si l'appareil répondeur est connecté au réseau et si cette commande n'a pas été émise par le gestionnaire de réseau, l'appareil doit répondre par "Accès limité". Sinon, si l'appareil répondeur n'est pas connecté au réseau et si cette commande n'a pas été reçue via le port de maintenance, l'appareil doit répondre par "Accès limité".

8.3.4.30 Unité PDU de couche FAL: Lire puissance de sortie radio

8.3.4.30.1 Primitive de demande

La valeur de la commande est sept cent quatre-vingt-dix-huit (798); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.30.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 192. Les valeurs des codes de réponse sont présentées au Tableau 193.

Tableau 192 – Champ "Valeur" de réponse Lire puissance de sortie radio

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Integer8	Puissance de sortie	Puissance d'émission en dBm

Tableau 193 – Codes de réponse spécifiques à la commande Lire puissance de sortie radio

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée

8.3.4.30.3 Procédure au niveau de l'appareil répondeur

Cette commande lit la puissance de sortie radio dans un appareil ou une passerelle.

8.3.4.31 Unité PDU de couche FAL: Demander indicateur horaire

8.3.4.31.1 Primitive de demande

La valeur de la commande est sept cent quatre-vingt-dix-neuf (799); la valeur du champ "Nombre d'octets" est dix (10) et le champ "Valeur" est présenté au Tableau 194.

Tableau 194 – Champ "Valeur" de Demander indicateur horaire

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Timetable_ID	Identifiant d'indicateur horaire fourni par un appareil demandeur auquel il est spécifique; la valeur doit être située dans la plage allant de 0x00 à 0x7F.
1	Champ binaire	Timetable_type	Fanions de demandes d'indicateurs horaires, comme présenté au Tableau F.15
2	Enumération	Application_domain	Domaine d'application tel que présenté au Tableau F.16
3	Unsigned16	Peer_nickname	Surnom de l'homologue avec lequel l'indicateur horaire est demandé
5	Temps	Service_duration	Si le service est intermittent, alors latence; sinon période (communications cycliques)

8.3.4.31.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 195. Les valeurs des codes de réponse sont présentées au Tableau 196.

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Tableau 195 – Champ "Valeur" de Réponse indicateur horaire

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Timetable_ID	Identifiant d'indicateur horaire fourni par un appareil demandeur auquel il est spécifique; la valeur doit être située dans la plage allant de 0x00 à 0x7F.
1	Champ binaire	Timetable_type	Fanions de demandes d'indicateurs horaires, comme présenté au Tableau F.15
2	Enumération	Application_domain	Domaine d'application tel que présenté au Tableau F.16
3	Unsigned16	Peer_nickname	Surnom de l'homologue avec lequel l'indicateur horaire est demandé
5	Temps	Service_duration	Si le service est intermittent, alors latence; sinon période (communications cycliques)
9	Unsigned8	Route_ID	Identifiant d'itinéraire pour cet indicateur horaire

Tableau 196 – Codes de réponse spécifiques à la commande Demander indicateur horaire

Valeur	Classe	Description
0	Succès	Pas d'erreur
4	Erreur	Paramètre passé plus petit que permis
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
8	Avertissement	Mis à la valeur la plus proche possible
14	Avertissement	Largeur de bande de communications fournie considérablement inférieure à celle demandée (réduite au-delà du réglage à la valeur la plus proche)
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit
65	Erreur	Demande d'indicateur horaire refusée
66	Erreur	Timetable_type inconnu
67	Erreur	Application_domain inconnu
68	Erreur	Peer_nickname inconnu
69	Erreur	Timetable_ID non valide

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8.3.4.31.3 Procédure au niveau de l'appareil répondeur

Cette commande doit être utilisée par un appareil sans fil pour ajouter un indicateur horaire à un autre appareil sans fil avec des caractéristiques spécifiées de largeur de bande et de latence. Une réponse sans erreurs à cette commande indique que le gestionnaire de réseau a accepté la demande et tentera de traiter la demande. Le Timetable_ID est unique seulement au sein de l'appareil demandeur.

Sur un réseau intensément utilisé, le gestionnaire de réseau peut refuser des demandes de largeur de bande de communications ou fournir une largeur de bande considérablement moindre que celle demandée. Lorsque cela se produit, l'appareil doit mettre l'état "Capacité refusée" en l'état Statut normalisé 3 (voir Tableau F.11) et le bit "Plus de statuts disponibles" dans l'octet "Statut de processus d'application". Lorsque la largeur de bande fournie est

inférieure à la largeur de bande désirée (tout en étant supérieure à zéro), l'appareil doit continuer à demander la largeur de bande dont il a besoin à chaque intervalle de compte-rendu de santé.

Si l'appareil reçoit une commande "Ecrire indicateur horaire" (voir Commande 973) sur le même Timetable_ID alors qu'il attend une réponse à cette commande, l'appareil doit rejeter la nouvelle commande "écrire indicateur horaire".

Les applications hôtes peuvent envoyer cette commande à la passerelle pour demander une largeur de bande supplémentaire pour communiquer avec l'appareil spécifié.

8.3.4.32 Unité PDU de couche FAL: Lire liste d'indicateur horaire

8.3.4.32.1 Primitive de demande

La valeur de la commande est huit cents (800); la valeur du champ "Nombre d'octets" est deux (2) et le champ "Valeur" est présenté au Tableau 197.

Tableau 197 – Champ "Valeur" de demande Lire liste d'indicateur horaire

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Indice de Table	Indice de la Table des indicateurs horaires
1	Unsigned8	Nombre d'entrées	Nombre d'entrées d'indicateur horaire devant être lues

8.3.4.32.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 198. Les valeurs des codes de réponse sont présentées au Tableau 199.

Tableau 198 – Champ "Valeur" de réponse Lire liste d'indicateur horaire

Décalage d'octet[a]	Type de données	Nom de paramètre	Description
0	Unsigned8	Indice de Table	Indice de la Table des indicateurs horaires
1	Unsigned8	Nombre d'entrées	Nombre d'entrées d'indicateur horaire à lire (doit être mis à 1)
2	Unsigned8	Nombre d'indicateurs horaires	Nombre total d'indicateurs horaires actifs
3	Unsigned8	Timetable_ID	Identifiant d'indicateur horaire pour cette entrée
4	Champ binaire	Timetable_type	Fanions de demandes d'indicateurs horaires, comme présenté au Tableau F.15
5	Enumération	Application_domain	Domaine d'application tel que présenté au Tableau F.16
6	Unsigned16	Peer_nickname	Surnom de l'homologue avec lequel le service est établi
8	Temps	Service_duration	Si le service est intermittent, alors latence; sinon période (communications cycliques)
12	Unsigned8	Route_ID	Identifiant d'itinéraire pour cet indicateur horaire
13..			

[a] Les champs dans les octets 3 à 12 sont répétés autant de fois que la valeur de "Nombre d'indicateurs horaires".

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Tableau 199 – Codes de réponse spécifiques à la commande Lire liste d'indicateur horaire

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
8	Avertissement	Mis à la valeur la plus proche possible
16	Erreur	Accès limité

8.3.4.32.3 Procédure au niveau de l'appareil répondeur

Cette commande lit les entrées de la Table des indicateurs horaires à partir de l'appareil de réseau. La Table des indicateurs horaires est une liste dont les entrées sont supprimées ou ajoutées. L'indice des indicateurs horaires et le nombre d'entrées changent suite à l'addition ou à la suppression d'un indicateur horaire. Par conséquent, si le(s) paramètre(s) de la demande ne sont pas valides, l'appareil doit répondre au moyen de la valeur valide la plus proche du/des paramètre(s) et envoyer le code de réponse "mis à la valeur la plus proche possible". Si l'indice des indicateurs horaires est supérieur au nombre maximal d'indicateurs horaires actuellement contenus dans l'appareil, celui-ci doit renvoyer la dernière entrée et mettre le code de réponse à "Mis à la valeur la plus proche possible". Le "Nombre d'entrées" doit être mis à une valeur valide et le code de réponse "Mis à la valeur la plus proche possible" renvoyé.

8.3.4.33 Unité PDU de couche FAL: Supprimer indicateur horaire

8.3.4.33.1 Primitive de demande

La valeur de la commande est huit cent un (801); la valeur du champ "Nombre d'octets" est deux (2) et le champ "Valeur" est présenté au Tableau 200.

Tableau 200 – Champ "Valeur" de demande Supprimer indicateur horaire

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Timetable_ID	Identifiant d'indicateur horaire spécifique à l'appareil
1	Enumération	Raison	Raison de la suppression d'indicateur horaire, comme spécifié au Tableau F.25

8.3.4.33.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 201. Les valeurs des codes de réponse sont présentées au Tableau 202.

Tableau 201 – Champ "Valeur" de réponse Supprimer indicateur horaire

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Timetable_ID	Identifiant d'indicateur horaire spécifique à l'appareil
1	Enumération	Raison	Raison de la suppression d'indicateur horaire, comme spécifié au Tableau F.25
2	Unsigned8	Nombre d'indicateurs horaires	Nombre total d'indicateurs horaires restants

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Tableau 202 – Codes de réponse spécifiques à la commande Supprimer indicateur horaire

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Nombre d'octets de données reçus trop faible
16	Erreur	Accès limité
65	Erreur	Entrée introuvable
66	Erreur	Code de raison non valide
67	Erreur	Code de raison rejeté, indicateur horaire non supprimé
68	Erreur	Suppression interdite – le demandeur n'est pas le propriétaire de l'indicateur horaire

8.3.4.33.3 Procédure au niveau de l'appareil répondeur

Cette commande notifie à un appareil la suppression d'indicateur horaire. L'opération de suppression peut être provoquée par la demande d'un homologue ou par décision du gestionnaire de réseau. Seul le créateur d'un indicateur horaire peut le supprimer. Si le propriétaire de l'indicateur horaire ne génère pas cette commande, le destinataire doit rejeter la commande et retourner le code de réponse "suppression interdite".

8.3.4.34 Unité PDU de couche FAL: Lire liste des itinéraires

8.3.4.34.1 Primitive de demande

La valeur de la commande est huit cent deux (802); la valeur du champ "Nombre d'octets" est deux (2) et le champ "Valeur" est présenté au Tableau 203.

Tableau 203 – Champ "Valeur" de demande Lire liste des itinéraires

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Indice de Table	Indice de Table des itinéraires
1	Unsigned8	Nombre d'entrées	Nombre d'entrées d'itinéraires à lire (doit être mis à 1)

8.3.4.34.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 204. Les valeurs des codes de réponse sont présentées au Tableau 205.

Tableau 204 – Champ "Valeur" de réponse Lire liste des itinéraires

Décalage d'octet[a]	Type de données	Nom de paramètre	Description
0	Unsigned8	Indice de Table	Indice de Table des itinéraires
1	Unsigned8	Nombre d'entrées	Nombre d'entrées d'itinéraires contenues dans la réponse
2	Unsigned8	Nombre d'itinéraires	Nombre total d'itinéraires actuellement configurés
3	Unsigned8	Itinéraires restants	Nombre d'entrées d'itinéraires non utilisées dans l'appareil
4	Unsigned8	Route_ID	Identifiant d'itinéraire pour cette entrée
5	Unsigned16	Surnom de l'appareil de destination	Surnom de l'appareil de destination de l'itinéraire
7	Unsigned16	Graph_ID	Graph_ID pour cet itinéraire
9	Unsigned8	Fanion d'itinéraire par source	Itinéraire par source attaché à cet itinéraire 1: Oui, 0: Non
10..			

[a] Les champs dans les octets 3 à 9 sont répétés autant de fois que la valeur de "Nombre d'itinéraires".

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Tableau 205 – Codes de réponse spécifiques à la commande Lire liste des itinéraires

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
8	Avertissement	Mis à la valeur la plus proche possible
16	Erreur	Accès limité

8.3.4.34.3 Procédure au niveau de l'appareil répondeur

Cette commande lit les entrées de la Table des itinéraires à partir de l'appareil de réseau. La Table des itinéraires est une liste dont les entrées sont supprimées ou ajoutées. L'indice des itinéraires et le compte d'entrées changent suite à l'addition ou à la suppression d'un itinéraire. Par conséquent, si le(s) paramètre(s) de la demande ne sont pas valides, l'appareil doit répondre au moyen de la valeur valide la plus proche du/des paramètre(s) et envoyer le code de réponse "mis à la valeur la plus proche possible".

8.3.4.35 Unité PDU de couche FAL: Lire itinéraire par source

8.3.4.35.1 Primitive de demande

La valeur de la commande est huit cent trois (803); la valeur du champ "Nombre d'octets" est un (1) et le champ "Valeur" est présenté au Tableau 206.

Tableau 206 – Champ "Valeur" de demande Lire itinéraire par source

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Route_ID	Identifiant d'itinéraire pour lequel l'itinéraire par source doit être lu

8.3.4.35.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 207. Les valeurs des codes de réponse sont présentées au Tableau 208.

Tableau 207 – Champ "Valeur" de réponse Lire itinéraire par source

Décalage d'octet[a]	Type de données	Nom de paramètre	Description
0	Unsigned8	Route_ID	Identifiant d'itinéraire pour lequel l'itinéraire par source doit être lu
1	Unsigned8	Nombre de sauts	Nombre de sauts sur cet itinéraire
2	Unsigned16	saut	Surnom pour l'entrée de saut 0
4..			

[a] Les champs dans les octets 2 à 3 sont répétés autant de fois que la valeur de "Nombre de sauts".

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Tableau 208 – Codes de réponse spécifiques à la commande Lire itinéraire par source

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide (Route_ID incorrect)
5	Erreur	Nombre d'octets de données reçus trop faible
16	Erreur	Accès limité
65	Erreur	Entrée non trouvée (pas d'itinéraire par source associé à Route_ID)

8.3.4.35.3 Procédure au niveau de l'appareil répondeur

Cette commande lit le contenu d'un itinéraire par source particulier. Les adresses de diffusion ne sont pas des valeurs d'adresses légitimes dans les itinéraires par source et ne doivent être incluses dans aucune réponse pour cette commande.

8.3.4.36 Unité PDU de couche FAL: Lire mode CCA

8.3.4.36.1 Primitive de demande

La valeur de la commande est huit cent quatre (804); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.36.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 209. Les valeurs des codes de réponse sont présentées au Tableau 210.

Tableau 209 – Champ "Valeur" de réponse Lire mode CCA

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	CCA Mode	Mode d'évaluation de canal libre selon le Tableau F.40

Tableau 210 – Codes de réponse spécifiques à la commande Lire mode CCA

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée

8.3.4.36.3 Procédure au niveau de l'appareil répondeur

Cette commande lit le mode évaluation de canal libre (CCA) dans un appareil de réseau.

8.3.4.37 Unité PDU de couche FAL: Ecrire mode CCA

8.3.4.37.1 Primitive de demande

La valeur de la commande est huit cent cinq (805); la valeur du champ "Nombre d'octets" est un (1) et le champ "Valeur" est présenté au Tableau 211. Le nouveau codage est conforme à celui de l'IEEE 802.15.4:2011. Afin de prendre en charge la gamme étendue des modes CCA, il convient de mettre à niveau le gestionnaire de réseau. Après mise à niveau, le gestionnaire de réseau sera en mesure d'utiliser des codages étendus, tout en maintenant une compatibilité ascendante avec les appareils plus anciens. Le gestionnaire de réseau sera en

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mesure d'exploiter sa connaissance de la version de l'appareil ou de sélectionner un mode CCA. Il peut également utiliser le code de réponse. S'il est envoyé à un appareil plus ancien une valeur autre que 0 ou 1, l'appareil répondra par le code de réponse 2 ("Choix non valide"). En conséquence, l'utilisation des codes de réponse permet au gestionnaire de réseau de s'adapter en fonction des besoins. Le codage est conforme à celui de l'IEEE 802.15.4.

Tableau 211 – Champ "Valeur" de Ecrire mode CCA

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	CCA Mode	Mode d'évaluation de canal libre selon le Tableau F.40

8.3.4.37.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 211. Les valeurs des codes de réponse sont présentées au Tableau 212.

Tableau 212 – Codes de réponse spécifiques à la commande Ecrire mode CCA

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide (par exemple, mode CCA non valide)
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
8	Avertissement	Mis à la valeur la plus proche
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pas pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit

8.3.4.37.3 Procédure au niveau de l'appareil répondeur

Cette commande écrit le mode évaluation de canal libre (CCA) dans un appareil de réseau. Si cette commande est reçue d'une source autre que le gestionnaire de réseau, l'appareil doit la rejeter avec le code de réponse "Accès limité".

8.3.4.38 Unité PDU de couche FAL: Lire supertrame de terminal portatif

8.3.4.38.1 Primitive de demande

La valeur de la commande est huit cent six (806); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.38.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 213. Les valeurs des codes de réponse sont présentées au Tableau 214.

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Tableau 213 – Champ "Valeur" de réponse Lire supertrame de terminal portatif

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Superframe_ID	Numéro d'identification attribué à la supertrame
1	Unsigned16	Num_Slots	Nombre d'intervalles de temps dans cette supertrame, c'est-à-dire la taille de la supertrame
3	Champ binaire	Mode Supertrame	Fanions de mode supertrame tels que spécifiés au Tableau F.23

Tableau 214 – Codes de réponse spécifiques à la commande Lire supertrame de terminal portatif

Valeur	Classe	Description
0	Succès	Pas d'erreur
9	Erreur	Absence de supertrame continue
16	Erreur	Accès limité

8.3.4.38.3 Procédure au niveau de l'appareil répondeur

Cette commande est utilisée pour déterminer si une supertrame de terminal portatif contenue dans un appareil de réseau est activée.

8.3.4.39 Unité PDU de couche FAL: Ecrire supertrame de terminal portatif

8.3.4.39.1 Primitive de demande

La valeur de la commande est huit cent sept (807); la valeur du champ "Nombre d'octets" est deux (2) et le champ "Valeur" est présenté au Tableau 215.

Tableau 215 – Champ "Valeur" de Ecrire supertrame de terminal portatif

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Superframe_ID	Numéro d'identification attribué à la supertrame
1	Champ binaire	Mode Supertrame	Fanions de mode supertrame tels que spécifiés au Tableau F.23

8.3.4.39.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 215. Les valeurs des codes de réponse sont présentées au Tableau 216.

Tableau 216 – Codes de réponse spécifiques à la commande Ecrire supertrame de terminal portatif

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide (par exemple, mode supertrame non valide)
5	Erreur	Nombre d'octets de données reçus trop faible
16	Erreur	Accès limité

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8.3.4.39.3 Procédure au niveau de l'appareil répondeur

Cette commande permet à un terminal portatif de demander à ce qu'un appareil de réseau active la supertrame contenue afin que la maintenance puisse être effectuée. La supertrame de terminal portatif est utilisée entre un appareil de réseau et un terminal portatif essentiellement à des fins de maintenance.

8.3.4.40 Unité PDU de couche FAL: Lire nombre de sauts de vie résiduelle de paquet

8.3.4.40.1 Primitive de demande

La valeur de la commande est huit cent huit (808); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.40.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 217. Les valeurs des codes de réponse sont présentées au Tableau 218.

Tableau 217 – Champ "Valeur" de réponse Lire nombre de sauts de vie résiduelle de paquet

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Sauts de vie résiduelle	Valeur actuellement configurée de Sauts de vie résiduelle

Tableau 218 – Codes de réponse spécifiques à la commande Lire nombre de sauts de vie résiduelle de paquet

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
16	Erreur	Accès limité

8.3.4.40.3 Procédure au niveau de l'appareil répondeur

Cette commande lit la valeur courante des sauts de vie résiduelle configurés pour un appareil de réseau.

8.3.4.41 Unité PDU de couche FAL: Ecrire nombre de sauts de vie résiduelle de paquet

8.3.4.41.1 Primitive de demande

La valeur de la commande est huit cent neuf (809); la valeur du champ "Nombre d'octets" est un (1) et le champ "Valeur" est présenté au Tableau 219.

Tableau 219 – Champ "Valeur" de Ecrire nombre de sauts de vie résiduelle de paquet

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Sauts de vie résiduelle	Valeur de Sauts de vie résiduelle

8.3.4.41.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 219. Les valeurs des codes de réponse sont présentées au Tableau 220.

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Tableau 220 – Codes de réponse spécifiques à la commande Ecrire nombre de sauts de vie résiduelle de paquet

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
8	Avertissement	Mis à la valeur la plus proche
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit

8.3.4.41.3 Procédure au niveau de l'appareil répondeur

Cette commande écrit la valeur du nombre de sauts de vie résiduelle dans un appareil de réseau. Si la valeur de "sauts de vie résiduelle" reçue dans la demande est inférieure à huit (8), cette valeur doit être passée à huit (8) et le code de réponse "Mis à la valeur la plus proche" doit être renvoyé. Si la commande est reçue en provenance d'une autre source que le gestionnaire de réseau, l'appareil doit rejeter cette demande avec le code de réponse "Accès limité". Cette commande est disponible via le port de maintenance lorsqu'il n'y a pas de connexion au réseau.

8.3.4.42 Unité PDU de couche FAL: Lire Join_priority

8.3.4.42.1 Primitive de demande

La valeur de la commande est huit cent dix (810); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.42.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 221. Les valeurs des codes de réponse sont présentées au Tableau 222.

Tableau 221 – Champ "Valeur" de réponse Lire Join_priority

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Join_priority	Join_priority à laquelle l'appareil doit faire l'annonce; un nombre inférieur indique un meilleur choix pour le rattachement

Tableau 222 – Codes de réponse spécifiques à la commande Lire Join_priority

Valeur	Classe	Description
0	Succès	Pas d'erreur
16	Erreur	Accès limité

8.3.4.42.3 Procédure au niveau de l'appareil répondeur

Cette commande lit la valeur courante de Join_priority dans un appareil de réseau.

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8.3.4.43 Unité PDU de couche FAL: Ecrire Join_priority

8.3.4.43.1 Primitive de demande

La valeur de la commande est huit cent onze (811); la valeur du champ "Nombre d'octets" est un (1) et le champ "Valeur" est présenté au Tableau 223.

Tableau 223 – Champ "Valeur" de Ecrire Join_priority

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Join_priority	Join_priority à laquelle l'appareil doit faire l'annonce; un nombre inférieur indique un meilleur choix pour le rattachement

8.3.4.43.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 223. Les valeurs des codes de réponse sont présentées au Tableau 224.

Tableau 224 – Codes de réponse spécifiques à la commande Ecrire Join_priority

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Nombre d'octets de données reçus trop faible
8	Avertissement	Mis à la valeur la plus proche
16	Erreur	Accès limité

8.3.4.43.3 Procédure au niveau de l'appareil répondeur

Cette commande écrit la valeur de Join_priority dans un appareil de réseau. Si la valeur de Join_priority reçue dans la demande est supérieure à quinze (15), cette valeur doit être passée à quinze (15) et le code de réponse "Mis à la valeur la plus proche" doit être renvoyé. Si cette commande est reçue d'une source autre que le gestionnaire de réseau, l'appareil doit la rejeter avec le code de réponse "Accès limité".

8.3.4.44 Unité PDU de couche FAL: Lire Priority_threshold de réception

8.3.4.44.1 Primitive de demande

La valeur de la commande est huit cent douze (812); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.44.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 225. Les valeurs des codes de réponse sont présentées au Tableau 226.

Tableau 225 – Champ "Valeur" de réponse Lire Priority_threshold de réception

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Priority_threshold	La DLPDU ayant la priorité la plus faible devant être acceptée en provenance d'un autre appareil.

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Tableau 226 – Codes de réponse spécifiques à la commande Lire Priority_threshold de réception

Valeur	Classe	Description
0	Succès	Pas d'erreur
16	Erreur	Accès limité

8.3.4.44.3 Procédure au niveau de l'appareil répondeur

Cette commande lit la valeur courante de Priority_threshold de réception dans un appareil de réseau.

8.3.4.45 Unité PDU de couche FAL: Ecrire Priority_threshold de réception

8.3.4.45.1 Primitive de demande

La valeur de la commande est huit cent treize (813); la valeur du champ "Nombre d'octets" est un (1) et le champ "Valeur" est présenté au Tableau 227.

Tableau 227 – Champ "Valeur" de Ecrire Priority_threshold de réception

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Priority_threshold	La DLPDU ayant la priorité la plus faible devant être acceptée en provenance d'un autre appareil.

8.3.4.45.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 227. Les valeurs des codes de réponse sont présentées au Tableau 228.

Tableau 228 – Codes de réponse spécifiques à la commande Ecrire Priority_threshold de réception

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Nombre d'octets de données reçus trop faible
8	Avertissement	Mis à la valeur la plus proche
16	Erreur	Accès limité

8.3.4.45.3 Procédure au niveau de l'appareil répondeur

Cette commande écrit la valeur de Priority_threshold de réception dans un appareil de réseau. Les valeurs permises pour ce paramètre sont zéro (0) à trois (3). Si une autre valeur est reçue dans la demande, l'appareil doit régler la valeur du paramètre à '3' et renvoyer la réponse "Mis à la valeur la plus proche". Si cette commande est reçue d'une source autre que le gestionnaire de réseau, l'appareil doit la rejeter avec le code de réponse "Accès limité".

8.3.4.46 Unité PDU de couche FAL: Lire liste des appareils

8.3.4.46.1 Primitive de demande

La valeur de la commande est huit cent quatorze (814); la valeur du champ "Nombre d'octets" est quatre (4) et le champ "Valeur" est présenté au Tableau 229.

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Tableau 229 – Champ "Valeur" de demande Lire liste des appareils

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Code d'appareil	Code de liste des appareils comme spécifié au Tableau F.30
1	Unsigned8	Nombre d'entrées	Nombre d'entrées d'appareils devant être lues
2	Unsigned16	Indice de Table	Indice de début de la Table des appareils

8.3.4.46.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 230. Les valeurs des codes de réponse sont présentées au Tableau 231.

Tableau 230 – Champ "Valeur" de réponse Lire liste des appareils

Décalage d'octet[a]	Type de données	Nom de paramètre	Description
0	Enumération	Code d'appareil	Code de liste des appareils comme spécifié au Tableau F.30
1	Unsigned8	Nombre d'entrées	Nombre d'entrées d'appareils contenues dans la réponse
2	Unsigned16	Indice de Table	Indice de début de la Table des appareils
4	Unsigned16	Nombre d'appareils	Nombre total d'entrées d'appareils dans le tableau
6	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.
11..			

[a] Les champs dans les octets 6 à 10 sont répétés autant de fois que la valeur de "Nombre d'appareils".

Tableau 231 – Codes de réponse spécifiques à la commande Lire liste des appareils

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide, c'est-à-dire code de liste d'appareils non pris en charge
5	Erreur	Nombre d'octets de données reçus trop faible
8	Avertissement	Mis à la valeur la plus proche possible
16	Erreur	Accès limité

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8.3.4.46.3 Procédure au niveau de l'appareil répondeur

Un appareil de réseau peut conserver plusieurs Tables d'appareils comportant une liste d'appareils. Les Tables d'appareils actuellement prises en charge sont les listes spécifiées au Tableau F.30, par exemple: 'Liste active', 'Liste blanche' et 'Liste noire'. Cette commande lit les entrées dans la Table des appareils pour le type de liste spécifié par le "Code d'appareil" dans la demande. La Table des appareils est une liste d'appareils dont les entrées sont supprimées ou ajoutées. L'indice des appareils et le nombre d'entrées changent suite à l'addition ou à la suppression d'un appareil. Par conséquent, en cas de non-validité de paramètre(s) "Nombre d'entrées" ou "Indice de Table" dans la demande, l'appareil doit répondre au moyen de la valeur valide la plus proche du/des paramètre(s) et envoyer le code de réponse "Mis à la valeur la plus proche possible".

La passerelle et le gestionnaire de réseau doivent conserver une Table des appareils pour la liste active et prendre en charge cette commande. Il convient que le gestionnaire de réseau conserve une Table des appareils pour la liste blanche et la liste noire. Il convient que tous les appareils de réseau conservent une Table des appareils pour la liste noire. Si un appareil

de réseau ne conserve pas une Table des appareils pour la liste noire et que le code d'appareil dans la demande concerne la liste noire, il doit répondre à cette commande par "Choix non valide".

8.3.4.47 Unité PDU de couche FAL: Ajouter entrée de liste d'appareils

8.3.4.47.1 Primitive de demande

La valeur de la commande est huit cent quinze (815); la valeur du champ "Nombre d'octets" est six (6) et le champ "Valeur" est présenté au Tableau 232.

Tableau 232 – Champ "Valeur" de demande Ajouter entrée de liste d'appareils

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Code d'appareil	Code de liste des appareils comme spécifié au Tableau F.30
1	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.

8.3.4.47.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 233. Les valeurs des codes de réponse sont présentées au Tableau 234.

Tableau 233 – Champ "Valeur" de réponse Ajouter entrée de liste d'appareils

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Code d'appareil	Code de liste des appareils comme spécifié au Tableau F.30
1	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.
6	Unsigned16	Nombre d'appareils	Nombre total d'entrées restantes de la Table des appareils non configurées ou non utilisées

Tableau 234 – Codes de réponse spécifiques à la commande Ajouter entrée de liste d'appareils

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide, c'est-à-dire code de liste d'appareils non pris en charge
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
8	Avertissement	Appareil déjà dans la liste
16	Erreur	Accès limité
65	Erreur	Plus d'autres entrées disponibles
66	Erreur	Conflit de listes d'appareils

8.3.4.47.3 Procédure au niveau de l'appareil répondeur

Cette commande ajoute un appareil dans la Table des appareils pour le type de liste spécifié par Code d'appareil. La Table des appareils pour la liste active ne peut pas être modifiée par

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cette commande. Si la demande tente d'ajouter à la liste noire un appareil qui est dans la liste active, l'appareil doit rejeter la demande et répondre par "Conflit de listes d'appareils".

8.3.4.48 Unité PDU de couche FAL: Supprimer entrée de liste d'appareils

8.3.4.48.1 Primitive de demande

La valeur de la commande est huit cent seize (816); la valeur du champ "Nombre d'octets" est six (6) et le champ "Valeur" est présenté au Tableau 235.

Tableau 235 – Champ "Valeur" de demande Supprimer entrée de liste d'appareils

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Code d'appareil	Code de liste des appareils comme spécifié au Tableau F.30
1	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.

8.3.4.48.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 236. Les valeurs des codes de réponse sont présentées au Tableau 237.

Tableau 236 – Champ "Valeur" de réponse Supprimer entrée de liste d'appareils

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Code d'appareil	Code de liste des appareils comme spécifié au Tableau F.30
1	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.
6	Unsigned16	Nombre d'appareils	Nombre total d'entrées restantes de la Table des appareils

Tableau 237 – Codes de réponse spécifiques à la commande Supprimer entrée de liste d'appareils

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide, c'est-à-dire code de liste d'appareils non pris en charge
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
16	Erreur	Accès limité
66	Erreur	Conflit de listes d'appareils

8.3.4.48.3 Procédure au niveau de l'appareil répondeur

Cette commande supprime un appareil de la Table des appareils pour le type de liste spécifié par Code d'appareil dans une passerelle ou un gestionnaire de réseau. Si l'appareil est supprimé de la liste active, le gestionnaire de réseau doit réacheminer le trafic et déconnecter l'appareil. Si l'identifiant unique est mis à zéro, tout le contenu de la liste est purgé.

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8.3.4.49 Unité PDU de couche FAL: Lire liste noire canaux

8.3.4.49.1 Primitive de demande

La valeur de la commande est huit cent dix-sept (817); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.49.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 238. Les valeurs des codes de réponse sont présentées au Tableau 239.

Tableau 238 – Champ "Valeur" de réponse Lire liste noire de canaux

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Nombre de canaux	Nombre de bits dans la matrice de cartes courantes de canaux; il dépend de la couche physique (par exemple pour la modulation DSSS OQPSK à 2,4 GHz, la matrice peut avoir une longueur de 16 bits, c'est-à-dire 2 octets)
1 – n	Champ binaire	Carte courante de canaux	Matrice de cartes courantes de canaux; il s'agit d'une matrice de bits commençant avec le bit de poids faible (bit 0 de l'octet 0) et ajoutant des octets autant que nécessaire jusqu'à ce que tous les bits soient comptabilisés. Chaque bit correspond à un canal. Si le bit est '1', le canal sera utilisé.
n+1-2n	Champ binaire	Carte de canaux en instance	Matrice de cartes de canaux en instance. Chaque bit correspond à un canal. Si le bit est '1', le canal sera utilisé après le prochain démarrage du réseau.

Le nombre d'octets dans une carte de canaux dépend du nombre total de canaux disponibles dans la couche physique.

Tableau 239 – Codes de réponse spécifiques à la commande Lire liste noire de canaux

Valeur	Classe	Description
0	Succès	Pas d'erreur
16	Erreur	Accès limité

8.3.4.49.3 Procédure au niveau de l'appareil répondeur

Cette commande lit la liste noire de canaux courante et la liste noire qui doit être utilisée après le prochain redémarrage.

8.3.4.50 Unité PDU de couche FAL: Ecrire liste noire de canaux

8.3.4.50.1 Primitive de demande

La valeur de la commande est huit cent dix-huit (818); la valeur du champ "Nombre d'octets" est variable et le champ "Valeur" est présenté au Tableau 240.

Tableau 240 – Champ "Valeur" de Ecrire liste noire de canaux

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Nombre de canaux	Nombre de bits dans la nouvelle matrice de cartes de canaux
1 – n	Champ binaire	Carte de canaux en instance	Matrice de cartes de canaux en instance; il s'agit d'une matrice de bits commençant avec le bit de poids faible (bit 0 de l'octet 0) et ajoutant des octets autant que nécessaire jusqu'à ce que tous les bits soient comptabilisés. Chaque bit correspond à un canal. Si le bit est '1', le canal sera utilisé après le prochain démarrage de la passerelle ou du gestionnaire de réseau.

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Le nombre d'octets dans une carte de canaux dépend du nombre total de canaux disponibles dans la couche physique.

8.3.4.50.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 240. Les valeurs des codes de réponse sont présentées au Tableau 241.

Tableau 241 – Codes de réponse spécifiques à la commande Ecrire liste noire de canaux

Valeur	Classe	Description
0	Succès	Pas d'erreur
3	Erreur	La valeur de paramètre devant être écrite est plus grande que celle permise le nombre de bits dépasse la valeur maximale.
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
16	Erreur	Accès limité
65	Erreur	Bits de canal de fréquence non valide (par exemple canal 16 pour la bande de fréquence à 2,4 GHz selon l'IEEE 802.15.4)

8.3.4.50.3 Procédure au niveau de l'appareil répondeur

Cette commande écrit la carte de canaux en instance, qui est la liste noire, dans la passerelle. Cette carte de canaux ne doit entrer en vigueur qu'après le redémarrage de la passerelle et du gestionnaire de réseau.

8.3.4.51 Unité PDU de couche FAL: Lire exposant de repli

8.3.4.51.1 Primitive de demande

La valeur de la commande est huit cent dix-neuf (819); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.51.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 242. Les valeurs des codes de réponse sont présentées au Tableau 243.

Tableau 242 – Champ "Valeur" de réponse Lire exposant de repli

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Max_backoff_exp	La valeur maximale pouvant être supposée pour l'exposant de repli utilisé dans des intervalles de temps partagés

Tableau 243 – Codes de réponse spécifiques à la commande Lire exposant de repli

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
16	Erreur	Accès limité

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8.3.4.51.3 Procédure au niveau de l'appareil répondeur

Cette commande lit la valeur courante de Max_backoff_exp dans un appareil de réseau.

8.3.4.52 Unité PDU de couche FAL: Ecrire exposant de repli

8.3.4.52.1 Primitive de demande

La valeur de la commande est huit cent vingt (820); la valeur du champ "Nombre d'octets" est un (1) et le champ "Valeur" est présenté au Tableau 244.

Tableau 244 – Champ "Valeur" de Ecrire exposant de repli

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Max_backoff_exp	La valeur maximale pouvant être supposée pour l'exposant de repli utilisé dans des intervalles de temps partagés

8.3.4.52.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 244. Les valeurs des codes de réponse sont présentées au Tableau 245.

Tableau 245 – Codes de réponse spécifiques à la commande Ecrire exposant de repli

Valeur	Classe	Description
0	Succès	Pas d'erreur
3	Erreur	Paramètre passé plus grand que permis
4	Erreur	Paramètre passé plus petit que permis
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
8	Avertissement	Mis à la valeur la plus proche
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit

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8.3.4.52.3 Procédure au niveau de l'appareil répondeur

Cette commande écrit la valeur de Max_backoff_exp dans un appareil de réseau. Si la valeur Max_backoff_exp reçue dans la demande n'est pas l'une des valeurs contenues dans l'ensemble 4, 5, 6, 7, cette valeur doit être changée en quatre (4) et le code de réponse "Mis à la valeur la plus proche" doit être renvoyé. Si cette commande est reçue d'une source autre que le gestionnaire de réseau, l'appareil doit la rejeter avec le code de réponse "Accès limité".

8.3.4.53 Unité PDU de couche FAL: Ecrire mode d'accès au réseau

8.3.4.53.1 Primitive de demande

La valeur de la commande est huit cent vingt et un (821); la valeur du champ "Nombre d'octets" est un (1) et le champ "Valeur" est présenté au Tableau 246.

Tableau 246 – Champ "Valeur" de Ecrire mode d'accès au réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Mode d'accès au réseau	Code de mode d'accès au réseau tel que spécifié au Tableau F.31

8.3.4.53.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 246. Les valeurs des codes de réponse sont présentées au Tableau 247.

Tableau 247 – Codes de réponse spécifiques à la commande Ecrire mode d'accès au réseau

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit

8.3.4.53.3 Procédure au niveau de l'appareil répondeur

Cette commande écrit la valeur de "Mode d'accès au réseau" dans un appareil de réseau. Elle peut être utilisée pour limiter l'accès au réseau. Tous les appareils doivent prendre en charge les valeurs '0' et '4' pour ce paramètre.

NOTE Le mode d'accès au réseau ne remplace pas la vérification pour les authentifiants de l'appareil tels que "Join_key", "Marqueur" ou "Identifiant d'appareil". Le mode d'accès au réseau fournit des vérifications complémentaires.

8.3.4.54 Unité PDU de couche FAL: Lire mode d'accès au réseau

8.3.4.54.1 Primitive de demande

La valeur de la commande est huit cent vingt-deux (822); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.4.54.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 248. Les valeurs des codes de réponse sont présentées au Tableau 249.

Tableau 248 – Champ "Valeur" de réponse Lire mode d'accès au réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Enumération	Mode d'accès au réseau	Code de mode d'accès au réseau tel que spécifié au Tableau F.31

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Tableau 249 – Codes de réponse spécifiques à la commande Lire mode d'accès au réseau

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
16	Erreur	Accès limité
32	Erreur	Occupé – une réponse différée n'a pu être lancée

8.3.4.54.3 Procédure au niveau de l'appareil répondeur

Cette commande de service lit la valeur courante de "Mode d'accès au réseau" dans un appareil de réseau.

8.3.4.55 Unité PDU de couche FAL: Demander session

8.3.4.55.1 Primitive de demande

La valeur de la commande est huit cent vingt-trois (823); la valeur du champ "Nombre d'octets" est deux (2) et le champ "Valeur" est présenté au Tableau 250.

Tableau 250 – Champ "Valeur" de demande Demander session

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Peer_nickname	Surnom de l'homologue avec lequel la session est demandée

8.3.4.55.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 251. Les valeurs des codes de réponse sont présentées au Tableau 252.

Tableau 251 – Champ "Valeur" de réponse Demander session

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Peer_nickname	Surnom de l'homologue avec lequel la session est demandée
2	Unsigned32	Peer_nonce_counter (compteur de nonces de l'appareil homologue)	Valeur la plus élevée du compteur de nonces reçue de l'appareil du correspondant
6	Clé de sécurité	Join_key	Il s'agit d'une clé réseau de 128 bits utilisée pour la sécurité

Tableau 252 – Codes de réponse spécifiques à la commande Demander session

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Nombre d'octets de données reçus trop faible
16	Erreur	Accès limité
65	Erreur	Homologue inconnu
66	Erreur	L'appareil de terrain a une capacité insuffisante pour prendre en charge une autre session.

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8.3.4.55.3 Procédure au niveau de l'appareil répondeur

Cette commande demande une session de monodiffusion d'un terminal portatif à un appareil. C'est seulement aux appareils autorisés qu'une session doit être accordée.

8.3.5 Structures d'APDU spécifiques à la passerelle et au gestionnaire de réseau

8.3.5.1 Unité PDU de couche FAL: Lire identité d'appareil de réseau en utilisant un identifiant unique

8.3.5.1.1 Primitive de demande

La valeur de la commande est huit cent trente-deux (832); la valeur du champ "Nombre d'octets" est cinq (5) et le champ "Valeur" est présenté au Tableau 253.

Tableau 253 – Champ "Valeur" de demande Lire identité d'appareil de réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.

8.3.5.1.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 254. Les valeurs des codes de réponse sont présentées au Tableau 255.

Tableau 254 – Champ "Valeur" de Lire identité d'appareil de réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.
5	Unsigned16	Surnom d'appareil	Surnom de l'appareil comme défini en 3.2.74
7 – 38	Latin-1	Long_tag	Marqueur long stocké dans l'appareil

Tableau 255 – Codes de réponse spécifiques à la commande Lire identité d'appareil de réseau

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible

8.3.5.1.3 Procédure au niveau de l'appareil répondeur

Cette commande lit dans la passerelle les informations relatives à l'identité de l'appareil avec l'identifiant unique correspondant.

8.3.5.2 Unité PDU de couche FAL: Lire santé des voisins de l'appareil

8.3.5.2.1 Primitive de demande

La valeur de la commande est huit cent trente-trois (833); la valeur du champ "Nombre d'octets" est sept (7) et le champ "Valeur" est présenté au Tableau 256.

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Tableau 256 – Champ "Valeur" de demande Lire santé des voisins de l'appareil

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.
5	Unsigned8	Indice de Table	Indice de la Table des voisins
6	Unsigned8	Nombre d'entrées	Nombre d'entrées de voisins à lire (doit être mis à 1)

8.3.5.2.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 257. Les valeurs des codes de réponse sont présentées au Tableau 258.

Tableau 257 – Champ "Valeur" de réponse Lire santé des voisins de l'appareil

Décalage d'octet[a]	Type de données	Nom de paramètre	Description
0	Identifiant unique	Identifiant unique	Identifiant unique attribué à l'appareil tel que défini en 3.2.105 et décrit en 6.3.1.2.4
5	Unsigned8	Indice de Table	Indice de la Table des voisins
6	Unsigned8	Nombre d'entrées	Nombre d'entrées de voisins contenues dans la réponse
7	Unsigned16	Neighbor_nickname	Surnom du voisin comme défini en 3.2.74
9	Integer8	Average_RSL (niveau moyen de signal reçu)	Niveau moyen de signal reçu (en dBm) par l'appareil en provenance de ce voisin
10	Unsigned32	Packets_transmitted (paquets émis)	Nombre de paquets émis vers ce voisin
14	Unsigned32	Missed_ACK_packets (paquets ACQ manqués)	Emission échouée vers ce voisin nombre de paquets attendant un ACQ et aucun reçu
18	Unsigned32	Packets_received (paquets reçus)	Nombre de paquets reçus de ce voisin
22	Champ binaire	Fanions de voisins	Fanions des voisins, comme spécifié au Tableau F.34
23..			

[a] Les champs dans les octets 7 à 22 sont répétés autant de fois que la valeur de "Nombre de voisins".

Tableau 258 – Codes de réponse spécifiques à la commande Lire santé des voisins de l'appareil

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
8	Avertissement	Mis à la valeur la plus proche possible
16	Erreur	Accès limité
65	Erreur	Indice non valide de Table des voisins

8.3.5.2.3 Procédure au niveau de l'appareil répondeur

Cette commande lit, à partir de la passerelle, les informations relatives à la qualité de la connexion vers chaque voisin actif ou potentiel pour l'appareil spécifié dans la demande. La passerelle peut trouver le nombre de voisins pour l'appareil en envoyant la demande "Unité

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PDU de couche FAL: Lire liste des appareils" (voir 8.3.4.46). L'application demandeuse peut utiliser ce service pour construire le graphe et la qualité du réseau.

8.3.5.3 Unité PDU de couche FAL: Lire informations de topologie du réseau

8.3.5.3.1 Primitive de demande

La valeur de la commande est huit cent trente-quatre (834); la valeur du champ "Nombre d'octets" est sept (7) et le champ "Valeur" est présenté au Tableau 259.

Tableau 259 – Champ "Valeur" de demande Lire informations de topologie du réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.
5	Unsigned16	Indice de Table	Indice de la Table des graphes

8.3.5.3.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 260. Les valeurs des codes de réponse sont présentées au Tableau 261.

Tableau 260 – Champ "Valeur" de réponse Lire informations de topologie du réseau

Décalage d'octet[a]	Type de données	Nom de paramètre	Description
0	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.
5	Unsigned16	Indice de Table	Indice de la Table des graphes
7	Unsigned16	Nombre de graphes	Nombre total de graphes
9	Unsigned16	Graph_ID	Numéro d'identification attribué à ce graphe
11	Unsigned16	Nombre de voisins	Nombre de voisins
13	Unsigned16	Voisin	Surnom de voisin pour ce graphe
15..			

[a] Les champs dans les octets 13 à 14 sont répétés autant de fois que la valeur de "Nombre de voisins".

Tableau 261 – Codes de réponse spécifiques à la commande Lire informations de topologie du réseau

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible
65	Erreur	Indice non valide de Table des graphes

8.3.5.3.3 Procédure au niveau de l'appareil répondeur

Cette commande lit un élément dans la Table des graphes pour l'appareil de réseau spécifié à partir de la passerelle. La passerelle peut trouver le nombre de graphes pour l'appareil en utilisant Unité PDU de couche FAL: 'Lire liste de graphes' (voir 8.3.4.18). L'application demandeuse peut utiliser ce service pour construire le graphe du réseau.

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8.3.5.4 Unité PDU de couche FAL: Lire liste des messages d'édition de données

8.3.5.4.1 Primitive de demande

La valeur de la commande est huit cent trente-cinq (835); la valeur du champ "Nombre d'octets" est cinq (5) et le champ "Valeur" est présenté au Tableau 262.

Tableau 262 – Champ "Valeur" de demande Lire liste des messages d'édition de données

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.

8.3.5.4.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 263. Les valeurs des codes de réponse sont présentées au Tableau 264.

Tableau 263 – Champ "Valeur" de réponse Lire liste des messages d'édition de données

Décalage d'octet[a]	Type de données	Nom de paramètre	Description
0	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.
5	Unsigned8	Nombre d'édition de données	Nombre de commandes différentes d'édition de données reçues de cet appareil
6	Unsigned16	Commande éditer	Numéro de commande en cours d'édition
8	Unsigned32	Nombre de paquets	Nombre de paquets d'édition de données reçus
12..			

[a] Les champs dans les octets 6 à 11 sont répétés autant de fois que la valeur de " Nombre d'édition de données".

Tableau 264 – Codes de réponse spécifiques à la commande Lire liste des messages d'édition de données

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible

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8.3.5.4.3 Procédure au niveau de l'appareil répondeur

Cette commande lit, dans la passerelle, la liste des messages d'édition de données à laquelle participe l'appareil spécifié, y compris le nombre de commandes du mode d'édition de données auxquelles l'appareil spécifié participe. L'application demandeuse peut utiliser ce service pour dresser la liste de tout le trafic du mode "édition de données" du système.

8.3.5.5 Unité PDU de couche FAL: Purger réponses mises en cache pour un appareil

8.3.5.5.1 Primitive de demande

La valeur de la commande est huit cent trente-six (836); la valeur du champ "Nombre d'octets" est cinq (5) et le champ "Valeur" est présenté au Tableau 265.

Tableau 265 – Champ "Valeur" de Purger réponses mises en cache

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.

8.3.5.5.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 265. Les valeurs des codes de réponse sont présentées au Tableau 266.

Tableau 266 – Codes de réponse spécifiques à la commande Purger réponses mises en cache

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Nombre d'octets de données reçus trop faible
16	Erreur	Accès limité

8.3.5.5.3 Procédure au niveau de l'appareil répondeur

Cette commande purge les réponses mises en cache dans la passerelle pour l'appareil de réseau spécifié.

8.3.5.6 Unité PDU de couche FAL: Lire statistiques d'appareil de réseau

8.3.5.6.1 Primitive de demande

La valeur de la commande est huit cent quarante (840); la valeur du champ "Nombre d'octets" est cinq (5) et le champ "Valeur" est présenté au Tableau 267.

Tableau 267 – Champ "Valeur" de demande Lire statistiques d'appareil de réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.

8.3.5.6.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 268. Les valeurs des codes de réponse sont présentées au Tableau 269.

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Tableau 268 – Champ "Valeur" de réponse Lire statistiques d'appareil de réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4
5	Unsigned16	Nombre de graphes	Nombre de graphes configurés
7	Unsigned16	Nombre de supertrames	Nombre de supertrames configurées
9	Unsigned16	Compteur de liaisons	Nombre de liaisons configurées
11	Unsigned8	Nombre de voisins	Nombre de voisins (reliés et non reliés)
12	Temps	Latence amont	Latence de communication moyenne de l'appareil vers la passerelle ou le gestionnaire de réseau
16	Unsigned16	Nombre de rattachements	Nombre de rattachements
18	Date	Date de rattachement	Date du rattachement le plus récent
21	Temps	Heure de rattachement	Temps en 1/32 d'une unité en ms écoulé depuis minuit de la date à laquelle l'appareil a le plus récemment rejoint le réseau
25	Unsigned32	Paquets générés	Nombre de paquets générés par cet appareil
29	Unsigned32	Paquets terminés	Nombre de paquets terminés par cet appareil
33	Unsigned32	Défaillances MIC de la DLL	Nombre de défaillances MIC de la DLL détectées
37	Unsigned32	Défaillances MIC de la couche NL	Nombre de défaillances détectées relatives au MIC (de session) de la couche NL
41	Unsigned32	Erreurs de CRC	Nombre d'erreurs de CRC détectées
45	Unsigned32	Paquets manqués	Nombre de paquets détectés comme absents
49	Unsigned32	Compteur de nonces manqués	Nombre de valeurs de compteur de nonces non reçues de l'appareil
53	Temps	Ecart type de latence amont	Ecart-type de la latence de l'appareil vers la passerelle ou le gestionnaire de réseau
57	Temps	Latence aval moyenne	Latence de communication moyenne de la passerelle ou du gestionnaire de réseau vers l'appareil
61	Temps	Ecart type de latence aval	Ecart-type de la latence de la passerelle ou du gestionnaire de réseau vers l'appareil
65	Temps	Disponibilité amont	Pourcentage de disponibilité (nœud vers la passerelle ou le gestionnaire de réseau)
69	Temps	Disponibilité aval	Pourcentage de disponibilité (passerelle ou gestionnaire de réseau vers le nœud)
73	Unsigned32	File d'attente maximale	Longueur maximale de la file d'attente de tampon de paquets
75	Float32	File d'attente moyenne	Longueur moyenne de la file d'attente de tampon de paquets (dans le temps)
79	Champ binaire	Etat de connexion	Bits 0..2: Statut de connexion de l'appareil sans fil comme présenté au Tableau F.41
79	Champ binaire	Statut de santé	Bits 4..7: Statut de santé de l'appareil sans fil comme présenté au Tableau F.42
80	Unsigned8	Compteur de sessions	Nombre de paquets ayant une session incorrecte ou inconnue reçus par appareil. Ce qui peut indiquer un problème de configuration ou de sécurité.

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Tableau 269 – Codes de réponse spécifiques à la commande Lire statistiques d'appareil de réseau

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible

8.3.5.6.3 Procédure au niveau de l'appareil répondeur

Cette commande lit dans la passerelle les statistiques de l'appareil spécifié. La passerelle est censée disposer de ces informations et doit répondre immédiatement. La valeur de "Paquets manqués" est incrémentée pour chaque zéro dans l'historique du compteur de Nonces qui est en soupassement de capacité.

8.3.5.7 Unité PDU de couche FAL: Lire Identité d'appareil de réseau en utilisant le surnom

8.3.5.7.1 Primitive de demande

La valeur de la commande est huit cent quarante et un (841); la valeur du champ "Nombre d'octets" est deux (2) et le champ "Valeur" est présenté au Tableau 270.

Tableau 270 – Champ "Valeur" de demande Lire identité d'appareil de réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Device_nickname	Surnom de l'appareil comme défini en 3.2.74

8.3.5.7.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 271. Les valeurs des codes de réponse sont présentées au Tableau 272.

Tableau 271 – Champ "Valeur" de Lire identité d'appareil de réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Device_nickname	Surnom de l'appareil comme défini en 3.2.74
2	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.
7 – 38	Latin-1	Long_tag	Marqueur long stocké dans l'appareil

Tableau 272 – Codes de réponse spécifiques à la commande Lire identité d'appareil de réseau

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible

8.3.5.7.3 Procédure au niveau de l'appareil répondeur

Cette commande lit dans la passerelle les informations relatives à l'identité de l'appareil qui a un surnom d'appareil concordant.

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8.3.5.8 Unité PDU de couche FAL: Ecrire Fanions de programmation d'appareil de réseau

8.3.5.8.1 Primitive de demande

La valeur de la commande est huit cent quarante-deux (842); la valeur du champ "Nombre d'octets" est six (6) et le champ "Valeur" est présenté au Tableau 273.

Tableau 273 – Champ "Valeur" de Ecrire Fanions de programmation d'appareil de réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Identifiant unique	Identifiant unique	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4
5	Champ binaire	Fanions de programmation	Fanions de programmation de l'appareil comme spécifié au Tableau F.37

8.3.5.8.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 273. Les valeurs des codes de réponse sont présentées au Tableau 274.

Tableau 274 – Codes de réponse spécifiques à la commande Ecrire Fanions de programmation d'appareil de réseau

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
8	Avertissement	Détection d'un fanion d'attribut non pris en charge, fanions d'attributs d'appareil mis à la valeur la plus proche possible
16	Erreur	Accès limité
9	Erreur	Fanion d'attribut non valide
65	Erreur	Identifiant unique inconnu

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8.3.5.8.3 Procédure au niveau de l'appareil répondeur

Cette commande permet à l'utilisateur de demander une prise en compte spéciale d'un appareil lorsque le gestionnaire de réseau crée des programmes. Cette commande doit seulement être prise en charge par les passerelles et les gestionnaires de réseau. Ces informations ne doivent pas être écrites dans l'appareil de réseau.

8.3.5.9 Unité PDU de couche FAL: Lire Fanions de programmation d'appareil de réseau

8.3.5.9.1 Primitive de demande

La valeur de la commande est huit cent quarante-trois (843); la valeur du champ "Nombre d'octets" est cinq (5) et le champ "Valeur" est présenté au Tableau 275.

Tableau 275 – Champ "Valeur" de demande Lire Fanions de programmation d'appareil de réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Identifiant unique	Unique_ID	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.

8.3.5.9.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 276. Les valeurs des codes de réponse sont présentées au Tableau 277.

Tableau 276 – Champ "Valeur" de réponse Lire Fanions de programmation d'appareil de réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Identifiant unique	Unique_ID	L'identifiant unique attribué à l'appareil, comme défini en 3.2.105 et décrit en 6.3.1.2.4.
5	Champ binaire	Fanions de programmation	Fanions de programmation de l'appareil comme spécifié au Tableau F.37

Tableau 277 – Codes de réponse spécifiques à la commande Lire Fanions de programmation d'appareil de réseau

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide
5	Erreur	Nombre d'octets de données reçus trop faible

8.3.5.9.3 Procédure au niveau de l'appareil répondeur

Cette commande lit les attributs de l'appareil de réseau que le gestionnaire de réseau peut prendre en considération lors de la création de programmes. Cette commande doit seulement être prise en charge par les passerelles et les gestionnaires de réseau.

8.3.5.10 Unité PDU de couche FAL: Lire Contraintes du réseau

8.3.5.10.1 Primitive de demande

La valeur de la commande est huit cent quarante-quatre (844); la valeur du champ "Nombre d'octets" est zéro (0) et le champ "Valeur" est vide.

8.3.5.10.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 278. Les valeurs des codes de réponse sont présentées au Tableau 279.

Tableau 278 – Champ "Valeur" de Lire Contraintes du réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Champ binaire	Fanions d'optimisation	Fanions d'optimisation du réseau comme spécifié au Tableau F.38
1	Unsigned8	Nombre de paires de messages	Nombre de paires de messages de demande / réponse que le gestionnaire de réseau est autorisé à envoyer en 10 s.

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Tableau 279 – Codes de réponse spécifiques à la commande Lire Contraintes du réseau

Valeur	Classe	Description
0	Succès	Pas d'erreur

8.3.5.10.3 Procédure au niveau de l'appareil répondeur

Cette commande lit le réglage courant de la stratégie de gestion de réseau et le nombre de messages de demande / réponse par 10 s.

8.3.5.11 Unité PDU de couche FAL: Ecrire Contraintes du réseau

8.3.5.11.1 Primitive de demande

La valeur de la commande est huit cent quarante-cinq (845); la valeur du champ "Nombre d'octets" est deux (2) et le champ "Valeur" est présenté au Tableau 280.

Tableau 280 – Champ "Valeur" de Ecrire Contraintes du réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Champ binaire	Fanions d'optimisation	Fanions d'optimisation du réseau comme spécifié au Tableau F.38
1	Unsigned8	Nombre de paires de messages	Nombre de paires de messages de demande / réponse que le gestionnaire de réseau est autorisé à envoyer en 10 s.

8.3.5.11.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 280. Les valeurs des codes de réponse sont présentées au Tableau 281.

Tableau 281 – Codes de réponse spécifiques à la commande Ecrire Contraintes du réseau

Valeur	Classe	Description
0	Succès	Pas d'erreur
2	Erreur	Choix non valide (stratégie illégitime ou non prise en charge)
5	Erreur	Nombre d'octets de données reçus trop faible
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
8	Avertissement	Mis à la valeur la plus proche possible
16	Erreur	Accès limité

8.3.5.11.3 Procédure au niveau de l'appareil répondeur

Cette commande écrit le réglage courant de la stratégie de gestion de réseau et le nombre de messages de demande / réponse par 10 s. La valeur minimale pour le nombre de messages demande / réponse par 10 s est un (1).

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8.3.5.12 Unité PDU de couche FAL: Lire statistiques réseau

8.3.5.12.1 Primitive de demande

La valeur de la commande est huit cent quarante-six (846); la valeur du champ "Nombre d'octets " est zéro (0).

8.3.5.12.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 282. Les valeurs des codes de réponse sont présentées au Tableau 283.

Tableau 282 – Champ "Valeur" de réponse Lire statistiques de réseau

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Float32	Débit	Nombre moyen de paquets par seconde communiqués par le gestionnaire de réseau et la passerelle
4	Float32	Utilisation	Pourcentage d'utilisation du réseau
8	Float32	Disponibilité	Pourcentage de disponibilité
12	Temps	Latence	Latence moyenne
16	Temps	Ecart type de latence	Ecart type de latence
20	Float32	Taux d'erreurs sur les paquets	Taux d'erreurs sur les paquets
24	Unsigned32	Paquets éliminés	Nombre de paquets éliminés par tous les appareils sur la liste active
28	Unsigned32	Echecs de rattachement	Nombre de demandes de rattachement reçues qui n'entraînent pas la mise en quarantaine de l'appareil demandeur.

Tableau 283 – Codes de réponse spécifiques à la commande Lire réseau

Valeur	Classe	Description
0	Succès	Pas d'erreur
16	Erreur	Accès limité

8.3.5.12.3 Procédure au niveau de l'appareil répondeur

Cette commande est une synthèse de la santé globale du réseau.

8.3.5.13 Unité PDU de couche FAL: Transférer liste de réseau à liste blanche

8.3.5.13.1 Primitive de demande

La valeur de la commande est huit cent quarante-sept (847); la valeur du champ "Nombre d'octets " est zéro (0).

8.3.5.13.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 284. Les valeurs des codes de réponse sont présentées au Tableau 285.

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Tableau 284 – Champ "Valeur" de réponse Transférer liste de réseau à liste blanche

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Count	Nombre d'appareils copiés sur la liste blanche

Tableau 285 – Codes de réponse spécifiques à la commande Transférer liste de réseau à liste blanche

Valeur	Classe	Description
0	Succès	Pas d'erreur
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
16	Erreur	Accès limité

8.3.5.13.3 Procédure au niveau de l'appareil répondeur

Cette commande copie la liste de réseaux vers la liste blanche. La liste blanche est purgée avant le transfert. Après exécution de cette commande, le contenu de la liste blanche sera identique à la liste de réseau.

8.3.5.13.4 Procédure au niveau de l'appareil répondeur

Cette commande est une synthèse de la santé globale du réseau.

8.3.5.14 Unité PDU de couche FAL: Générer clé

8.3.5.14.1 Primitive de demande

La valeur de la commande est huit cent quarante-huit (848); la valeur du champ "Nombre d'octets" est un (1) et le champ "Valeur" est présenté au Tableau 286.

Tableau 286 – Champ "Valeur" de demande Générer clé

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Valeur	La valeur doit être mise à zéro (0)

8.3.5.14.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 287. Les valeurs des codes de réponse sont présentées au Tableau 288.

Tableau 287 – Champ "Valeur" de réponse Générer clé

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned16	Valeur	La valeur doit être mise à zéro (0)
1	Clé de sécurité	Légende	Valeur de clé de sécurité aléatoire

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Tableau 288 – Codes de réponse spécifiques à la commande Générer clé

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Trop peu d'octets reçus
6	Erreur	Erreur de commande spécifique à l'appareil
16	Erreur	Accès limité

8.3.5.14.3 Procédure au niveau de l'appareil répondeur

Cette commande est utilisée par une application pour obtenir une clé aléatoire du gestionnaire de sécurité. Sachant que l'application ne peut pas s'adresser directement au gestionnaire de sécurité, la passerelle est utilisée comme proxy. Il est admis d'utiliser cette clé pour écrire une nouvelle clé de rattachement vers un appareil.

8.3.5.15 Unité PDU de couche FAL: Lire clé de rattachement d'appareil

8.3.5.15.1 Primitive de demande

La valeur de la commande est huit cent quarante-neuf (849); la valeur du champ "Nombre d'octets" est six (6) et le champ "Valeur" est présenté au Tableau 289.

Tableau 289 – Lire clé de rattachement d'appareil Champ "Valeur" de demande Lire clé de rattachement d'appareil

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Valeur	La valeur doit être mise à zéro (0)
1	Identifiant unique	Identifiant unique	Identifiant unique de l'appareil

8.3.5.15.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 290. Les valeurs des codes de réponse sont présentées au Tableau 291.

Tableau 290 – Champ "Valeur" de réponse Lire clé de rattachement d'appareil

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Valeur	La valeur doit être mise à zéro (0)
1	Identifiant unique	Identifiant unique	Identifiant unique de l'appareil
6	Clé de sécurité	Légende	Valeur de clé aléatoire

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Tableau 291 – Codes de réponse spécifiques à la commande Lire clé de rattachement d'appareil

Valeur	Classe	Description
0	Succès	Pas d'erreur
5	Erreur	Trop peu d'octets reçus
6	Erreur	Erreur de commande spécifique à l'appareil
7	Erreur	Protégé en écriture
9	Erreur	Appareil actif ou mis en quarantaine
10	Erreur	Réseau fermé, le nouvel appareil ne peut pas être ajouté
11	Erreur	Le nombre d'appareils du réseau ne peut pas être augmenté
16	Erreur	Accès limité
32	Erreur	Occupé une DR n'a pas pu être lancée
33	Erreur	Réponse différée déclenchée
34	Erreur	Réponse différée en cours
35	Erreur	Réponse différée morte
36	Erreur	Réponse différée en conflit

8.3.5.15.3 Procédure au niveau de l'appareil répondeur

Cette commande lit une nouvelle clé de rattachement aléatoire pour l'appareil spécifié. Cette commande peut être utilisée pour la configuration d'un appareil avant de l'ajouter à un réseau. Si l'appareil n'est pas déjà sur la liste blanche, il y est alors ajouté. La liste de réseau demeure inchangée (l'appareil n'est ni ajouté ni supprimé de la liste de réseau). Cette commande renverra une erreur si l'appareil est sur la liste active ou la liste de mise en quarantaine. La commande renverra une erreur si le réseau est fermé.

8.3.5.16 Unité PDU de couche FAL: Ecrire clé de rattachement d'appareil

8.3.5.16.1 Primitive de demande

La valeur de la commande est huit cent cinquante (850); la valeur du champ "Nombre d'octets" est vingt-deux (22) et le champ "Valeur" est tel que présenté au Tableau 292.

Tableau 292 – Ecrire clé de rattachement d'appareil

Décalage d'octet	Type de données	Nom de paramètre	Description
0	Unsigned8	Valeur	La valeur doit être mise à zéro (0)
1	Identifiant unique	Identifiant unique	Identifiant unique de l'appareil
6	Clé de sécurité	Clé de sécurité	Clé de rattachement pour l'appareil sélectionné

8.3.5.16.2 Primitive de réponse

Le champ "Valeur" de la réponse est présenté au Tableau 292. Les valeurs des codes de réponse sont présentées au Tableau 293.

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