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INTERNATIONAL STANDARD

Industrial communication networks – Fieldbus specifications – Part 6-2: Application layer protocol specification – Type 2 elements

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FOREWORD

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Attention is drawn to the fact that the use of the associated protocol type is restricted by its intellectual-property-right holders. In all cases, the commitment to limited release of intellectual-property-rights made by the holders of those rights permits a layer protocol type to be used with other layer protocols of the same type, or in other type combinations explicitly authorized by its intellectual-property-right holders.

NOTE Combinations of protocol types are specified in the IEC 61784-1 series and the IEC 61784-2 series.

IEC 61158-6-2 has been prepared by subcommittee 65C: Industrial networks, of IEC technical committee 65: Industrial-process measurement, control and automation. It is an International Standard.

This fifth edition cancels and replaces the fourth edition published in 2019. This edition constitutes a technical revision.

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

a) update of normative and bibliographic references;
b) review of Get/Set_Attributes_All parameter format in 3.5.3;
c) new services in 4.1.2.1, 4.1.8.1 and 8.2, 8.3;
d) clarifications of services in 4.1.5;
e) definition of specific connection path in 4.1.6.12;
f) clarifications and updates of Get/Set_attribute_list services in 4.1.8.1;
g) clarifications, new attributes for the Identity object in 4.1.8.2;
h) new attributes, service parameters and service for the Message Router object in 4.1.8.3;
i) clarifications, new attribute and other extensions for the Assembly object in 4.1.8.4;
j) clarifications, new attributes, service parameters, services and diagnostics connection points for the Time Sync object in 4.1.8.6;
k) clarifications, new services and addition of diagnostics connection points for the Connection Manager object in 4.1.8.9;
l) clarifications and extensions of Path Segments in 4.1.9;
m) updates and extensions of class, attribute and service codes in 4.1.10;
n) clarifications and additions of error codes in 4.1.11;
o) update of STIME, UTIME and NTIME data types in 4.2.3 and 5.1.3.5;
p) updates of encapsulation protocol in 4.3.1;
q) addition of internal services in 7.1;
r) removal of obsoleted transport options and related services in Clause 9 and Clause 11;
s) updates of DMPM2 in Clause 11;
t) removal of all references to CPF and CPs (material moved to profile documents);
u) miscellaneous editorial corrections.

The text of this International Standard is based on the following documents:

Draft	Report on voting
65C/1204/FDIS	65C/1245/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts of the IEC 61158 series, published under the general title *Industrial communication networks – Fieldbus specifications*, can be found on the IEC web site.

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

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

INTRODUCTION

This part of IEC 61158 is one of a series produced to facilitate the interconnection of automation system components. It is related to other standards in the set as defined by the "three-layer" fieldbus reference model described in IEC 61158-1.

The application protocol provides the application service by making use of the services available from the data-link or other immediately lower layer. The primary aim of this document is to provide a set of rules for communication expressed in terms of the procedures to be carried out by peer application entities (AEs) at the time of communication. These rules for communication are intended to provide a sound basis for development in order to serve a variety of purposes:

- as a guide for implementers and designers;
- for use in the testing and procurement of equipment;
- as part of an agreement for the admittance of systems into the open systems environment;
- as a refinement to the understanding of time-critical communications within OSI.

This document is concerned, in particular, with the communication and interworking of sensors, effectors and other automation devices. By using this document together with other standards positioned within the OSI or fieldbus reference models, otherwise incompatible systems can work together in any combination.

INDUSTRIAL COMMUNICATION NETWORKS – FIELDBUS SPECIFICATIONS –

Part 6-2: Application layer protocol specification – Type 2 elements

1 Scope

1.1 General

The Fieldbus Application Layer (FAL) provides user programs with a means to access the fieldbus communication environment. In this respect, the FAL can be viewed as a "window between corresponding application programs."

This part of IEC 61158 provides common elements for basic time-critical and non-time-critical messaging communications between application programs in an automation environment and material specific to Type 2 fieldbus. The term "time-critical" is used to represent the presence of a time-window, within which one or more specified actions are required to be completed with some defined level of certainty. Failure to complete specified actions within the time window risks failure of the applications requesting the actions, with attendant risk to equipment, plant and possibly human life.

This document specifies interactions between remote applications and defines the externally visible behavior provided by the Type 2 fieldbus application layer in terms of

- the formal abstract syntax defining the application layer protocol data units conveyed between communicating application entities;
- the transfer syntax defining encoding rules that are applied to the application layer protocol data units;
- the application context state machine defining the application service behavior visible between communicating application entities;
- the application relationship state machines defining the communication behavior visible between communicating application entities.

The purpose of this document is to define the protocol provided to

- define the wire-representation of the service primitives defined in IEC 61158-5-2, and
- define the externally visible behavior associated with their transfer.

This document specifies the protocol of the Type 2 fieldbus application layer, in conformance with the OSI Basic Reference Model (ISO/IEC 7498-1) and the OSI application layer structure (ISO/IEC 9545).

1.2 Specifications

The principal objective of this document is to specify the syntax and behavior of the application layer protocol that conveys the application layer services defined in IEC 61158-5-2.

A secondary objective is to provide migration paths from previously-existing industrial communications protocols.

1.3 Conformance

This document does not specify individual implementations or products, nor does it constrain the implementations of application layer entities within industrial automation systems. Conformance is achieved through implementation of this application layer protocol specification.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE All parts of the IEC 61158 series, as well as the IEC 61784-1 series and the IEC 61784-2 series are maintained simultaneously. Cross-references to these documents within the text therefore refer to the editions as dated in this list of normative references.

IEC 61158-1:2023, *Industrial communication networks – Fieldbus specifications – Part 1: Overview and guidance for the IEC 61158 and IEC 61784 series*

IEC 61158-3-2:2023, *Industrial communication networks – Fieldbus specifications – Part 3-2: Data-link layer service definition – Type 2 elements*

IEC 61158-4-2:2023, *Industrial communication networks – Fieldbus specifications – Part 4-2: Data-link layer protocol specification – Type 2 elements*

IEC 61158-5-2:2023, *Industrial communication networks – Fieldbus specifications – Part 5-2: Application layer service definition – Type 2 elements*

IEC 61588:2021, *Precision clock synchronization protocol for networked measurement and control systems*

IEC 61784-3-2, *Industrial communication networks – Profiles – Part 3-2: Functional safety fieldbuses – Additional specifications for CPF 2*

IEC 61800-7-202, *Adjustable speed electrical power drive systems – Part 7-202: Generic interface and use of profiles for power drive systems – Profile type 2 specification*

IEC 62026-3:2014, *Low-voltage switchgear and controlgear – Controller-device interfaces (CDIs) – Part 3: DeviceNet*

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

ISO/IEC/IEEE 8802-3, *Telecommunications and exchange between information technology systems – Requirements for local and metropolitan area networks – Part 3: Standard for Ethernet*

ISO/IEC 8824-1, *Information technology – Abstract Syntax Notation One (ASN.1) – Part 1: Specification of basic notation*

ISO/IEC 8825-1, *Information technology – ASN.1 encoding rules – Part 1: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER)*

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

ISO/IEC 10646, *Information technology – Universal Coded Character Set (UCS)*

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

ISO 639-2, *Codes for the representation of names of languages – Part 2: Alpha-3 code*

ISO 11898-1:2015, *Road vehicles – Controller area network (CAN) – Part 1: Data link layer and physical signalling*

IEEE Std 802.1Q-2018, *IEEE standard for local and metropolitan area networks – Bridges and bridged networks*

IEEE Std 802.3-2018, *IEEE Standard for Ethernet*

IETF RFC 791, J. Postel, *Internet Protocol*, September 1981, available at https://www.rfc-editor.org/info/rfc791 [viewed 2022-02-18]

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IETF RFC 1112, S.E. Deering, *Host Extensions for IP Multicasting*, August 1989, available at https://www.rfc-editor.org/info/rfc1112 [viewed 2022-02-18]

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IETF RFC 1759, R. Smith, F. Wright, T. Hastings, S. Zilles, J. Gyllenskog, *Printer MIB*, March 1995, available at https://www.rfc-editor.org/info/rfc1759 [viewed 2022-02-18]

IETF RFC 2236, W. Fenner, *Internet Group Management Protocol, Version 2*, November 1997, available at https://www.rfc-editor.org/info/rfc2236 [viewed 2022-02-18]

IETF RFC 2474, K. Nichols, S. Blake, F. Baker, D. Black, *Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers*, December 1998, available at https://www.rfc-editor.org/info/rfc2474 [viewed 2022-02-18]

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IETF RFC 3246, B. Davie, A. Charny, J.C.R. Bennet, K. Benson, J.Y. Le Boudec, W. Courtney, S. Davari, V. Firoiu, D. Stiliadis, *An Expedited Forwarding PHB (Per-Hop Behavior)*, March 2002, available at https://www.rfc-editor.org/info/rfc3246 [viewed 2022-02-18]

IETF RFC 3376, B. Cain, S. Deering, I. Kouvelas, B. Fenner, A. Thyagarajan, *Internet Group Management Protocol, Version 3*, October 2002, available at https://www.rfc-editor.org/info/rfc3376 [viewed 2022-02-18]

IETF RFC 4594, J. Babiarz, K. Chan, F. Baker, *Configuration Guidelines for DiffServ Service Classes*, August 2006, available at https://www.rfc-editor.org/info/rfc4594 [viewed 2022-02-18]

3 Terms, definitions, symbols, abbreviated terms and conventions

For the purposes of this document, the following terms, definitions, symbols, abbreviated terms and conventions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1 Terms and definitions from other ISO/IEC standards

3.1.1 Terms and definitions from ISO/IEC 7498-1

a) abstract syntax
b) application entity
c) application process
d) application protocol data unit
e) application service element
f) application entity invocation
g) application process invocation
h) application transaction
i) presentation context
j) real open system
k) 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 8824-1

a) object identifier
b) type
c) value
d) simple type
e) structured type
f) component type
g) tag
h) Boolean type
i) true
j) false
k) integer type
l) bitstring type
m) octetstring type
n) null type
o) sequence type
p) sequence of type
q) choice type
r) tagged type
s) any type
t) module
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 document)
d) length octet(s) (both singular and plural forms are used in this document)
e) contents octets

3.2 Terms and definitions from IEC 61158-5-2

a) application relationship
b) client
c) peer
d) server

3.3 Additional terms and definitions

3.3.1
allocate
take a resource from a common area and assign that resource for the exclusive use of a specific entity

3.3.2
application
function or data structure for which data is consumed or produced

3.3.3
application objects
multiple object classes that manage and provide a run time exchange of messages across the network and within the network device

3.3.4
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 can also affect the behavior of an object. Attributes are divided into class attributes and instance attributes.

3.3.5
behavior
indication of how an object responds to particular events

3.3.6
Best Master Clock Algorithm
BMCA
algorithm performed by each node to determine the clock that will become the master clock on a subnet and the grandmaster clock for the domain

Note 1 to entry: The algorithm primarily compares priority1, clock quality, priority2, and source identity to determine the best master among available candidates.

3.3.7
boundary clock
clock that has multiple Precision Time Protocol (PTP) ports in a domain and maintains the timescale used in the domain

Note 1 to entry: It may serve as the source of time, i.e., be a master clock, and may synchronize to another clock, i.e., be a slave clock.

[SOURCE: IEC 61588:2009, 3.1.3, modified [1] – second sentence changed to a Note]

3.3.8
called
service user or a service provider that receives an indication primitive or a request APDU

3.3.9
calling
service user or a service provider that initiates a request primitive or a request APDU

3.3.10
class
set of objects, all of which represent the same kind of system component

Note 1 to entry: A class is a generalization of an 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.

3.3.11
class attribute
attribute that is shared by all objects within the same class

[1] This definition and several others are based on the legacy IEC 61588:2009 and not the latest IEC 61588:2021.

3.3.12
class code
unique identifier assigned to each object class

3.3.13
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.

3.3.14
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

3.3.15
clock
node participating in the Precision Time Protocol (PTP) that is capable of providing a measurement of the passage of time since a defined epoch

Note 1 to entry: There are three types of clocks in IEC 61588:2009, boundary, transparent and ordinary clocks.

[SOURCE: IEC 61588:2009, 3.1.4, modified – different Note]

3.3.16
communication objects
components that manage and provide a run time exchange of messages across the network

EXAMPLES Connection Manager object, Unconnected Message Manager (UCMM) object, and Message Router object.

3.3.17
connection
logical binding between application objects that may be within the same or different devices

Note 1 to entry: Connections may be either point-to-point or multipoint.

3.3.18
connection ID
CID
identifier assigned to a transmission that is associated with a particular connection between producers and consumers, providing a name for a specific piece of application information

3.3.19
connection path
octet stream that defines the application object to which a connection instance applies

3.3.20
connection point
buffer which is represented as a subinstance of an Assembly object

3.3.21
consume
act of receiving data from a producer

3.3.22
consumer
node or sink that is receiving data from a producer

3.3.23
consuming application
application that consumes data

3.3.24
cyclic
repetitive in a regular manner

3.3.25
device
physical hardware connected to the link

Note 1 to entry: A device may contain more than one node.

3.3.26
device profile
collection of device dependent information and functionality providing consistency between similar devices of the same device type

3.3.27
domain
logical grouping of clocks that synchronize to each other using the protocol, but that are not necessarily synchronized to clocks in another domain

[SOURCE: IEC 61588:2009, 3.1.7]

3.3.28
end node
producing or consuming node

3.3.29
end point
one of the communicating entities involved in a connection

3.3.30
epoch
origin of a time scale

[SOURCE: IEC 61588:2021, 3.1.12]

3.3.31
error
discrepancy between a computed, observed or measured value or condition and the specified or theoretically correct value or condition

3.3.32
frame
denigrated synonym for DLPDU

3.3.33
grandmaster clock
within a domain, clock that is the ultimate source of time for clock synchronization using the PTP protocol

[SOURCE: IEC 61588:2009, 3.1.13]

3.3.34
implementation profile
collection of information and functionality supported by a device, independently of its device type

Note 1 to entry: Unlike device profiles, implementation profiles group subsets of Type 2 technologies and characteristics, providing a high-level description of the capabilities of a device.

3.3.35
instance
actual physical occurrence of an object within a class that identifies one of many objects within the same object class

EXAMPLE California is an instance of the object class state.

Note 1 to entry: The terms object, instance, and object instance are used to refer to a specific instance.

3.3.36
instance attribute
attribute whose value is unique to an object instance and whose definition is shared by all instances of an object

3.3.37
instantiated
object that has been created in a device

3.3.38
interoperability
capability of User Layer entities to perform coordinated and cooperative operations using the services of the FAL

3.3.39
Keeper
object responsible for distributing link configuration data to all nodes on the link

3.3.40
little endian
model of memory organization which stores the least significant octet at the lowest address, or for transfer, which transfers the lowest order octet first

Note 1 to entry: Native Type 2 data types are sent in little endian order.

3.3.41
Lpacket
Link packet
piece of application information that contains a size, control octet, tag, and link data

Note 1 to entry: Peer data-link layers use Lpackets to send and receive service data units from higher layers in the OSI stack.

3.3.42
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.

3.3.43
master clock
in the context of a single Precision Time Protocol (PTP) communication path, clock that is the source of time to which all other clocks on that path synchronize

[SOURCE: IEC 61588:2009, 3.1.17]

3.3.44
member
piece of an attribute that is structured as an element of an array

3.3.45
Message Router
object within a node that distributes messaging requests to appropriate application objects

3.3.46
multipoint connection
connection from one node to many

Note 1 to entry: Multipoint connections allow messages from a single producer to be received by many consumer nodes.

3.3.47
network
set of nodes connected by some type of communication medium, including any intervening repeaters, bridges, routers and lower-layer gateways

3.3.48
object
abstract representation of a particular component within a device, usually a collection of related data (in the form of variables) and methods (procedures) for operating on that data that have clearly defined interface and behavior

3.3.49
object specific service
service unique to the object class which defines it

3.3.50
ordinary clock
clock that has a single Precision Time Protocol (PTP) port in a domain and maintains the timescale used in the domain

Note 1 to entry: It may serve as a source of time, i.e., be a master clock, or may synchronize to another clock, i.e., be a slave clock.

[SOURCE: IEC 61588:2009, 3.1.22, modified – second sentence changed to a Note]

3.3.51
originator
client responsible for establishing a connection path to the target

3.3.52
parent clock
master clock to which a clock is synchronized

[SOURCE: IEC 61588:2009, 3.1.23]

3.3.53
point-to-point connection
connection that exists between exactly two application objects

3.3.54
Precision Time Protocol
PTP
protocol defined by IEC 61588:2021

Note 1 to entry: As an adjective, it indicates that the modified noun is specified in or interpreted in the context of IEC 61588:2021.

[SOURCE: IEC 61588:2021, 3.1.48, modified – second sentence changed to a Note, and references to IEEE Std 1588 replaced by IEC 61588:2021]

3.3.55
produce
act of sending data to be received by a consumer

3.3.56
producer
node that is responsible for sending data

3.3.57
PTP message
one of the messages defined in IEC 61588:2021

[SOURCE: IEC 61588:2021, 3.1.58, modified – NOTE deleted, and reference to IEEE Std 1588 replaced by IEC 61588:2021]

3.3.58
PTP port
logical access point of a clock for PTP communications to the communications network

[SOURCE: IEC 61588:2021, 3.1.61, modified – “PTP instance” changed to “clock”]

3.3.59
receiving
service user that receives a confirmed primitive or an unconfirmed primitive, or a service provider that receives a confirmed APDU or an unconfirmed APDU

3.3.60
resource
processing or information capability of a subsystem

3.3.61
sending
service user that sends a confirmed primitive or an unconfirmed primitive, or a service provider that sends a confirmed APDU or an unconfirmed APDU

3.3.62
server
a) role of an AREP in which it returns a confirmed service response APDU to the client that initiated the request

b) object which provides services to another (client) object

3.3.63
service
operation or function than an object and/or object class performs upon request from another object and/or object class

3.3.64
synchronized clocks
(to a specified uncertainty) absent relativistic effects, two clocks which have the same epoch and for which measurements of the time of the same single event at an arbitrary instant differ by no more than the specified uncertainty

[SOURCE: IEC 61588:2021, 3.1.75, modified – reworded according to IEC rules]

3.3.65
system time
absolute time value as defined by Type 2 time synchronization in the context of a distributed time system where all devices have a local clock that is synchronized with a common master clock

Note 1 to entry: In the context of Type 2, System Time is a 64-bit integer value in units of nanoseconds with a value of 0 corresponding to the date 1970-01-01.

3.3.66
target
end-node to which a connection is established

3.3.67
temporary node
transient node

3.3.68
transaction id
field within a UCMM header that matches a response with the associated request

3.3.69
transparent clock
device that measures the time taken for a Precision Time Protocol (PTP) event message to transit the device and provides this information to clocks receiving this PTP event message

[SOURCE: IEC 61588:2009, 3.1.46, modified – truncated]

3.3.70
unconnected message manager
UCMM
component within a node that transmits and receives unconnected explicit messages and sends them directly to the Message Router object

3.3.71
unconnected service
messaging service which does not rely on the set up of a connection between devices before allowing information exchanges

3.3.72
vendor ID
identification of each product manufacturer/vendor by a unique number

Note 1 to entry: Vendor IDs are assigned by the ODVA, Inc. organization (see <www.odva.org>).

3.4 Abbreviated terms and symbols

ASCII	American Standard Code for Information Interchange
CID	connection ID
CAN	Controller Area Network (see ISO 11898-1)
CM_API	actual packet interval
CM_RPI	requested packet interval
DLL	data-link layer
DSCP	DiffServ Codepoint
IGMP	Internet Group Management Protocol (see IETF RFC 1112, IETF RFC 2236)
IP	Internet Protocol (see IETF RFC 791)
IPv4	Internet Protocol version 4 (see IETF RFC 791)
IPv6	Internet Protocol version 6 (see IETF RFC 791)
O2T or O⇒T	originator to target (connection parameters)
OSI	open systems interconnection (see ISO/IEC 7498-1)
PDU	protocol data unit
PHB	per-hop behavior
PTP	Precision Time Protocol (see IEC 61588)
QoS	quality of service
Rcv	receive
Rx	receive
SDU	service data unit
SEM	state event matrix
STD	state transition diagram, used to describe object behavior
T2O or T⇒O	target to originator (connection parameters)
TCP	Terminal Control Protocol (see IETF RFC 793)
ToS	type of service
TPDU	transport protocol data unit
TUI	table unique identifier
Tx	transmit
UDP	User Datagram Protocol (see IETF RFC 768)
Xmit	transmit

3.5 Conventions

3.5.1 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 IEC 61158-5-2. The protocol specification for each of the ASEs is defined in this document.

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 IEC 61158-5-2. The service specification defines the services that are provided by the ASE.

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

Bold font is used in this document to highlight parameter names or important requirement elements from surrounding text. Italic font is also used in Tables and Notes for that purpose for better visibility.

3.5.2 Attribute specification

Attributes are defined in an Attribute Table using the format and terms defined in Figure 1.

Attribute ID	Name	Data type	Semantics of values

Figure 1 – Attribute table format and terms

The **Attribute ID** shall be a unique integer identification value assigned to an attribute. The valid ranges for Attribute IDs shall be as specified in 4.1.10.1.3. The Attribute ID shall identify the particular attribute being accessed.

Name shall refer to the name assigned to the attribute. An attribute may contain sub-elements, which may also have names, as is the case with the **STRUCT of** data type. The attribute name shall be the name which appears first, or at the top row in the name column (the row that contains the Attribute ID).

Every attribute shall be assigned a **Data type** which shall be either an elementary or a derived data type. The data types specified for the defined attributes shall be used in all implementations.

NOTE The elementary data types are defined in IEC 61158-5-2.

Semantics of values shall specify the meaning of the value(s) of the attribute. If this information needs more room than can fit in the table it will immediately follow the Class Attribute table. Included in the Class Attribute table will be an appropriate reference to this information.

If a Class Attribute is optional, then a default value or a special case processing method shall be defined such that the Client (Requester) can process the error message that occurs when accessing those objects that choose not to implement the class attribute.

3.5.3 Common services

3.5.3.1 Service_PDU definitions

Each service has unique parameters for request and response. The service request and response parameters shall be defined using service Request/Response parameter tables as defined in Figure 2.

Name	Data type	Semantics of values

Figure 2 – Service request/response parameter

Name shall refer to the name given to the service request/response parameter.

Type shall specify the data type of the service request/response parameter.

Semantics of values shall specify the meaning of the values of the service request/response parameter, e.g. "the value is counts of microseconds."

3.5.3.2 Get_Attributes_All response

3.5.3.2.1 General definition

When the Get_Attributes_All common service is included in the list of supported System/Object Management services for an object class, then the **Get_Attributes_All** response shall be detailed for this class: the structure of the data returned in the Service_ResponsePDU shall be specified.

The rules specified in Table 1 shall be adhered to when specifying the Get_Attributes_All Service_ResponsePDU of an object class for both the Class Attributes and the Instance Attributes.

Table 1 – Get_Attributes_All response service rules

Rule number	Rule
1	If the definition of the Get_Attributes_All response includes optional attributes, then default values shall be specified in the response description. Optional attributes at the end of the list that are not implemented may be omitted in the response data. Optional attributes in the middle of the list that are not implemented shall be included in the response data, and set to specified default values. If any of the following optional attributes are included in an object specification, but not supported in the implementation of the object, then the following shall be adhered to: – if the class attribute "Optional attribute list" is not supported, the default value of zero shall be inserted into the response array and no optional attribute numbers shall follow; – if the class attribute "optional service list" is not supported, the default value of zero shall be inserted into the response array and no optional service numbers shall follow.
2	If new attributes are added to an existing object, those attributes shall be added to the end of the response attribute list or data array to ensure compatibility with different object revisions.
3	Whichever method is used to specify the response, it shall be done in such a way as to be unambiguous, including rules to deal with variable length fields and padding.
4	The Get_Attributes_All response for objects specified in this document shall include only the open attributes; it shall not include any vendor specific attributes.

Table 2 is an example of how to specify the service data portion of a Get_Attributes_All response for class level attributes of an object which supports **optional gettable** class attributes 1, 2, 3 and 4.

Table 2 – Example class level object/service specific response data of Get_Attributes_All

Attribute ID	Data type	Attribute Name	Default Value (if not implemented)
1	UINT	Revision	1
2	UINT	Max Instance	
3	UINT	Number of Instances	
4	STRUCT of	Optional attribute list	
	UINT	Number of attributes	0
	ARRAY of UINT	Optional attributes	(null)

3.5.3.2.2 Revisions

The defined Get_Attributes_All response for an object may increase in size with each revision of the object; however, to insure interoperability, the format of the first part of the response shall remain parseable by a client of the older revision of the object. Clients (Requesters) need not make use of this compatibility requirement.

NOTE The Revision class attribute is not the revision of an implementation (which is reflected in the Identity object, Minor/Major revision status bits), but the revision of the class definition.

3.5.3.3 Set_Attributes_All request

3.5.3.3.1 General definition

When the Set_Attributes_All common service is included in the list of supported common services, then the format of the **Set_Attributes_All request** shall be included in the object specification. The structure of the data supplied in the Service_RequestPDU shall be specified.

The rules specified in Table 3 shall be adhered to when specifying an object's Set_Attributes_All request in the object specification for both the Class Attributes and the Instance Attributes.

Table 3 – Set_Attributes_All request service rules

Rule number	Rule
1	An object shall support the Set_Attributes_All service only if all settable attributes shown in the Set_Attributes_All request are implemented as settable.
2	Default values shall be specified for all optional attributes that are not implemented. If an implementation does not support an optional attribute, it shall accept the specified default value for the unsupported attribute.
3	If new settable attributes are added to an existing object, those attributes shall be added to the end of the request attribute list or data array.
4	Whichever method is used to specify the response, it shall be done in such a way as to be unambiguous, including rules to deal with variable length fields and padding.
5	The Set_Attributes_All request response for objects specified in this document shall include only the open attributes. It shall not include any vendor specific attributes.

Table 4 is an example of how to specify the service data portion of a Set_Attributes_All request for instance level attributes of an object which supports required settable instance attributes 1, 4, 10, 11, 15, 32.

Table 4 – Example request data of Set_Attributes_All

Attribute ID	Data type	Attribute name	Default Value (if not implemented)
1	UINT	Output Range	
4	USINT	Value Data Type	
10	UINT	Fault State	0
11	UINT	Idle State	0
15	UINT	Fault Value	0
32	UINT	Idle Value	0

3.5.3.3.2 Revisions

A server processing a Set_Attributes_All request can need to process more data than is expected by the server if the client has implemented a newer revision of this object while the server an older revision. As a result, the server object can have to process a Set_Attributes_All request that contains more data because the additional attributes were not recognized. If the server receives more data in a Set_Attributes_All request than it expects the server shall respond with a general status code equal to 0x15 (too much data).

NOTE The Revision class attribute is not the revision of an implementation (which is reflected in the Identity object, Minor/Major revision status bits), but the revision of the class definition.

3.5.4 State machine conventions

3.5.4.1 General

State changes can be triggered by events (internal or external) or service invocations. Reaction to service invocations may depend on the value(s) of the attribute(s) accessed by the service.

Behavior of the state machine shall be defined for combinations of:

- the **event** the machine receives;
- the **state** the machine is in when it receives notification of a state-changing event.

To define behavior in these terms, a State Transition Diagram (STD) and a State Event Matrix (SEM) are used when applicable in the state machine specification.

3.5.4.2 State Transition Diagram (STD)

An **event** is an external stimulus that can cause a state transition. An STD graphically illustrates the states of an object and includes events, service calls and changes of attributes that cause it to transition to another state. Figure 3 shows an example of an STD.

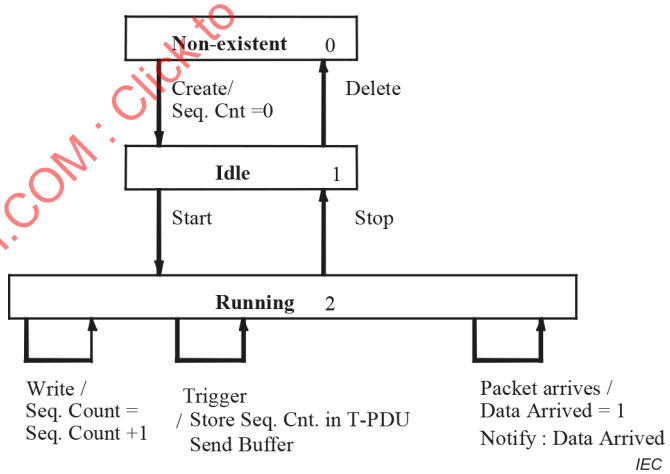


Figure 3 – Example of an STD

NOTE Event that is the primary cause of the State Transition is followed by "/" mark. Notification to upper layer is marked by "Notify:"

3.5.4.3 State Event Matrix

A **state** is the current active mode of operation of the state machine object (e.g. Running, Idle).

A state event matrix is a table that lists all possible events, services and changes in attribute values that initiate a state change, and indicates the response by the object to the event based on the state of the object when it receives notification of that event.

State event matrix format is as shown in Table 5.

Table 5 – State event matrix format

Event	State [a]		
	State 1	....	State n
Event A description	Function triggered by event A in State 1 (if any) Notification to FAL user (if any) Transition to another state (if any)		Function triggered by event A in State n (if any) Notification to FAL user (if any) Transition to another state (if any)
.....	.....		.....
Event X description	Function triggered by event X in State 1 (if any) Notification to FAL user (if any) Transition to another state (if any)		Function triggered by event X in State n (if any) Notification to FAL user (if any) Transition to another state (if any)

[a] In absence of function, notification or transition, the corresponding entry shall not be made in the table.

3.5.4.4 Example state event matrix

Table 6 shows an example of a state machine with three states:

- **Non-existent**: the object has not yet been created; objects transition to the existent state via the create service (if the object may be dynamically created) or at power-up (if the object is fixed by design/implementation);
- **Idle**: the object accepts services (e.g. Get_Attribute_Single), but does not produce or consume data onto or from the link;
- **Running**: the object is performing all its specified functions.

Table 6 – Example state event matrix

Event	State		
	Non-existent	Idle	Running
Create	Transition to Idle	Error: Object already exists.	Error: Object already exists.
Delete	Error: Object does not exist. (General Error Code 0x16)	Transition to Non-existent	Error: Object State Conflict (General Error Code 0x0C)
Start	Error: Object does not exist. (General Error Code 0x16)	Transition to Running	Error: Object State Conflict (General Error Code 0x0C)
Stop	Error: Object does not exist. (General Error Code 0x16)	Error: Object State Conflict (General Error Code 0x0C)	Transition to Idle
Get_Attribute_Single	Error: Object does not exist. (General Error Code 0x16)	Validate/service the request. Return response	Validate/service the request. Return response
Set_Attribute_Single	Error: Object does not exist. (General Error Code 0x16)	Validate/service the request. Return response	Error: Object State Conflict (General Error Code 0x0C)

4 Abstract syntax

4.1 FAL PDU abstract syntax

4.1.1 General

FAL_PDU shall be either a UCMM_PDU or a Transport_PDU.

UCMM_PDU is used to convey information for connection-less services.

Transport_PDU is used to convey information for connection-oriented services.

A connected message assumes previously negotiated resources and parameters at its source, its destination(s), and any intermediate transit points (routers). These resources are referenced by a unique connection identifier and do not need to be contained in each message, only the connection ID is needed to identify the message and refer to its related parameters, thus giving significant savings in message efficiency.

An unconnected message provides a means to communicate on the local link without previously negotiated resources at the destination so it shall carry full destination ID details, internal data descriptors and full source ID details if a reply is requested. Unconnected messages are used mainly to create connections.

The unconnected service is provided by the Unconnected Message Manager (UCMM). Messages received through the UCMM are forwarded to the Message Router (MR), which direct them to the appropriate internal object for execution. Connections are established by specific unconnected messages sent through the Connection Manager (CM) using UCMM services. Connections may be established either to the Message Router (for messaging purpose), or directly to an application object. Connection target is specified using a connection path, and may be either on the local or a remote link, through several routers. Once a connection is established with an application object, the UCMM, MR and CM are no longer required, since data will be exchanged directly with the connected objet, based on the corresponding connection ID. Connected messages sent to the Message Router will be forwarded to the appropriate internal object for execution.

4.1.2 PDU structure

4.1.2.1 UCMM_PDU structure

UCMM_PDU is a sequence of a UCMM_Header, followed by either OM_Service (Object Management ASE) or CM_Service (Connection Manager ASE).

OM_Service shall be either OM_Request or OM_Response.

OM_Request shall consist of MR_Request_Header and a Service_RequestPDU.

Service_RequestPDU shall be one of the following:

- Get_Attribute_Single_RequestPDU
- Get_Attributes_All_RequestPDU
- Get_Attribute_List_RequestPDU
- Set_Attribute_Single_RequestPDU
- Set_Attributes_All_RequestPDU
- Set_Attribute_List_RequestPDU
- Reset_RequestPDU
- Create_RequestPDU

- Delete_RequestPDU
- Start_RequestPDU
- Stop_RequestPDU
- Find_Next_Object_Instance_RequestPDU
- NOP_RequestPDU
- Apply_Attributes_RequestPDU
- Save_RequestPDU
- Restore_RequestPDU
- Get_Member_RequestPDU
- Set_Member_RequestPDU
- Insert_Member_RequestPDU
- Remove_Member_RequestPDU
- Group_Sync_RequestPDU
- Add_AckData_Path_RequestPDU
- Remove_AckData_Path_RequestPDU
- Get_Enum_String_RequestPDU
- Symbolic_Translation_RequestPDU
- Send_Receive_Fragment_RequestPDU
- Connection_Bind_RequestPDU
- Producing_Application_Lookup_RequestPDU
- Flash_LEDs_RequestPDU
- Multiple_Service_Packet_RequestPDU
- Get_Connection_Point_Member_List_RequestPDU

OM_Response shall consist of MR_Response_Header and a Service_ResponsePDU.

Service_ResponsePDU shall be one of the following:

- Get_Attribute_Single_ResponsePDU
- Get_Attributes_All_ResponsePDU
- Get_Attribute_List_ResponsePDU
- Set_Attribute_Single_ResponsePDU
- Set_Attributes_All_ResponsePDU
- Set_Attribute_List_ResponsePDU
- Reset_ResponsePDU
- Create_ResponsePDU
- Delete_ResponsePDU
- Start_ResponsePDU
- Stop_ResponsePDU
- Find_Next_Object_Instance_ResponsePDU
- NOP_ResponsePDU
- Apply_Attributes_ResponsePDU
- Save_ResponsePDU
- Restore_ResponsePDU
- Get_Member_ResponsePDU

- Set_Member_ResponsePDU
- Insert_Member_ResponsePDU
- Remove_Member_ResponsePDU
- Group_Sync_ResponsePDU
- Add_AckData_Path_ResponsePDU
- Remove_AckData_Path_ResponsePDU
- Get_Enum_String_ResponsePDU
- Symbolic_Translation_ResponsePDU
- Send_Receive_Fragment_RequestPDU
- Connection_Bind_ResponsePDU
- Producing_Application_Lookup_ResponsePDU
- Flash_LEDs_ResponsePDU
- Multiple_Service_Packet_ResponsePDU
- Get_Connection_Point_Member_List_ResponsePDU

CM_Service shall be either CM_Request or CM_Response.

CM_Request shall consist of MR_Request_Header and a CM_RequestPDU.

CM_RequestPDU shall be one of the following:

- Forward_Open_RequestPDU
- Forward_Close_RequestPDU
- Large_Forward_Open_RequestPDU
- Unconnected_Send_RequestPDU
- Get_Connection_Data_RequestPDU
- Search_Connection_Data_RequestPDU
- Get_Connection_Owner_RequestPDU

CM_Response consists of MR_Response_Header and a CM_ResponsePDU.

CM_ ResponsePDU shall be one of the following:

- Forward_Open_ResponsePDU
- Forward_Close_ResponsePDU
- Large_Forward_Open_ResponsePDU
- Unconnected_Send_ResponsePDU
- Get_Connection_Data_ResponsePDU
- Search_Connection_Data_ResponsePDU
- Get_Connection_Owner_ResponsePDU

4.1.2.2 Transport_PDU structure

Transport_PDU is a sequence of a Transport_Header, followed by either OM_Service (Object Management ASE) or Application Data.

OM_Service is defined in 4.1.2.1 above.

Application Data comes from the source to which the connection has been made.

4.1.3 UCMM_PDUs

Subclause 4.1.3 defines the requirements for UCMM PDU's when using a Type 2 data-link layer.

All UCMM_PDUs shall be sent and received using fixed tag 0x83 or Management tag 0x88. When a device becomes powered, the UCMM shall invoke the `DLL_enable_fixed_request` service of the data-link layer to request that fixed tag 0x83 or 0x88 Lpackets be routed to the UCMM. All sending and receiving of TPDUs shall use the `DLL_fixed_request.req` and `DLL_fixed_request.ind` service primitives of the data-link layer, respectively. The packet parameter of these services shall be prefixed with the following header to form the Transport PDU before sending to the data-link layer. The format of the UCMM_PDU Header is shown in Table 7.

Table 7 – UCMM_PDU header format

Parameter name	Format
command_code	USINT
Timeout	USINT
TransactionID	UINT

The `command_code` shall specify the type of UCMM_PDU as shown in Table 8. UCMM packets received with a reserved `command_code` shall be discarded without acknowledgement.

Table 8 – UCMM command codes

Command_code	Description
0	Reserved
1	acknowledge a request
2	request with retry until acknowledged
3	response with retry until acknowledged
4	request with no acknowledge and no response
5	acknowledge a response
6	response which shall not retry (no acknowledge)
7	request with retry until response (no acknowledge)
8	Request which shall not retry and shall cause a code 6 response
9 to 255	Reserved

The timeout field shall specify the duration of the transaction in an 8-bit floating-point format. The most significant 5 bits of the field shall be an unsigned exponent that is not biased. The least significant 3 bits shall be the least significant 3 bits of a 4 bit unsigned mantissa. The most significant bit of the mantissa shall be 1 and shall not appear explicitly in the 8-bit representation. The binary point shall be positioned between the implied 1 and the rest of the mantissa. The units of the transaction duration computed using the timeout field shall be in milliseconds.

NOTE Using ANSI C precedence rules, the number of 0,125 ms ticks is
(8 | `timeout` & 7) << (`timeout` >> 3 & 31).

The transactionID field shall be composed of two sub-fields:

- the least significant 10 bits, RECORD, shall identify a specific transaction;
- the most significant 6 bits, SEQUENCE, shall be used for duplicate detection. It shall be incremented for every unique message on this RECORD; however it shall not be incremented on a retry.

Only one message shall be outstanding for a given RECORD.

If multiple outstanding messages are required then multiple RECORDs are required.

When an I'm alive fixed tag packet is received from a node (see IEC 61158-4-2, 6.10 and 8.1), all UCMM transactions with that node shall be aborted.

4.1.4 Transport_Headers

4.1.4.1 General

Contents of Transport headers varies depending on the class of transport selected during the connection establishment.

4.1.4.2 Class 0 (null or base)

The class 0 transport header shall be an unsigned 16-bit number. This header shall be written to the TPDU buffer by the transport and shall be simply discarded by the transport from the packet coming from the consumer. The format of the Header is shown in Table 9.

Table 9 – Transport class 0 header

Parameter name	Format
don't_care	UINT

4.1.4.3 Class 1 (duplicate detection)

The class 1 transport header shall be an unsigned 16-bit sequence count. This header shall be written to the TPDU buffer by the transport and shall be read by the transport from the packet coming from the consumer. The format of the Header is shown in Table 10.

Table 10 – Transport class 1 header

Parameter name	Format
sequence_count	UINT

4.1.4.4 Class 2 (acknowledged)

Like the class 1 transport header, the class 2 transport header shall be a 16-bit sequence count. This header shall be written to the TPDU buffer by the transport and shall be read by the transport from the packet coming from the consumer. The format of the Header is shown in Table 11.

Table 11 – Transport class 2 header

Parameter name	Format
sequence_count	UINT

4.1.4.5 Class 3 (verified)

Like the class 1 transport header, the class 3 transport header shall be a 16-bit sequence count. This header shall be written to the TPDU buffer by the transport and shall be read by the transport from the packet coming from the consumer. The format of the Header is shown in Table 12.

Table 12 – Transport class 3 header

Parameter name	Format
sequence_count	UINT

4.1.4.6 Listen only O⇒T data format

The O=>T connection shall use a specific heartbeat format (no 32-bit header, 0 octets of application data).

4.1.4.7 Input only O⇒T data format

The O=>T connection shall use a specific heartbeat format (no 32-bit header, 0 octets of application data).

4.1.4.8 Exclusive owner O⇒T data format

Exclusive owner connections shall have either of two real-time transfer formats:

- 32-bit header, fixed size;
- no header, variable size.

The 32-bit header prefixed to the real-time data shall be in the form shown in Table 13.

Table 13 – Real-time data header – exclusive owner

Parameter	Format	Size (bits)
Run_idle	RUN_IDLE	1
Reserved	UDINT	31

The `run_idle` flag (bit 0) shall be set (1 = `RUN`) to indicate that the following data shall be sent to the target application. It shall be clear (0 = `IDLE`) to indicate that the idle event shall be sent to the target application. The `reserved` field (bits 1 to 31) shall be reserved and set to 0.

If the no_header transfer format is used, the reception of a packet with data beyond the transport header shall indicate the RUN mode. If the packet is truncated after the transport header, the target shall be sent an idle event.

4.1.4.9 Redundant owner O⇒T data format

4.1.4.9.1 General format

Redundant owner shall have a 32-bit header prefixed to the real-time data. This header shall be in the form shown in Table 14.

Table 14 – Real-time data header– redundant owner

Parameter	Format	Size (bits)
Run_idle	RUN_IDLE	1
COO	BOOLEAN	1
ROO	USINT	2
Reserved	UDINT	28

4.1.4.9.2 Run_idle flag

The run_idle flag (bit 0) shall be have the same meaning as it does in an exclusive owner connection and shall be one of RUN or IDLE. The reserved field (bits 4 to 31) shall be reserved and set to 0.

4.1.4.9.3 Claim output ownership (COO) flag

The COO flag shall be set (1) when an originator application wants its connection to be the owning connection of the target application. The COO flag shall be reset (0) when an originator application does not want its connection to be the owning connection of the target application. When the owning connection resets (0) its COO flag, its sibling connections shall be checked for a set (1) COO flag. The new owner shall be any of the connections that have their COO flag set.

NOTE This results in undefined behavior if more than one other connection has its COO flag set.

4.1.4.9.4 Ready for ownership of outputs (ROO) priority value

The ROO priority value shall be non-zero when an originator application does not want to force its connection to be the owning connection of the target application, but is ready to be the owning connection should there be no originator applications claiming to be the owning connection. The ROO priority value shall be zero when the originator application does not want to be the owning connection of the target connection and is not to be the owning connection should there be no originator application claiming to be the owning connection. The ROO priority value shall be used only when the COO flag is reset.

The value of the ROO field can range from 0 to 3. The originator applications shall each determine a unique non-zero ROO value.

4.1.4.9.5 Determining the owning connection

The originator applications shall determine among themselves which originator application has the owning connection. The owning connection shall be determined by the originator application that sets its COO flag. In situations where multiple originator applications have their COO flag set or where no originator connections have their COO flag set, the following rules shall be applied by the target transport to determine the owning connection.

- There shall be no owning connection until an originator application sends a real-time packet with the COO flag set;
- If there is only one originator application which had the COO flag set in its last real-time packet, that originator application shall have the owning connection;
- If there are multiple originator applications which had the COO flag set in its last real-time packet, the last originator application that transitioned its COO flag from reset to set shall have the owning connection.
- If the originator application with the owning connection resets its COO flag, closes its connection, or if that connection times out, and no other originator applications have their COO flags set, the originator application with the highest non-zero ROO priority value shall have the owning connection.
- If all of the originator applications have their COO flags reset and ROO priority values set to zero, there shall be no owning connection.
- When the first real-time packet containing a set COO flag is received by the target transport, the originator application that sent the real-time packet shall have the owning connection.

4.1.4.9.6 Transporting events and data to a target application

The connection related events from each of the redundant owner connections shall be combined using the following rules such that the target application sees only a single exclusive owner connection:

- Until an owning connection is initially determined, the transport shall not indicate real-time data reception to the target application;
- If an owning connection is determined, the transport shall indicate the event consistent with the owning connections real-time data to the target application. If the Run/Idle flag is reset in the real-time data for the owning connection, the transport shall indicate the idle state to the target application. If the Run/Idle flag is set in the real-time data for the owning connection, the transport shall indicate the run state and the real-time data to the target application;
- If an owning connection had been previously determined, but no originator is currently claiming or ready for ownership, the transport shall indicate idle state to the target application;
- If all the redundant connections are closed or have been timed out, the target transport shall indicate the event consistent with the last connection to have been closed or timed out to the target application.

4.1.5 CM_PDUs

4.1.5.1 General

Connection establishment and maintenance services are provided by the Connection Manager. They are

CM_Forward_Open (corresponds to Forward_Open and Large_Forward_Open PDUs)

CM_Forward_Close (corresponds to Forward_Close PDUs)

CM_Unconnected_Send (corresponds to Unconnected_Send PDUs)

CM_Get_Connection_Data (corresponds to Get_Connection_Data PDUs)

CM_Search_Connection_Data (corresponds to Search_Connection_Data PDUs)

CM_Get_Connection_Owner (corresponds to Get_Connection_Owner PDUs)

4.1.5.2 Connection Manager

The Connection Manager object is used to manage the establishment and maintenance of communication connections.

The Connection Manager objects at different nodes shall communicate using the UCMM services described in IEC 61158-5-2. The TPDUs with which peer Connection Managers communicate shall be derived from the services of the Connection Manager.

4.1.5.3 Forward_Open

4.1.5.3.1 General

The Forward_Open service is used to establish a connection with a target device. This service results in local connection establishment on each link along the path.

NOTE The processing of a single Forward_Open service can result in the creation of multiple active Connection object instances.

A Forward Open can be either a non-null Forward_Open or a null Forward_Open. A non-null Forward_Open is a Forward_Open service request for which at least one of the connection types in the O2T_ or T2O_connection_parameters field is not 00 (NULL). A null Forward_Open is a Forward_Open service request for which the connection type in both the O2T_ and T2O_connection_parameters fields is 00 (NULL) and results in no connection being established.

A Forward_Open (both null and non-null) can be either not matching or matching. A matching Forward_Open service request received by the target device is one where the Connection Triad matches an existing connection.

The usage of each of the combinations of non-null/null and not matching/matching Forward_Open is described in 4.1.5.3.2 and summarized in the list below:

- non-null / not matching – open a connection;
- non-null / matching – error;
- null / not matching – ping a device, or configure;
- null / matching – reconfigure.

The response to the Forward_Open_Request_PDU is a Forward_Open_ResponsePDU. The Forward_Open response shall contain the originator connection serial number and owner vendor and serial number and the connection IDs (CID) necessary to complete the connection if successful and error information if the connection failed.

4.1.5.3.2 Forward_Open variants

4.1.5.3.2.1 Non null Forward_Open, not matching

The Forward_Open request sets up network, transport, and application connections. An application connection consists of a single transport connection, and one or two network connections that are in turn comprised of multiple link connections. Each port segment in the connection path uses a link connection. The Forward_Open service between two devices builds one or two link connections as specified by the network connection parameter and the requested packet intervals (CM_RPI). Since up to two network connections can be required for a single transport connection, they are differentiated by the O2T and T2O designations; O2T means originator to target, and T2O means target to originator.

The path specified in the MR_Request_Header for the Forward_Open service shall not contain any Electronic Key segment. Electronic key segments may be included in the path specified in the connection_path parameter of the Forward_Open service.

Success shall be returned when the connection requested has been established from this point forward in the path. This response also shall indicate the connection serial number and the actual packet interval of the connection. Once the successful response has been received, the connection shall be open from this point forward in the path. Targets shall wait at least 10 seconds after sending the `CM_Forward_Open_Good_Response` for the first packet on a connection.

4.1.5.3.2.2 Non null Forward_Open, matching

A non-null Forward_Open for which the Connection Triad matches an existing connection shall return a general status = 0x01, extended status = 0x0100 (Connection in use or Duplicate Forward_Open).

The suggested originator behavior in the non-null Forward_Open, matching case should be to either close and re-establish the connection or wait for the connection to time-out and then establish the connection again. It shall be recognized that in the latter case, it shall take the connection 60 s (first data time-out) to time-out before the connection can be re-established.

4.1.5.3.2.3 Null Forward_Open, not matching

A null Forward_Open for which the Connection Triad does not match an existing connection's parameters can be used for the following functions.

a) Ping a device, with the following characteristics:
   - the single application path "20 01 24 01" (i.e. Identity object);
   - an electronic key segment may be included;
   - no data segment is included;
   - no connection is established.

b) Configure a device's application, with the following characteristics:
   - a configuration application path and data segment shall be included in the request (the data is sent to the application specified by the path and applied);
   - if the entire configuration cannot be applied, then none of the configuration shall be applied and the appropriate error code returned;
   - an electronic key segment may be included;
   - no connection is established.

A target device shall respond to a null Forward_Open request with one of the following errors when the target does not support the requested function ("ping a device" or "configure a device's application"):

- Null Forward_Open function not supported (general status 0x01, extended status 0x0132) (recommended).
- Invalid network connection parameter (general status 0x01, extended status 0x0108) (deprecated).

A client shall interpret any other error response returned by the target to mean that the target exists but does not support the requested function.

4.1.5.3.2.4 Null Forward_Open, matching

A Null Forward_Open for which the Connection Triad matches an existing connection's parameters can be used to reconfigure a target device's application. Routers shall always forward these requests. The associated behaviors are:

- a configuration application path and data segment shall be included in the request and they are sent to the application to change the application configuration;
- if the entire configuration cannot be applied then none of the configuration shall be applied and the appropriate error code returned;
- the connection shall not be interrupted due to this request.

A target device shall respond to a null Forward_Open request with one of the following errors when the target does not support the requested function ("reconfigure a target device's application"):

- Null Forward_Open function not supported (general status 0x01, extended status 0x0132) (recommended).
- Invalid network connection parameter (general status 0x01, extended status 0x0108 (deprecated).

If the interpretation of the consumed/produced data changes as a result of the reconfigure operation, care shall be taken in the producing and consuming applications. There is no specified mechanism to coordinate between the producing and consuming applications, so a change in the meaning of the real time data can result in unexpected operation. Devices have the option to reject a reconfiguration request, with an Object state conflict error (general status = 0x0c), to prevent this situation.

4.1.5.3.3 Format of Forward_Open request

The format of the Forward_Open request TPDU shall be of the form shown in Table 15.

Table 15 – Forward_Open request format

Parameter name	Format
priority_and_tick	SWORD
connection time-out ticks	USINT
O2T_CID	UDINT
T2O_CID	UDINT
connection_serial_number	UINT
originator_vendor_ID	UINT
originator_serial_number	UDINT
connection timeout multiplier	USINT
reserved[3]	USINT
O2T_CM_RPI	UDINT
O2T_connection_parameters [a]	UINT
T2O_CM_RPI	UDINT
T2O_connection_parameters [a]	UINT
xport_type_and_trigger	SWORD
connection_path_size	USINT
connection_path	Padded EPATH

[a] Connection type in this parameter shall be 00 (NULL) for a null Forward_Open.

4.1.5.3.4 Format of Forward_Open response if success

If the `status` parameter of the `CM_open_response` is zero (no error), the format of the Forward_Open response TPDU shall be of the form shown in Table 16.

Table 16 – Forward_Open_Good response format

Parameter name	Format
O2T_CID	UDINT
T2O_CID	UDINT
connection_serial_number	UINT
originator_vendor_ID	UINT
originator_serial_number	UDINT
O2T_CM_API	UDINT
T2O_CM_API	UDINT
Application_reply_size; (in 16-bit words)	USINT
Reserved	USINT
application_reply[]	UINT

If a Connection object is instantiated to support this connection:

- the values of O2T_CM_API and O2T_CM_API are used for the Connection object Expected_packet_rate attribute, after converting to milliseconds.
- the Expected_packet_rate will not be used for the Connection object Inactivity/Watchdog Timer. See 4.1.6.2 for connection timeout handling.

4.1.5.3.5 Format of Forward_Open response if failure

If the `status` parameter of the `CM_open_response` is not zero (error), the format of the Forward_Open response TPDU shall be of the form shown in Table 17.

Table 17 – Forward_Open_Bad response format

Parameter name	Format
connection_serial_number	UINT
originator_vendor_ID	UINT
originator_serial_number	UDINT
remaining_path_size	STRUCT of
number of words in connection_path parameter	USINT
reserved (shall be set to 0)	SWORD

This format shall be used for all failures of the connection system. The requested connection shall not be established, and the object specific status words shall contain information about the reason for the failure.

The `remaining_path_size` field is required if the error was detected by a router,optional if detected by the target. It shall contain the length of the path at the point the connection failed, i.e. the number of words in the connection_path parameter of the request as received by the device that detects the error.

In the failure response, the `remaining_path_size` shall be the “pre-stripped” size. This shall be the size of the path when the node first receives the request and has not yet started processing it. A target node may return either the “pre-stripped” size or 0 for the `remaining_path_size`.

A duplicate Forward_Open service shall be defined as a Forward_Open service whose `originator_vendor_ID`, `connection_serial_number`, and `originator_serial_number` match an existing connection's parameters. If the duplicate Forward_Open service is a null Forward_Open service (defined as the connection type in both the O2T and T2O network connection parameter fields are NULL), then the Forward_Open service shall be forwarded to the application for further processing. Null Forward_Open requests may be used to reconfigure the connection. The Connection Manager in the routers need not allocate additional resources for a duplicate Forward_Open request since the resources have already been allocated. If the duplicate Forward_Open request is not NULL, then an general status = 0x01, extended status = 0x0100 shall be returned.

4.1.5.4 Large_Forward_Open

4.1.5.4.1 General

The Large_Forward_Open shall have the same function and same behavior as the Forward_Open except that it shall allow the establishment of connections larger than 511 octets.

The response to the Large_Forward_Open_Request_PDU is an Large_Forward_Open_ResponsePDU. All other requirements are identical to those specified for the Forward_Open service in 4.1.5.3.

4.1.5.4.2 Format of Large_Forward_Open request

The format of the Large_Forward_Open request TPDU shall be of the form shown in Table 18.

Table 18 – Large_Forward_Open request format

Parameter name	Format
priority_and_tick	SWORD
connection time-out ticks	USINT
O2T_CID	UDINT
T2O_CID	UDINT
connection_serial_number	UINT
originator_vendor_ID	UINT
originator_serial_number	UDINT
connection timeout multiplier	USINT
reserved[3]	USINT
O2T_CM_RPI	UDINT
O2T_ex_connection_size	UINT
O2T_connection_parameters	UDINT
T2O_CM_RPI	UDINT
T2O_ex_connection_size	UINT
T2O_connection_parameters	UDINT
xport_type_and_trigger	SWORD
connection_path_size	USINT
connection_path	Padded EPATH

The connection size field in the two connection_parameters shall be reserved in this case and set to zero. The ex_connection_size parameters shall be used instead to specify the maximum size of the connection (up to 65 535).

4.1.5.4.3 Format of Large_Forward_Open response if success

If the `status` parameter of the `CM_open_response` is zero (no error), the format of the Large_Forward_Open response TPDU shall be of the form shown in Table 19.

Table 19 – Large_Forward_Open_Good response format

Parameter name	Format
O2T_CID	UDINT
T2O_CID	UDINT
connection_serial_number	UINT
originator_vendor_ID	UINT
originator_serial_number	UDINT
O2T_CM_API	UDINT
T2O_CM_API	UDINT
Application_reply_size; (in 16-bit words)	USINT
Reserved	USINT
application_reply[]	UINT

4.1.5.4.4 Format of Large_Forward_Open response if failure

If the `status` parameter of the `CM_open_response` is not zero (error), the format of the Large_Forward_Open response TPDU shall be of the form shown in Table 20.

Table 20 – Large_Forward_Open_Bad response format

Parameter name	Format
connection_serial_number	UINT
originator_vendor_ID	UINT
originator_serial_number	UDINT
remaining_path_size	STRUCT of
number of words in connection_path parameter	USINT
reserved (shall be set to 0)	SWORD

Either a target device or an intermediate router shall return an Invalid Connection Size extended error code, along with the maximum connection size supported extended status word, if the connection size requested is not supported while processing a Large_Forward_Open request.

4.1.5.5 Forward_Close

4.1.5.5.1 General

The Forward_Close request shall remove a connection from all the nodes participating in the original connection. The Forward_Close shall be sent between Connection Managers as specified in the connection_path. The Forward_Close request shall cause all non-shared resources in all nodes participating in the connection to be deallocated, including connection IDs, link transmit time, and internal memory buffers. Shared resources are those still in use by other connection(s) due to multicast.

If a router cannot find the connection that is to be closed (it could have timed out at the node), the Forward_Close request shall still be forwarded to downstream nodes or the target application (via the CM_close_indication).

NOTE The Forward_Close is always forwarded to allow downstream nodes or the target application to release any resources that were allocated for the connection.

4.1.5.5.2 Format of Forward_Close request

The format of the Forward_Close request shall be of the form shown in Table 21.

The path specified in the MR_Request_Header for the Forward_Close service shall not contain any Electronic Key segment. Electronic key segments may be included in the path specified in the connection_path parameter of the Forward_Close service.

Table 21 – Forward_Close request format

Parameter name	Format
connection_priority/tick time	SWORD
connection_timeout	USINT
connection_serial_number	UINT
originator_vendor_ID	UINT
originator_serial_number	UDINT
connection_path_size	USINT
Reserved	USINT
connection_path	Padded EPATH

4.1.5.5.3 Format of Forward_Close response if success

The Forward_Close response shall be sent between Connection Managers in response to a Forward_Close request, and shall contain the status of the close request. If the status parameter of the CM_close_response is zero (no error), the format of the Forward_Close response TPDU shall be of the form shown in Table 22.

Table 22 – Forward_Close_Good response format

Parameter name	Format
connection serial number	UINT
originator_vendor ID	UINT
originator serial number	UDINT
application_reply_size; in 16-bit words	USINT
Reserved	USINT
application_reply[]	UINT

A successful Forward_Close response shall be returned when the close has been acknowledged by all the nodes from this point in the path to the end of the path. The response shall indicate the connection_serial_number, originator_vendor_ID, and originator_serial_number of the closed connection. Once the response indicating success has been received, the connection shall be closed from this point in the path to the end. The target application may optionally pass back application specific information in the successful close response. If no application_reply information is contained in the service the application_reply_size shall be zero.

4.1.5.5.4 Format of Forward_Close response if failure

If the `status` parameter of the `CM_close_response` is not zero (error), the format of the Forward_Close response shall be of the form shown in Table 23.

Table 23 – Forward_Close_Bad response format

Parameter name	Format
connection_serial_number	UINT
originator_vendor_ID	UINT
originator_serial_number	UDINT
remaining_path_size	STRUCT of
number of words in connection_path parameter	USINT
reserved (shall be set to 0)	SWORD

The object specific status words shall contain information about the reason for the failure. The `remaining_path_size` field is required if the error was detected by a router, optional if detected by the target. It shall contain the path size from the point at which the close connection failed, i.e. the number of words in the connection_path parameter of the request as received by the device that detects the error.

In the failure response, the `remaining_path_size` shall be the “pre-stripped” size. This shall be the size of the path when the node first receives the request and has not yet started processing it. A target node shall return either the “pre-stripped” size or 0 for the `remaining_path_size`.

4.1.5.6 Unconnected_Send

4.1.5.6.1 General

The Unconnected_Send service shall allow an application to send a message to a device without first setting up a connection. The Unconnected_Send service shall use the Connection Manager object in each router to forward the message and to remember the return path. The UCMM of each link shall be used to forward the request from Connection Manager to Connection Manager just as it is for the Forward_Open service; however. No connection shall be built. The Unconnected_Send service shall be sent to the local Connection Manager and shall be sent between routers. When a router removes the last port segment, the embedded message request shall be formatted as an OM_Request and sent to the port and link address of the last port segment using the UCMM for that link type.

NOTE The target node never sees the Unconnected_Send service but only the embedded message request arriving via the UCMM.

4.1.5.6.2 Format of Unconnected_Send request

The format of the Unconnected_Send request shall be of the form shown in Table 24.

Table 24 – Unconnected_Send request format

Parameter name	Format	Description
priority/tick time	SWORD	Used to calculate request timeout information
conn time-out ticks	USINT	
Message_size	UINT	Number of octets in the embedded Message Router PDU
Message Router PDU	OM_Request	Embedded Messager Router PDU
pad	USINT	Only present if Message_size is an odd value. This allows the remaining fields to be aligned on a 16-bit boundary.
Route_path_size	USINT	Number of 16-bit words in the route_path field
Reserved	USINT	Reserved, shall be set to zero (0)
route_path	Padded EPATH	Indicates the route to the remote target device

The path specified in the MR_Request_Header for the Unconnected_Send service shall not contain any Electronic Key segment. Electronic key segments may be included in the path specified in the MR_Request_Header of the embedded message request and in the route_path parameter of the Unconnected_Send service.

The route path shall be of the form:

[Electronic Key segment1] } Port Segment Group for 1st router
Port segment1 }

[[Electronic Key segment2] } Port Segment Group for 2nd router
Port segment2] }

…

[[Electronic Key segmentN] } Port Segment Group for Nth router
Port segmentN] }

All segments listed in brackets […] are optional. If the Electronic Key segment is present the target shall evaluate the key. See 4.1.9.3 for the definition of Port segment and 4.1.9.4.2 for the definition of Electronic Key segment.

4.1.5.6.3 Unconnected_Send response

The Unconnected_Send response shall be generated by the last router from the UCMM response generated by the target node or by a router as the result of a UCMM time-out, a problem with the embedded message, or a problem with the Unconnected Service Request itself. The packet shall be routed from router to router using the information stored when the Unconnected_Send request was processed. The response shall contain a header with status information about the request and a variable length response generated by the target node.

4.1.5.6.4 Format of Unconnected_Send response if success

This format shall be used when a successful Unconnected_Send response is received. The structure of the response is shown in Table 25.

Table 25 – Unconnected_Send_Good response format

Parameter name	Format
application_response [ ]	OCTET

The application_response field contains the data returned by the target device/object in the Service_ResponsePDU for the embedded request. If the Service_ResponsePDU returned by the target device/object did not contain any data, then this field shall be empty.

EXAMPLE This field would contain Attribute Data in response to an embedded Get_Attribute_Single request.

4.1.5.6.5 Format of Unconnected_Send response if failure

In case of a failure of the Unconnected_Send service, the Service code returned in the MR_Response_Header for the Unconnected_Send service may correspond either to the Service code sent inside the Unconnected_Send service data (embedded message request) or to the Unconnected_Send Service code itself:

- when a router detects the error, the Unconnected_Send response Service code (0xD2) shall be returned in the MR_Response_Header;
- when the target device detects the error, the response Service code for the embedded message request shall be returned in the MR_Response_Header.

EXAMPLE If the target device detects the error and the requested service was a Get_Attribute_Single, then the Service code in the MR_Response_Header will be 0x8E.

This is advantageous to originators and routers because:

- of the two service codes (Unconnected Send and embedded), the service code that failed is returned to the originator;
- routers are not required to parse the Service code of the embedded message within the Unconnected_Send request.

The format of the Unconnected_Send response service for a failure shall be of the form shown in Table 26.

Table 26 – Unconnected_Send_Bad response format

Parameter name	Format
remaining_path_size	STRUCT of
number of words in route_path parameter	USINT
reserved (shall be set to 0)	SWORD

The remaining_path_size field shall only be present if the error was detected by a router. It indicates the number of words in the route_path parameter of the request as received by the router that detects the error.

4.1.5.7 Get_Connection_Data

4.1.5.7.1 General

This service shall return the parameters associated with a specified connection number. The connection number may be different from device to device even for the same connection. The connection number corresponds to the offset into the Connection Manager attribute that enumerates the status of the connections.

NOTE This service can be used for network diagnostics.

4.1.5.7.2 Format of Get_Connection_Data request

The format of the Get_Connection_Data request shall be of the form shown in Table 27.

Table 27 – Get_Connection_Data request format

Parameter name	Format
connection_number	UINT

4.1.5.7.3 Format of Get_Connection_Data response

The format of the Get_Connection_Data response TPDU shall be of the form shown in Table 28.

Table 28 – Get_Connection_Data response format

Parameter name	Format
connection_number	UINT
connection_state	UINT
originator_port	UINT
target_port	UINT
connection_serial_number	UINT
originator_vendor_ID	UINT
originator_serial_number	UDINT
originator_O2T_CID	UDINT
target_O2T _CID	UDINT
O2T_connection timeout multiplier	USINT
reserved1[3]	USINT
originator_O2T_CM_RPI	UDINT
originator_O2T_CM_API	UDINT
originator_T2O_CID	UDINT
target_ T2O_CID	UDINT
T2O_connection timeout multiplier	USINT
reserved2[3]	USINT
originator_T2O_CM_RPI	UDINT
originator_T2O_CM_API	UDINT

4.1.5.8 Search_Connection_Data

4.1.5.8.1 General

This service shall return the parameters associated with a specified connection within a device identified by vendor and serial number.

NOTE This service can be used for network diagnostics.

4.1.5.8.2 Format of Search_Connection_Data request

The format of the Search_Connection_Data request shall be of the form shown in Table 29.

Table 29 – Search_Connection_Data request format

Parameter name	Format
connection_serial_number	UINT
originator_vendor_ID	UINT
originator_serial_number	UDINT

4.1.5.8.3 Format of Search _Connection_Data response

The format of the Search_Connection_Data response shall be the same as the response from the Get_Connection_Data service (see 4.1.5.7).

4.1.5.9 Get_Connection_Owner

4.1.5.9.1 General

The Get_Connection_Owner service of the Connection Manager shall return data about the connection(s) that own(s) a particular object. It shall be implemented in any device that accepts redundant connections.

4.1.5.9.2 Format of Get_Connection_Owner request

The format of the Get_Connection_Owner request TPDU shall be of the form shown in Table 30:

Table 30 – Get_Connection_Owner request format

Parameter name	Format
reserved	USINT
path_size	USINT
path[]	Padded EPATH

The reserved field shall be set to zero.

4.1.5.9.3 Format of Get_Connection_Owner response

The format of the Get_Connection_Owner response TPDU shall be of the form shown in Table 31.

Table 31 – Get_Connection_Owner response format

Parameter name	Format	Description
number_of_connections	USINT	
number_claiming_ownership	USINT	
number_ready_for_ownership	USINT	
last_action	USINT	Ownership status: 0 = there is no owning connection.* 1 = the owning connection is in idle mode 2 = the owning connection is in run mode 3 to 254 = reserved 255 = the implementation does not support one of these fields
connection_serial_number	UINT	If there is no owner the value shall be 0
originator_vendor_ID	UINT	If there is no owner the value shall be 0
originator_serial_number	UDINT	If there is no owner the value shall be 0

4.1.6 CM PDU components

4.1.6.1 Network connection parameters

4.1.6.1.1 Format

Network connection parameters shall be provided as a single 16-bit word that contains five fields, shown in Figure 4. The fields within the 16-bit word shall indicate

- the type of network connection desired;
- whether the buffer size is variable or fixed;
- the priority of the connection;
- the size of the connection buffer required.

The size of the connection buffer shall include any transport header.

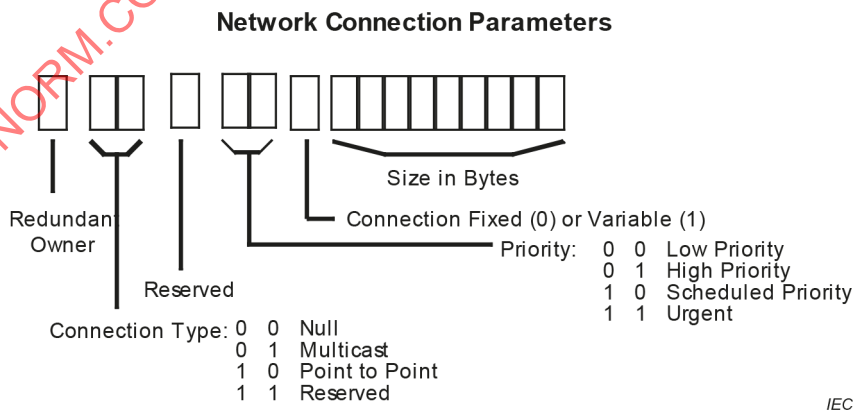


Figure 4 – Network connection parameters

4.1.6.1.2 Connection type

The connection type shall be one of NULL, MULTIPOINT, or POINT2POINT. The NULL type shall indicate that no network connection is required, while MULTIPOINT and POINT2POINT

refer to the network connection types as defined in IEC 61158-5-2. The NULL connection type may be used to reconfigure a connection.

4.1.6.1.3 Priority

Priority shall be one of `LOW`, `HIGH`, `SCHEDULED` and `URGENT`, with `URGENT` being the highest priority (see 4.1.6.3 for detailed specification and usage).

4.1.6.1.4 Connection fixed/variable

The connection can be set up to use fixed or variable sized connections. With a fixed size connection, each transmission on the connection shall use the same size buffer. Otherwise, either a buffer overrun or underrun condition shall occur. With a variable sized connection, each transmission on the connection may send a variable amount of data up to the maximum size, which shall be specified when the connection is opened. Buffer underruns shall not be reported, but a buffer overrun can still occur if too much data is sent.

4.1.6.1.5 Connection size

The network connection size shall be the size of the buffer required for the connection, which includes the data and any transport header. For a variable sized connection, the size shall be the maximum size of the buffer for any transfer. The actual size of the transfer for a variable connection shall be equal to or less than the size specified for the network connection. The maximum buffer size shall be dependent on the links that the connection traverses.

4.1.6.1.6 Redundant owner

The redundant owner bit in the O⇒T direction shall be set (= 1) to indicate that more than one owner is permitted to make a connection simultaneously. The bit shall be clear (= 0) to indicate an exclusive-owner, input only or listen-only connection.

4.1.6.1.7 Reserved parameters

Reserved bits shall be clear (= 0).

4.1.6.2 Requested and actual packet interval (CM_RPI and CM_API)

The connection originator provides a requested time between productions for each direction of the connection. The target provides the actual time between productions. When a connection traverses some Type 2 networks, the actual time may be further adjusted as specified in the corresponding Type 2 network communication profile.

The requested packet interval (CM_RPI) shall be the requested time between packets in microseconds. The format of the CM_RPI shall be a 32-bit integer in microseconds.

The actual packet interval (CM_API) shall be the maximum time between packets in microseconds. The CM_API is equivalent to the Transmission Trigger Timer value specified in IEC 61158-5-2, 6.2.3.2.1.7. The format of the CM_API shall be a 32-bit integer in microseconds.

The influence of the CM_API and CM_RPI values on the behavior of the connection is dependent on the Transport Class and Trigger definitions in 4.1.8.9.1.2. The CM_RPI value shall be used to allocate capacity usage at each of the producing nodes. The allocation of capacity usage could have to be adjusted when the CM_API is returned, since it is possible for the CM_RPI and CM_API to differ.

The CM_API shall equal the CM_RPI within the device's timer resolution limits, except if specified otherwise in the Type 2 network communication profile. If the CM_API is not equal to the CM_RPI it shall be faster than the CM_RPI unless the resulting CM_API would be 0, in which case the CM_RPI cannot be supported and an error shall be returned, either:

- CM_RPI Value(s) Not Acceptable, General Status 0x01, Extended Status 0x0112 (recommended);
- CM_RPI Not Supported, General Status 0x01, Extended Status 0x0111.

The Inactivity/Watchdog time-out value at each of the intermediate and target nodes shall be set to the connection time-out multiplier times the CM_RPI. If the resulting time-out is not achievable within the device's timer resolution limits, the time-out shall be rounded up the next value within the device's timer resolution limits.

4.1.6.3 Function of priorities

The order of priorities, from highest to lowest are: urgent, scheduled, high and low.

While there are no specific implementation requirements for end devices to internally differentiate traffic with different priorities, devices are recommended to give preferential processing to higher priority connections over lower priority connections. At a minimum, devices are recommended to give higher priority to processing implicit messages over explicit messages.

The mapping of Type 2 Priorities to link priorities is specific to each Type 2 network communication profile.

Urgent priority

Urgent priority shall only be used where defined explicitly in the Type 2 companion standards.

EXAMPLE Urgent priority is used for I/O connections established with the Motion Device Axis object specified in IEC 61800-7-202.

Nodes shall map the urgent priority to the corresponding network specific link priority.

Scheduled Priority

Nodes shall map the scheduled priority to the corresponding network specific link priority.

High Priority

Nodes shall map the high priority to the corresponding network specific link priority.

Low Priority

Nodes shall map the low priority to the corresponding network specific link priority.

4.1.6.4 Connection time-out multiplier

The Connection Time-out Multiplier specifies the multiplier applied to the CM_RPI to obtain the connection time-out value. Device shall stop transmitting on a connection whenever the connection times out even if the pending close has been sent. The multiplier shall be as represented by Table 32.

Table 32 – Time-out multiplier

Value	Multiplier	Notes
0	× 4	Default
1	× 8	
2	× 16	
3	× 32	
4	× 64	
5	× 128	
6	× 256	
7	× 512	
8 to 255	reserved	

4.1.6.5 Connection request priority and tick time

The Priority/Tick_time parameter determines the priority of the unconnected message and the time duration of a “tick” (Tick Time) specified in the Time-out_ticks parameter. The bit fields are specified in Figure 5.

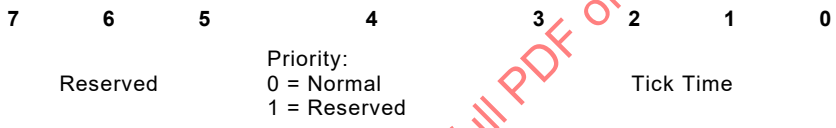


Figure 5 – Priority/Tick_time bit definition

The Reserved and Priority fields shall be set to zero (0). The Tick Time shall be used in conjunction with the Time-out_ticks parameter value to determine the total time out value.

The following formula is used:

$$\text{Actual Time Out value} = 2^{\text{Tick\_Time}} \times \text{Time\_out\_tick}$$

EXAMPLE If the tick time is 0000 (1 ms), a Time-out_ticks value of 5 would translate into 5 ms. If the tick time is 0010 (4 ms), a Time-out_ticks value of 5 would translate into 20 ms.

Table 33 shall determine the time between ticks.

Table 33 – Tick time units

Tick time		
Tick time (binary)	**Time per tick**	**Max. time**
0000	1 ms	255 ms
0001	2 ms	510 ms
0010	4 ms	1 020 ms
0011	8 ms	2 040 ms
0100	16 ms	4 080 ms
0101	32 ms	8 160 ms
0110	64 ms	16 320 ms
0111	128 ms	32 640 ms
1000	256 ms	65 280 ms
1001	512 ms	130 560 ms
1010	1 024 ms	261 120 ms
1011	2 048 ms	522 240 ms
1100	4 096 ms	1 044 480 ms
1101	8 192 ms	2 088 960 ms
1110	16 384 ms	4 177 920 ms
1111	32 768 ms	8 355 840 ms

4.1.6.6 Connection request time-out ticks

The Time-out ticks parameter shall be used to specify the amount of time the originating application shall wait for the transaction to be completed. When used with the Tick_Time portion of the Priority/Tick_time field, a total timeout value can be calculated.

Timeout Algorithm

The *Priority/Tick_time* and *Time-out ticks* parameters are used to convey timeout information as an unconnected request flows through interconnecting devices. The originator states how long it will wait for a response (total round trip time).

Each router subtracts the approximate amount of time it needs to process and forward both the request and the associated response. If a router cannot determine specifically how much time to subtract, it shall subtract 512 ms.

When encoding the result of the subtraction, the router shall use the smallest *Tick_time* possible (see 4.1.6.5) and ensure that the outgoing value is less than the received value. This provides the best granularity for decreasing the timeout as the message traverses the system. This also means that the *Tick_time* can change as the message is passed through multiple hops.

Each router shall use the new value as a timer for the resources used to manage the unconnected message and also to check to see if a timeout is imminent, i.e. the remaining time is zero or less, before forwarding the message. If a timeout is imminent, the router returns a General Status code of 0x01 with Extended Status code of 0x204 (Unconnected Request Timed Out) error response immediately rather than just letting the originator timeout.

If a router can detect that the next hop device is not present (e.g. the router supports an active node table function), it returns a General Status code of 0x01 with Extended Status code of 0x0204 (Unconnected Request Timed Out) error response immediately.

When a router fails to receive a response in the remaining time, a General Status code of 0x01 with Extended Status code of 0x0204 (Unconnected Request Timed Out) error response is returned.

When a target receives a Forward_Open, Large_Forward_Open or Forward_Close request, the target may either:

- ignore the *Priority/Tick_time* and *Time-out ticks* parameters and process the request, or;
- evaluate the *Priority/Tick_time* and *Time-out ticks* parameters and return a General Status code of 0x01 with Extended Status code of 0x0204 (Unconnected Request Timed Out) error response immediately if it knows it will not have enough time to complete the request.

If a target evaluates the *Priority/Tick_time* and *Time-out ticks* parameters:

- Adding the timing evaluation to a target as part of a product update needs to be carefully considered. An updated product shall use its best case time for comparison. Thus, an updated target should always accept connections that previously succeeded.
- Supporting the timing evaluation in a target as part of a new product shall use its worst case time for comparison. The result is that the target (if present) sends the timeout response instead of any router device.
- If a new or updated product can emulate one or more existing device(s), it shall perform the timing behavior of the device indicated in the compatible key of the request.

In all error cases, the node that generates the error response includes the Remaining Path Size parameter and every node that receives it releases all resources associated with that unconnected message. The Remaining Path Size in the error response facilitates the ability to know how far along the route the request progressed before encountering the error.

When an “Unconnected Request Timed Out” error is encountered, it is most likely due to one of the devices in the path (including the target) not being available (e.g. powered off, cable disconnected). Though less likely, the “Unconnected Request Timed Out” error can also result when there is network congestion and/or one or more of the devices along the path including the target take longer than the time provided by the originator to process the unconnected request. When an “Unconnected Request Timed Out” error persists and it is known through other means that all nodes are available, the originator timeout value should be increased after taking the topology into account.

A default originator timeout value of 5 s is recommended; based on the case of an originator request covering 2 hops (allowing the default 512 ms for each hop and about 4 s for the target).

4.1.6.7 Connection serial number

The connection serial number shall be a unique 16-bit value selected by the Connection Manager at the originator of the connection. The originator shall make sure that the 16-bit value is unique for the device. There shall be no other significance placed on the number by any other nodes in the connection path. The connection serial numbers shall be unique but do not have to be sequential. For example, an operator interface may have a large number of connections open at the same time, each with a unique number. The same values could be repeated at other operator interface stations. A possible implementation would be to have a connection list which points to the descriptor for each connection, and the connection serial number could be the index into the table.

4.1.6.8 Vendor ID

The vendor number shall be a unique number assigned to the various vendors of products. Each vendor has a unique number assigned.

NOTE Vendor IDs are assigned by the ODVA, Inc. organization.

4.1.6.9 Originator serial number

The originator serial number shall be a unique 32-bit value that is assigned to a device at the time of manufacture. This value shall be guaranteed to be unique for all devices manufactured by the same vendor. No significance shall be attached to the number. The combination of Vendor ID and Originator Serial Number shall be unique throughout the entire system.

4.1.6.10 Connection number

The connection number shall be a 16-bit value that is assigned by the Connection Manager when a connection is opened. This value allows other nodes to obtain connection data from the Connection Manager. This number shall not be confused with the Connection Serial Number.

4.1.6.11 Connection path size

The connection path size shall be the length of the connection path in 16-bit words. The length of the connection path varies during the connection process, since each node in the connection path removes the current port segment and forwards only the remaining path segments to the next node.

4.1.6.12 Connection path /connection remaining path

The connection path parameter shall contain one or more encoded paths as required by a combination of the service and the value of other parameters within the service data.

The connection path shall be of the form:

[[Electronic Key segment1]	}	
[Network segment11]...[Network segment1N]	}	Port Segment Group for 1st router
Port segment1]	}	
[[Electronic Key segment2]	}	
[Network segment21]...[Network segment2N]	}	Port Segment Group for 2nd router
Port segment2]	}	
...		
[[Electronic Key segmentM]		
[Network segmentM1]...[Network segmentMN]	}	
[[Application Path]	}	Port Segment Group for Mth router
[Network segmentO1] ... [Network segmentON]]	}	
Port segmentM]		
[Electronic Key segmentP]		
[Network segmentP1]...[Network segmentPN]	}	
Application Path1	}	
[Application Path2]	}	Application Segment Group for target
[Application Path3]	}	
[Simple Data segment]	}	
[Network segmentQ1] ... [Network segmentQN]		

NOTE In the last format above, for the target, the network segment(s) that follow the application path(s) and the data segment are limited to certain safety network segments as defined by IEC 61784-3-2.

All segments listed in brackets [...] are optional.

Network segments are allowed at the specified locations only if allowed by the specific network segment definition.

When a configuration data segment is included in the connection path the configuration data segment shall follow the applications path(s).

The components of a connection path are specified in 4.1.9.1 to 4.1.9.7, and the hierarchy of a connection path is specified in 4.1.9.8.

The Connection Manager object of each intermediate and target node shall process all segments preceding application path(s) that are directed to it. For the last-hop router (M^{th} router), the use of network segments that follow the application path shall be directly associated with the object identified by that application path and that object shall define its use.

Depending on the O2T_connection_parameters and T2O_connection_parameters fields and the presence of a data segment, one or more encoded application paths shall be specified. In general, the application paths are in the order of configuration path, consumption path, and production path. However, a single encoded path can be used when configuration, consumption, and/or production use the same path. See Table 34 for the valid combinations and the implied meaning of the application paths. The application paths are relative to the target node.

Any O2T or T2O application path may be a heartbeat application path, however the following application paths are defined for the Assembly object:

- “20 04 2C ED” is an O2T Listen Only Heartbeat
- “20 04 2C EE” is an O2T Input Only Heartbeat
- “20 04 2C EF” is a T2O Heartbeat

These pre-defined application paths shall be used for heartbeat connections when the target device is reached through a Type 2 router to a target device that does not support the Connection Manager object.

These pre-defined heartbeat application paths may also be used for heartbeat connections when the target device supports the Connection Manager object.

Table 34 – Encoded application path ordering

Network connection parameters		Data segment present	Number of encoded application paths		
O2T connection type	T2O connection type		1	2	3
NULL	NULL	Yes	Path is for configuration	First path is for configuration, second path is ignored	First path is for configuration, second and third paths are ignored
		No	Path is for pinging a device [a]	Invalid	Invalid
not NULL	NULL	Yes	Path is for configuration and consumption	First path is for configuration, second path is for consumption	Invalid
		No	Path is for consumption	Invalid	Invalid
NULL	not NULL	Yes	Path is for configuration and production	First path is for configuration, second path is for production	Invalid
		No	Path is for production	Invalid	Invalid
not NULL	not NULL	Yes	Path is for configuration, consumption and production	First path is for configuration, second path is for consumption and production	First path is for configuration, second path is for consumption, third path is for production
		No	Path is for consumption and production	First path is for consumption, second path is for production	First path is ignored, second path is for consumption, third path is for production

[a] If path is “20 01 24 01” used to ping a device, see 4.1.5.3.2.3 (null Forward_Open, not matching), invalid otherwise.

Encoded path compression rules are specified in 4.1.9.9.

4.1.6.13 Network connection ID

The Network Connection ID shall be link specific and shall not be related to the connection serial number, which is connection specific and the same over all the links. The fields of the Network Connection ID shall be used to set the screening mechanism for the specified link.

The Network connection ID is either a produced connection ID or a consumed connection ID.

A multicast connection ID shall not be reused until all connections associated with the connection ID have been closed or timed out.

The network connection ID is further specified in the DMPMs corresponding to the different link layers which can be associated with the Type 2 application layer (see Clause 10, Clause 11 and Clause 12).

4.1.6.14 Transport class and trigger

The transport class and trigger specify the type of transport and the production trigger required for the connection. The octet that encode the transport class and trigger shall be of the following form shown in Table 35.

Table 35 – Transport class, trigger and Is_Server format

TransportClass (4 bits)	TriggerMode (3 bits)	Is_Server (1 bit)
NULL = 0 DUPLICATE_DETECT = 1 ACKNOWLEDGED = 2 VERIFIED = 3	CYCLIC = 0 CHANGE_OF_STATE = 1 APPLICATION = 2	IS_NOT_SERVER = 0 IS_SERVER = 1

The least significant 4 bits, `class`, shall determine which transport type is specified and shall be in the range 0 to 6. The `class` values 7 through 15 shall be reserved. Bits 4 to 6, called `trigger`, shall determine what event causes the production of data on the connection and shall be in the range 0 to 2. The `trigger` values 3 through 7 shall be reserved. For transports that need to specify the target as a server, the `is_server` field shall be 1; otherwise, it shall be 0. For transport classes 0 and 1, the `is_server` field shall be ignored. Bit 7 shall be the `is_server` field;

See IEC 61158-5-2 for details on the behavior for the different combinations of `is_server`, `class`, and `trigger`, CM_RPI, and CM_API.

4.1.7 MR headers

4.1.7.1 MR request packets

All request packets delivered to the Message Router, either from a connection or from the UCMM, shall have a header of the form shown in Table 36.

Table 36 – MR_Request_Header format

Parameter	Format
Service	USINT
path_size	USINT
path	Padded EPATH

The first octet, service, shall be directly delivered to the application object and shall be in the range 1 through 127. The `path_size` shall determine the number of 16-bit words in the `path` field.

The `path` field shall contain addressing information for the packet (application path) and other information, and shall be padded.

The `path` field shall be of the form:

[Electronic Key segment]

Application Path

The Electronic Key segment is conditional. If the request is being sent across a connection the Electronic Key segment is not allowed, otherwise it is optional. If the Electronic Key segment is present the target shall evaluate the key. See 4.1.9.4.2 for the definition of Electronic Key segment and see 4.1.9.8 for the definition of the Application Path format.

EXAMPLE

34 04 42 42 0C 00 01 00 81 01	Electronic Key segment indicating the target device shall be compatible with a Vendor 0x4242, Device Type 0x000C, Product Code 0x0001, Major Revision 0x01, Minor Revision 0x01 device
20 04 24 01 30 03	Application path that specifies Instance 1 of the Assembly Object, Attribute 3.

4.1.7.2 MR response packets

Response packets from the Message Router shall have a header of the form shown in Table 37.

Table 37 – MR_Response_Header format

Parameter	Format
Service	USINT
Reserved	USINT
general_status	USINT
Extended_status_size	USINT
Extended_status[]	WORD

The `service` field shall be the value of the `MR_Request_Header.service` field with its most significant bit set (i.e. plus 0x80). If `MR_Request_Header.service` equals 0x05, the `MR_Response_Header.service` shall equal 0x85. The `general_status` field shall be filled using the `Status Code` parameter of the service response. Likewise the `extended_status`, `extended_status_size`, and `response` shall be filled using the `Extended Status` and other response parameters from the service response, respectively. If `extended_status_size` is 0, there is no `extended_status`. The `response_size` shall not be explicitly included in the `MR_Response_Header`; it shall be implied by number of octets in the `MR_Response_Header`.

4.1.8 OM_Service_PDU

4.1.8.1 General syntax

4.1.8.1.1 Get_Attributes_All

The Get_Attributes_All_RequestPDU body is empty.

The Get_Attributes_All_ResponsePDU body shall be as specified in Table 38.

Table 38 – Structure of Get_Attributes_All_ResponsePDU body

Name	Data type
Attribute Data	Object/class attribute-specific

4.1.8.1.2 Set_Attributes_All

The Set_Attributes_All_RequestPDU body shall be as specified in Table 39.

Table 39 – Structure of Set_Attributes_All_RequestPDU body

Name	Data type
Attribute Data	Object/class attribute-specific

The Set_Attributes_All_ResponsePDU body is empty.

4.1.8.1.3 Get_Attribute_List

The Get_Attribute_List_RequestPDU body shall be as specified in Table 40.

Table 40 – Structure of Get_Attribute_List_RequestPDU body

Name	Data type
Attribute Count	UINT
Attribute List	Array of UINT

The Get_Attribute_List_ResponsePDU body shall be as specified in Table 41.

Table 41 – Structure of Get_Attribute_List_ResponsePDU body

Name	Data type	Semantics of values
Attribute Count	UINT	
Attribute Response Structures	Array of STRUCT	
Attribute ID	UINT	
Attribute Status	USINT	See 4.1.11.2.1
	OCTET	Reserved (shall be set to 0)
Attribute Data	Object/class attribute- specific	Shall be omitted if the Attribute status value is not 0x00 (Success)

4.1.8.1.4 Set_Attribute_List

The Set_Attribute_List_RequestPDU body shall be as specified in Table 42.

Table 42 – Structure of Set_Attribute_List_RequestPDU body

Name	Data type
Attribute Count	UINT
Attribute Request Structures	Array of STRUCT
Attribute ID	UINT
Attribute Value	Object/class attribute- specific

The Set_Attribute_List_ResponsePDU body shall be as specified in Table 43.

Table 43 – Structure of Set_Attribute_List_ResponsePDU body

Name	Data type	Semantics of values
Attribute Count	UINT	
Attribute Response Structures	Array of STRUCT	
Attribute ID	UINT	
Attribute Status	USINT	See 4.1.11.2.1
	OCTET	Reserved (shall be set to 0)
Attribute Data	Object/class attribute- specific	If defined by the object and Attribute Status is 0x00 (Success)

4.1.8.1.5 Reset

The Reset_RequestPDU body shall be as specified in Table 44, if the **optional** "Object Specific Data" service parameter of the Reset request is specified. Else it shall be empty.

Table 44 – Structure of Reset_RequestPDU body

Name	Data type
Object Specific Data	Object/class service- specific

The Reset_ResponsePDU body shall be as specified in Table 45, if the **optional** "Object Specific Data" service parameter of the Reset response is specified. Else it shall be empty.

Table 45 – Structure of Reset_ResponsePDU body

Name	Data type
Object Specific Data	Object/class service- specific

4.1.8.1.6 Start

The Start_RequestPDU body shall be as specified in Table 46, if the **optional** "Object Specific Data" service parameter of the Start request is specified. Else it shall be empty.

Table 46 – Structure of Start_RequestPDU body

Name	Data type
Object Specific Data	Object/class service- specific

The Start_ResponsePDU body shall be as specified in Table 47, if the **optional** "Object Specific Data" service parameter of the Start response is specified. Else it shall be empty.

Table 47 – Structure of Start_ResponsePDU body

Name	Data type
Object Specific Data	Object/class service- specific

4.1.8.1.7 Stop

The Stop_RequestPDU body shall be as specified in Table 48, if the **optional** "Object Specific Data" service parameter of the Stop request is specified. Else it shall be empty.

Table 48 – Structure of Stop_RequestPDU body

Name	Data type
Object Specific Data	Object/class service- specific

The Stop_ResponsePDU body shall be as specified in Table 49, if the **optional** "Object Specific Data" service parameter of the Stop response is specified. Else it shall be empty.

Table 49 – Structure of Stop_ResponsePDU body

Name	Data type
Object Specific Data	Object/class service- specific

4.1.8.1.8 Create

The Create_RequestPDU body shall be as specified in Table 50, if the **optional** "Object Specific Data" service parameter of the Create request is specified. Else it shall be empty.

Table 50 – Structure of Create_RequestPDU body

Name	Data type
Object Specific Data	Object/class service- specific

The Create_ResponsePDU body shall be as specified in Table 51, if the **optional** "Object Specific Data" service parameter of the Create response is specified. Else it shall be empty.

Table 51 – Structure of Create_ResponsePDU body

Name	Data type
InstanceID	UINT
Object Specific Data	Object/class service- specific

4.1.8.1.9 Delete

The Delete_RequestPDU body shall be as specified in Table 52, if the **optional** "Object Specific Data" service parameter of the Delete request is specified. Else it shall be empty.

Table 52 – Structure of Delete_RequestPDU body

Name	Data type
Object Specific Data	Object/class service- specific

The Delete_ResponsePDU body shall be as specified in Table 53, if the **optional** "Object Specific Data" service parameter of the Delete response is specified. Else it shall be empty.

Table 53 – Structure of Delete_ResponsePDU body

Name	Data type
Object Specific Data	Object/class service- specific

4.1.8.1.10 Get_Attribute_Single

The Get_Attribute_Single_RequestPDU body is empty, except as noted below.

Some Type network communication profiles support link specific explicit message formats (i.e. they do not support the Message Router request format), which do not enable the Attribute ID to be specified in the Path parameter. For those formats, the Attribute ID is limited to a USINT and is transmitted as Get_Attribute_Single_ResponsePDU body.

The Get_Attribute_ Single_ResponsePDU body shall be as specified in Table 54.

Table 54 – Structure of Get_Attribute_Single_ResponsePDU body

Name	Data type
Attribute Data	Object/class attribute-specific

4.1.8.1.11 Set_Attribute single

The Set_Attribute_Single_RequestPDU body shall be as specified in Table 55.

Table 55 – Structure of Set_Attribute_Single_RequestPDU body

Name	Data type
Attribute Data	Object/class attribute-specific

Some Type network communication profiles support link specific explicit message formats (i.e. they do not support the Message Router request format), which do not enable the Attribute ID to be specified in the Path parameter. For those formats, the Attribute ID is limited to a USINT and is transmitted as the first parameter (octet) of the Set_Attribute_Single_RequestPDU body.

The Set_Attribute_Single_ResponsePDU body shall be as specified in Table 56, if the **optional** "Object Specific Data" service parameter of the Set_Attribute_Single response is specified. Else it shall be empty.

Table 56 – Structure of Set_Attribute_Single_ResponsePDU body

Name	Data type
Object Specific Data	Object/class service- specific

4.1.8.1.12 Find_Next_Object_Instance

The Find_Next_Object_Instance_RequestPDU body shall be as specified in Table 57.

Table 57 – Structure of Find_Next_Object_Instance_RequestPDU body

Name	Data type
Maximum Returned Values	USINT

The Find_Next_Object_Instance_ResponsePDU body shall be as specified in Table 58.

Table 58 – Structure of Find_Next_Object_Instance_ResponsePDU body

Name	Data type
Number Of List Members	USINT
Instance ID List	Array of UINT

4.1.8.1.13 NOP

The NOP_RequestPDU body is empty.

The NOP_ResponsePDU body is empty.

4.1.8.1.14 Apply_Attributes

The Apply_Attributes_RequestPDU body shall be as specified in Table 59, if the **optional** "Object Specific Data" service parameter of the Apply_Attributes request is specified. Else it shall be empty.

Table 59 – Structure of Apply_Attributes_RequestPDU body

Name	Data type
Object Specific Data	Object/class service- specific

The Apply_Attributes_ResponsePDU body shall be as specified in Table 60, if the **optional** "Object Specific Data" service parameter of the Apply_Attributes response is specified. Else it shall be empty.

Table 60 – Structure of Apply_Attributes_ResponsePDU body

Name	Data type
Object Specific Data	Object/class service- specific

4.1.8.1.15 Save

The Save_RequestPDU body shall be as specified in Table 61, if the **optional** "Object Specific Data" service parameter of the Save request is specified. Else it shall be empty.

Table 61 – Structure of Save_RequestPDU body

Name	Data type
Object Specific Data	Object/class service- specific

The Save_ResponsePDU body shall be as specified in Table 62, if the **optional** "Object Specific Data" service parameter of the Save response is specified. Else it shall be empty.

Table 62 – Structure of Save_ResponsePDU body

Name	Data type
Object Specific Data	Object/class service- specific

4.1.8.1.16 Restore

The Restore_RequestPDU body shall be as specified in Table 63, if the **optional** "Object Specific Data" service parameter of the Restore request is specified. Else it shall be empty.

Table 63 – Structure of Restore_RequestPDU body

Name	Data type
Object Specific Data	Object/class service- specific

The Restore_ResponsePDU body shall be as specified in Table 64, if the **optional** "Object Specific Data" service parameter of the Restore response is specified. Else it shall be empty.

Table 64 – Structure of Restore_ResponsePDU body

Name	Data type
Object Specific Data	Object/class service- specific

4.1.8.1.17 Get_Member

The Get_Member_RequestPDU body is empty.

The Get_Member_ResponsePDU body shall be as specified in Table 65.

Table 65 – Structure of Get_Member_ResponsePDU body

Name	Data type
Member ID Member Data	See 4.1.8.1.21 for details

4.1.8.1.18 Set_Member

The Set_Member_RequestPDU body shall be as specified in Table 66.

Table 66 – Structure of Set_Member_RequestPDU body

Name	Data type
Member Data	See 4.1.8.1.21 for details

The Set_Member_ResponsePDU body shall be as specified in Table 67, if the **optional** "Member Data" service parameter of the Set_Member response is specified. Else it shall be empty.

Table 67 – Structure of Set_Member_ResponsePDU body

Name	Data type
Member ID Member Data	See 4.1.8.1.21 for details

4.1.8.1.19 Insert_Member

The Insert_Member_RequestPDU body shall be as specified in Table 68, if the **optional** "Member Data" service parameter of the Insert_Member request is specified. Else it shall be empty.

Table 68 – Structure of Insert_Member_RequestPDU body

Name	Data type
Member Data	See 4.1.8.1.21 for details

The Insert_Member_ResponsePDU body shall be as specified in Table 69. If the **optional** "Member Data" service parameter of the Insert_Member response is not specified, this field shall be empty.

Table 69 – Structure of Insert_Member_ResponsePDU body

Name	Data type
Member ID Member Data	See 4.1.8.1.21 for details

4.1.8.1.20 Remove_Member

The Remove_Member_RequestPDU body is empty.

The Remove_Member_ResponsePDU body shall be as specified in Table 70.

Table 70 – Structure of Remove_Member_ResponsePDU body

Name	Data type
Member ID Member Data	See 4.1.8.1.21 for details

4.1.8.1.21 Common syntax elements for the _Member services

4.1.8.1.21.1 General

Attributes of object classes may consist of arrays of basic data types or structures. To manipulate members of an array, the following member services use the common syntax elements defined in 4.1.8.1.21:

- Get_Member;
- Set_Member;
- Insert_Member;
- Remove_Member.

The first member in an array is specified by a Member ID value of one (1).

4.1.8.1.21.2 Member ID/EX description

Two message formats are defined for member services: basic and extended. Within the extended format, there exist up to 255 protocol options. The message format is selected by the most significant bit of the Member ID.

- When a subnet does not support Attribute and Member level addressing, the Member ID/EX parameter is sent as a 16 bit (WORD) parameter within the service data.
- If the subnet does support Attribute and Member level addressing, the Member ID/EX parameter is sent within the Logical Segment and can be either 8, 16, or 32 bits (SWORD, WORD, DWORD).

Figure 6 defines the bits contained within the Member ID/EX field when sent as a WORD.

Bits							
7	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Member ID Bits 0 to 7							
EX	Member ID Bits 8 to 14						

Figure 6 – Member ID/EX description (WORD)

The lower bits (0 to 14 for a WORD) of the Member ID/EX field identify the member to be manipulated. The highest bit EX (15 for a WORD), selects either the basic (EX=0) or extended (EX=1) message format.

4.1.8.1.21.3 Member request – basic format

Table 71 specifies the common structure basic of the _RequestPDU body for Member services using the basic format.

Table 71 – Common structure of _Member_RequestPDU body (basic format)

Name	Data type	Description of parameter
Attribute ID [a]	USINT	Identifies the attribute the member is to be serviced.
Member ID/ EX [b]	WORD	The lower 15 bits identifies the Member ID of the member to be serviced. If the value is zero (0) the service used determines the behavior. Extended Protocol Option EX = 0 (bit 15)
Member Data (conditional)	Member specific	This field is required by some services, see individual service descriptions.

[a] This parameter shall be present when the target of the request is on a subnet which does not support explicit message addressing to the attribute level. If the subnet does support attribute level addressing then this parameter shall not be present. In the latter case, the data type of the Attribute ID can be either USINT, UINT, or UDINT.

[b] This parameter shall be present when the target of the request is on a subnet which does not support explicit message addressing to the member or attribute level. If the subnet does support attribute and member level addressing then this parameter shall not be present. In this latter case, the data type of the Member ID/EX can be either SWORD, WORD, or DWORD with the most significant bit being the Extended Protocol Option parameter and the remaining bits being the Member ID.

Table 72 specifies the common structure basic of the _ResponsePDU body for Member services using the basic format.

Table 72 – Common structure of _Member_ResponsePDU body (basic format)

Name	Data type	Description of parameter
Member ID (conditional)	UINT	The Member ID of the member serviced. This field is required by some services, see individual service descriptions. This field is required if the Member Data field is present.
Member Data (conditional)	Member specific	This field is required by some services, see individual service descriptions.

4.1.8.1.21.4 Member request – extended format (general)

If the Extended protocol bit [EX] of the Member ID/EX field is set to a one [1], the octet following the Member ID/EX defines the remainder of the protocol.

Ranges of values for the Extended Protocol ID are divided into three categories (open, vendor specific, reserved), as specified in 4.1.10.1.1.

Table 73 specifies the common structure basic of the _RequestPDU body for Member services using the extended format.

Table 73 – Common structure of _Member_RequestPDU body (extended format)

Name	Data type	Description of parameter
Attribute ID [a]	USINT	Identifies the attribute the member is to be serviced.
Member ID/ EX [b]	WORD	The lower 15 bits identifies the Member ID of the member to be serviced. If the value is zero (0) the service used determines the behavior. Extended Protocol Option EX = 1 (bit 15)
Extended Protocol ID	USINT	Selects the extended protocol used for the remainder of message. See Table 75.
Additional data	Protocol specific	Additional request data is defined by the extended protocol.

[a] This parameter shall be present when the target of the request is on a subnet which does not support explicit message addressing to the attribute level. If the subnet does support attribute level addressing then this parameter shall not be present. In the latter case, the data type of the Attribute ID can be either USINT, UINT, or UDINT.

[b] This parameter shall be present when the target of the request is on a subnet which does not support explicit message addressing to the member or attribute level. If the subnet does support attribute and member level addressing then this parameter shall not be present. In this latter case, the data type of the Member ID/EX can be either SWORD, WORD, or DWORD with the most significant bit being the Extended Protocol Option parameter and the remaining bits being the Member ID.

Table 74 specifies the common structure basic of the _ResponsePDU body for Member services using the extended format.

Table 74 – Common structure of _Member_ResponsePDU body (extended format)

Name	Data type	Description of parameter
Response data	Protocol specific	Response data is defined by the extended protocol option.

Table 75 lists the values currently defined for the Extended Protocol ID.

Table 75 – Extended Protocol ID

Value	Description
0x00	Open
0x01	Multiple Sequential Members
0x02	International String Selection
0x03 to 0x63	Open
0x64 to 0xC7	Vendor specific
0xC8 to 0xFF	Reserved
NOTE Reserved ranges can be further defined by the ODVA, Inc. organization.	

4.1.8.1.21.5 Member request – extended format (Multiple Sequential Members)

When the Extended Protocol ID is set to Multiple Sequential Members [1], the structure of the _RequestPDU body is specified in Table 76.

Table 76 – Structure of _Member_RequestPDU body (Multiple Sequential Members)

Name	Data type	Description of parameter
Attribute ID [a]	USINT	Identifies the attribute the member is to be serviced.
Member ID/ EX [b]	WORD	The lower 15 bits identifies the Member ID of the member to be serviced. If the value is zero (0) the service used determines the behavior. Extended Protocol Option EX = 1 (bit 15)
Extended Protocol ID	USINT	Selects the Multiple Sequential Members protocol option (value =1).
Number of Members	UINT	Number of members to be serviced.
Member Data (conditional)	Member specific	Multiple sequential Member Data. This field is required by some services, see individual service descriptions.

[a] This parameter shall be present when the target of the request is on a subnet which does not support explicit message addressing to the attribute level. If the subnet does support attribute level addressing then this parameter shall not be present. In the latter case, the data type of the Attribute ID can be either USINT, UINT, or UDINT.

[b] This parameter shall be present when the target of the request is on a subnet which does not support explicit message addressing to the member or attribute level. If the subnet does support attribute and member level addressing then this parameter shall not be present. In this latter case, the data type of the Member ID/EX can be either SWORD, WORD, or DWORD with the most significant bit being the Extended Protocol Option parameter and the remaining bits being the Member ID.

The structure of the _ResponsePDU body is specified in Table 77.

Table 77 – Structure of _Member_ResponsePDU body (Multiple Sequential Members)

Name	Data type	Description of parameter
Number of Members	UINT	Number of members serviced. This field is required
Member ID (conditional)	UINT	Member ID of the first member serviced. This field is required by some services, see individual service descriptions. This field is required if the Member Data field is present.
Member Data (conditional)	Member specific	Multiple sequential Member Data. This field is required by some services, see individual service descriptions.

4.1.8.1.21.6 Member request – extended format (International String Selection)

This service returns a single international character string from an attribute, which has a data type of STRINGI. This service can request a specific language or default to the current active language as specified by the Identity object.

The International String Selection protocol is only valid with the Get_Member service.

The structure of the _RequestPDU body is specified in Table 78.

Table 78 – Structure of _Member_RequestPDU body (International String Selection)

Name	Data type	Description of parameter
Attribute ID	USINT	Identifies the attribute containing the international string.
Member ID/ EX	WORD	The lower 15 bits identifies the language to retrieve. This value is the member ID (array index, starting at one) of the language within the Supported Language List attribute (Attribute ID 12) of the Identity object. Extended Protocol Option EX = 1 (bit 15).
Extended Protocol ID	USINT	Selects the International String Selection protocol option (value = 2).

The structure of the _ResponsePDU body is specified in Table 79.

Table 79 – Structure of _Member_ResponsePDU body (International String Selection)

Name	Data type	Description of parameter
International String	STRUCT of	The character string in the requested language. This parameter follows the definition of a single international character string within the STRINGI data type (see 4.2).
	USINT	The language1 field from the STRINGI data type.
	USINT	The language2 field from the STRINGI data type.
	USINT	The language3 field from the STRINGI data type.
	USINT	The structure of the character string, limited to the values 0xD0, 0xD5, 0xD9 and 0xDA.
	UINT	Character set of the international string.
	OCTET_STRING	International string

4.1.8.1.22 Group_Sync

The Group_Sync_RequestPDU body shall be as specified in Table 80.

Table 80 – Structure of Group_Sync_RequestPDU body

Name	Data type
Object Specific Data	Object/class service- specific

The Group_Sync_ResponsePDU body shall be as specified in Table 81.

Table 81 – Structure of Group_Sync_ResponsePDU body

Name	Data type	Semantics of values
IsSynchronized	BOOL	Indicates if object is synchronized to the PTP Time Master 0 = Not synchronized 1 = Is synchronized
Object Specific Data	Object/class service- specific	Object/class service- specific

4.1.8.1.23 Multiple_Service_Packet

The Multiple_Service_Packet_RequestPDU body shall be as specified in Table 82.

Table 82 – Structure of Multiple_Service_Packet_RequestPDU body

Name	Data type	Semantics of values
Number of Services	UINT	Number of embedded services in the Service List.
Service Offsets	ARRAY of UINT	Array of octet offsets to the start of each embedded service in the Service List. Each octet offset is relative to the Number of Services parameter. Therefore the first element in this array shall be (2 + Number of Services x 2).
Service List	Array of STRUCT	Array of service request structures. The format of the service request follows the Message Router Request header.
	USINT	Service code of the request.
	USINT	The number of 16 bit words in the Request_Path field (next element).
	Padded EPATH	This is an array of octets whose contents convey the path of the request (Class ID, Instance ID, etc.) for this transaction.
	ARRAY of octet	Service specific data to be delivered in the Explicit Messaging Request. If no additional data is to be sent with the Explicit Messaging Request, then this array will be empty.

The Multiple_Service_Packet_ResponsePDU body shall be as specified in Table 83.

Table 83 – Structure of Multiple_Service_Packet_ResponsePDU body

Name	Data type	Semantics of values
Number of Responses	UINT	Number of embedded service responses in the Response List.
Response Offsets	ARRAY of UINT	Array of octet offsets to the start of each embedded service response in the Response List. Each octet offset is relative to the Number of Responses parameter. Therefore the first element in this array shall be (2 + Number of Responses x 2).
Response List	Array of STRUCT	Array of service response structures. The format of the service response follows the Message Router Response header.
	USINT	Response service code.
	USINT	Shall be zero.
	USINT	One of the General Status codes.
	USINT	Number of 16 bit words in Extended Status array.
	ARRAY of UINT	Extended status.
	ARRAY of octet	Response data from request or additional error data if General Status indicated an error.

4.1.8.1.24 Get_Connection_Point_Member_List

The Get_Connection_Point_Member_List_RequestPDU body is empty.

The Get_Connection_Point_Member_List_ResponsePDU body shall be as specified in Table 84.

Table 84 – Structure of Get_Connection_Point_Member_List_ResponsePDU body

Name	Data type	Semantics of values
Item Count	UINT	Number of STRUCTs returned
Members	Array of STRUCT	A list of EPATHs of each member of the Connection Point structure, or the EPATH to the full Parameter Object Instance that refers to the member
Member Data Size	UINT	Size of member data (in bits)
Member Path Size	UINT	Size of member path (in octets)
Member Path	Packed EPATH	EPATH of the member or EPATH of the full Parameter object instance that refers to the member

4.1.8.2 Identity object specific syntax elements

4.1.8.2.1 Attributes

4.1.8.2.1.1 Class attributes

The format of the Identity object class attributes shall be as specified in Table 85.

Table 85 – Identity object class attributes

Attribute ID	Name	Data type	Semantics of values
1	Revision	UINT	Revision of this object. Value = 1 or 2 The value shall be 2 if attributes greater than #10 are included in the Get_Attributes_All response (recommended when applicable) or attribute #30 is supported.
2	Max Instance	UINT	
3 – 7, 200, 201	These optional Class Attributes are specified in 4.1.10.2.2.		

4.1.8.2.1.2 Instance attributes

The format of the Identity object instance attributes is as specified in Table 86.

Table 86 – Identity object instance attributes

Attribute ID	Name	Data type	Semantics of values
1	Vendor ID	UINT	The value zero shall not be used. A list of the Vendor ID ranges can be found in Table 87.
2	Device Type	UINT	A list of the Device Type ranges can be found in 4.1.10.3.
3	Product Code	UINT	The value zero is not valid.
4	Revision	STRUCT of	Revision of the hardware the Identity object represents. The value zero is not valid for either the Major or Minor Revision fields of a compliant product. If the Device Type of the instance is Embedded Component, the Major Revision and/or Minor Revision may be zero.
	Major Revision	USINT	The Major Revision attribute shall be limited to values between 1 and 127 (7 bits). The eighth bit is reserved and shall be zero.
	Minor Revision	USINT	1 to 255
5	Status	WORD	Bit definitions are described in Table 88.
6	Serial Number	UDINT	The value zero is not a valid serial number and shall not be assigned to a product nor reported by a compliant device. Reception of the value zero when accessing this attribute indicates the target is not a Type 2 device and does not contain a serial number.
7	Product Name	SHORT_STRING	The maximum number of 8-bit characters in this string shall be 32.
8	State	USINT	Present state of the device as represented by the state transition diagram: 0 = Nonexistent 1 = Device Self Testing 2 = Standby 3 = Operational 4 = Major Recoverable Fault 5 = Major Unrecoverable Fault 6 to 254 = Reserved 255 = Default value The default value shall be used in the Get_Attributes_All response if the attribute is not implemented.
9	Configuration Consistency Value	UINT	Contents identify configuration of device

Attribute ID	Name	Data type	Semantics of values
10	Heartbeat Interval	USINT	The nominal interval between heartbeat messages in seconds. The default value is 0. Zero disables transmission of the heartbeat message.
11	Active Language	STRUCT of	Currently active language for the device (based on ISO 639-2/T).
	Language1	USINT	The language1 field from the STRINGI data type.
	Language2	USINT	The language2 field from the STRINGI data type.
	Language3	USINT	The language3 field from the STRINGI data type.
12	Supported Language List	ARRAY of STRUCT of	List of languages supported by character strings of data type STRINGI within the device. The array index of the language is used within the International String Selection member protocol.
	Language1	USINT	The language1 field from the STRINGI data type.
	Language2	USINT	The language2 field from the STRINGI data type.
	Language3	USINT	The language3 field from the STRINGI data type.
13	International Product Name	STRINGI	Names of the product in various languages
14	Semaphore	STRUCT of	Access Synchronization Semaphore
	Vendor Number	UINT	Client electronic key
	Client Serial Number	UDINT	Default: All zero values
	Semaphore Timer	ITIME	Timer valid range 100 ms thru 32 767 ms
15	Assigned_Name	STRINGI	User assigned name
16	Assigned_Description	STRINGI	User assigned description
17	Geographic_Location	STRINGI	User assigned location
18	Type15 Identity Info		Reserved for Type 15 devices.
19	Protection Mode	WORD	Bit definitions are described in Table 90.
20	Uptime	UDINT	Number of seconds
21	Catalog Number	SHORT STRING	Textual catalog or model number
22	Manufacture Date	DATE	Date the product was manufactured
23	Type 9 Identity Info		Reserved for Type 9 devices
24	Type 9 Status		
25	Implementation Profiles	STRUCT of	Implementation profiles supported
		UINT	Number of implementation profiles supported
		ARRAY of STRUCT of	
		UINT	Profile number
		DWORD	Features supported (see Table 91)
26	IEC 61131-9 Identity Info 1		Reserved for IEC 61131-9 devices
27	IEC 61131-9 Identity Info 2		
28	IEC 61131-9 Identity Info 3		
29	IEC 61131-9 Identity Info 4		

Attribute ID	Name	Data type	Semantics of values
30	Supported Language List 2	STRUCT of	List of languages supported by character strings of data type STRINGI within the device. The array index of the language is used within the International String Selection member protocol.
		UINT	Number of languages in the list
		ARRAY of STRUCT of	List of languages
	Language1	USINT	The language1 field from the STRINGI data type.
	Language2	USINT	The language2 field from the STRINGI data type.
	Language3	USINT	The language3 field from the STRINGI data type.
31	Vendor Name	STRING	Name of the company that manufactured the device
32	Vendor URI	STRING	The maximum length is 246 characters. If this attribute is not supported, a client or gateway shall report a value of "www.odva.org/vendor_id_NNNNN", where NNNNN is the value of the Vendor ID attribute in decimal with leading zeroes. EXAMPLE The Vendor URI for a device from Vendor ID 24 would be "www.odva.org/vendor_id_00024".
33	Configuration Counter	DINT	The Configuration Counter shall use an incrementing count mechanism and wrap around from 0xFFFFFFFF to 0x00000000.
34	Configuration Date	STIME	Date and time of last change to Configuration.
35	Manufacture Serial Number	SHORT_STRING	Alphanumeric character sequence used to identify the asset.
36	Device Manual	STRUCT of	Points to a manual for the device
	Device Manual Data Type	USINT	Enumeration indicating the data type for the next field: 0xDC = Padded EPATH 0xD0 = STRING
	Pointer to Device Manual		Data type is defined in Device Manual Data Type member
37	Hardware Revision	STRUCT of	If the firmware cannot determine the hardware revision value, it shall return zero for both the Major and Minor Revision, else 0 is not a valid value for either the Major or Minor Revision.
	Major Revision	USINT	
	Minor Revision	USINT	
38	Reserved		
39	Product Identity Certificate	STRUCT of USINT USINT USINT Padded EPATH	Reserved for security related information

Table 87 – Identity object Vendor ID ranges

Range	Usage
0	Reserved – shall not be used
0x0001 to 0xFEFF	Assigned by the ODVA, Inc. organization
0xFF00 to 0xFFFB	Reserved for future use
0xFFFC	Unspecified IEC 61131-9 vendor
0xFFFD	Unspecified Type 9 vendor
0xFFFE	Unspecified Type 15 vendor
0xFFFF	Reserved – shall not be used

Table 88 – Identity object bit definitions for status instance attribute

Bit(s)	Called	Definition
0	Owned	1 for TRUE, 0 for FALSE
1		Reserved, set to 0
2	Configured	1 for TRUE, 0 for FALSE
3		Reserved, set to 0
4 to 7	Extended Device Status	Vendor specific, or as specified in Table 89
8	Minor Recoverable Fault	1 for TRUE, 0 for FALSE
9	Minor Unrecoverable Fault	1 for TRUE, 0 for FALSE
10	Major Recoverable Fault	1 for TRUE, 0 for FALSE
11	Major Unrecoverable Fault	1 for TRUE, 0 for FALSE
12 to 15	Extended Device Status 2	Reserved (shall be set to 0) or vendor specific

The values of the status bits 4 to 7 shall be as shown in Table 89.

Table 89 – Default values for extended device status field (bits 4 to 7) of status instance attribute

Value	Meaning
0	Self–Testing or State Unknown
1	Firmware Update in progress
2	At least one faulted I/O connection)
3	No I/O connection established
4	Non–Volatile Configuration Bad
5	Major Fault (either bit 10 or bit 11 in Table 88 is TRUE (1))
6	At least one I/O connection in run mode
7	At least one I/O connection established, all in idle mode
8	The Status attribute is not applicable to this instance. Valid only for instances greater than one (1).
9	reserved, shall not be used
10 to 15	reserved for vendor specific states

Table 90 – Identity object bit definitions for protection mode instance attribute

Bit(s)	Called	Definition
0 to 2	Implicit Protection Setting	Indicates the current implicit protection setting of the device. Bit 0 = Implicit Protection (clear if Not Protected; set if Protected) Bits 1 to 2 = reserved for future use
3	Explicit Protection Setting	Indicates the current explicit setting of the device Explicit Protection (clear if Not Protected; set if Protected)
4 to 15	Reserved	Reserved (shall be set to 0)

Table 91 – Identity object bit definitions for features supported attribute

Bit(s)	Definition
0 to 30	Characteristics, or sets of characteristics that are included in the implementation profile. The exact definition of this field is specific to each implementation profile
31	Reserved
NOTE The list of public implementation profiles is managed by the ODVA, Inc. organization. Definition of the implementation profiles and their feature values is outside the scope of this document.	

4.1.8.2.2 Common services

4.1.8.2.2.1 Get_Attributes_All Response

At the **class level**, the order of the attributes returned in the "Attribute Data" parameter of the Get_Attributes_All response shall be as defined in Table 92.

Table 92 – Class level object/service specific response data of Get_Attributes_All

Attribute ID	Data type	Attribute name	Default value (if not implemented)
1	UINT	Revision	1
2	UINT	Max Instance	1
6	UINT	Max ID Number Class Attributes	0
7	UINT	Max ID Number Instance Attributes	0

Default values shall be inserted for all unsupported attributes.

At the **instance level**, the order of the attributes returned in the "Attribute Data" parameter of the Get_Attributes_All response shall be as defined in Table 93.

Table 93 – Instance level object/service specific response data of Get_Attributes_All

Attribute ID	Data type	Attribute name	Default value (if not implemented)
1	UINT	Vendor ID	
2	UINT	Device Type	
3	UINT	Product Code	
4	STRUCT of:	Revision	
	USINT	Major Revision	
	USINT	Minor Revision	
5	WORD	Status	
6	UDINT	Serial Number	
7	SHORT STRING	Product Name	
8	USINT	State	255
9	UINT	Configuration Consistency Value	0
10	USINT	Heartbeat Interval	0
n/a	STRUCT of:	Revision 2 indication	
	USINT		0xFF
	USINT		0xFF
	USINT		0xFF
14	STRUCT of:	Semaphore	
	UINT	Client Electronic Key	0
	UDINT		0
	ITIME	Semaphore Timer	0
19	WORD	Protection Mode	0
20	UDINT	Uptime	0
21	SHORT_STRING	Catalog Number	Zero-length string
22	DATE	Manufacture Date	0
33	DINT	Configuration Counter	0
34	STIME	Configuration Date	0
37	STRUCT of:	Hardware Revision	
	USINT	Major Revision	0
	USINT	Minor Revision	0

Default values shall be inserted for all unsupported attributes.

If the Get_Attributes_All service returns data after the Heartbeat Interval and the Identity object Revision is 1, the data after the Heartbeat Interval (octet n+4) shall be ignored (since previous editions of the standard contained unparsable content past that point). Attributes 14 and 19 to 22 shall be returned if implemented and Identity object Revision is greater than 1.

Revision 2 Indication shall be used as a marker for Identity Object Revision 2 support. All fields of this structure shall be set to 0xFF. The marker is used to differentiate between devices supporting Revision 2, and Revision 1 devices that could return attribute 11 in the Get_Attributes_All response.

4.1.8.2.2.2 Reset service

The Reset common service shall have the object–specific request parameter specified in Table 94.

Table 94 – Object-specific request parameter for Reset

Name	Data type	Semantics of values
Reset Type	USINT	Type of Reset. See Table 95. This parameter is optional. If this parameter is omitted, the default value of Power cycle (0) is used.

Table 95 – Reset service parameter values

Value	Need in implementation	Name	Type of Reset
0	Required	Power cycle	Emulate as closely as possible cycling power on the item the Identity object represents. This value shall be the default if this parameter is omitted.
1	Optional	Return to factory defaults	Return as closely as possible to the factory default configuration, then emulate cycling power as closely as possible.
2	Optional	Return to factory defaults except communications parameters	Return as closely as possible to the out-of-box configuration with the exception of communication link parameters and emulate cycling power as closely as possible. The communication link parameters that are to be preserved are defined by each network type. See the Reset service of the network specific link object(s) or Table 96 for complete information.
3 to 99			Reserved.
100 to 199			Vendor specific
200 to 255			Reserved

Table 96 indicates the communication link attributes that shall be preserved when the device receives a Reset service with the Reset Type parameter value of 2.

Table 96 – Communication link attributes that shall be preserved

Class	Instance number	Attribute	Attribute ID
TCP/IP Interface Object (0xF5)	All except 0	Configuration Control	3
		Interface Configuration	5
		Host Name	6
Ethernet Link Object (0xF6)	All except 0	Interface Control	6

The Reset common service has no object-specific response parameters.

4.1.8.2.3 Object specific services

Flash_LEDs

The Flash_LEDs_RequestPDU body shall be as specified in Table 97.

Table 97 – Structure of Flash_LEDs_RequestPDU body

Name	Data type	Semantics of values
Time	USINT	The amount of time, in seconds, from when the service was received, that the device flashes its LEDs. If the device is currently flashing, this Time value replaces the time remaining. When the time expires, the device may either complete the current sequence or stop immediately. Values 1-8 are not valid values. The minimum value of 9 allows for a minimum of 6 flashing sequences of the LEDs. Value 0 stops the flashing.

The Flash_LEDs_ResponsePDU body is empty.

4.1.8.3 Message Router object specific syntax elements

4.1.8.3.1 Attributes

4.1.8.3.1.1 Class attributes

The Message Router object class attributes shall be as specified in Table 98.

Table 98 – Message Router object class attributes

Attribute ID	Name	Data type	Semantics of values
1	Revision	UINT	Revision of this object. Value = 1
2 – 7, 200, 201	These optional Class Attributes are specified in 4.1.10.2.2.		

4.1.8.3.1.2 Instance attributes

The format of the Message Router object instance attributes is as specified in Table 99.

Table 99 – Message Router object instance attributes

Attribute ID	Name	Data type
1	Object_List	STRUCT of
	Number	UINT
	Classes	ARRAY of UINT
2	Number available	UINT
3	Number active	UINT
4	Active connections	ARRAY of UINT

4.1.8.3.2 Common services

Get_Attributes_All Response

At the **class level**, the order of the attributes returned in the "Attribute Data" parameter of the Get_Attributes_All response shall be as specified in Table 100.

Table 100 – Class level object/service specific response data of Get_Attributes_All

Attribute ID	Data type	Attribute Name	Default Value (if not implemented)
1	UINT	Revision	1
4	STRUCT of	Optional attribute list	
	UINT	Number of attributes	0
	ARRAY of UINT	Optional attributes	(null)
5	STRUCT of	Optional service list	
	UINT	Number services	0
	ARRAY of UINT	Optional services	(null)
6	UINT	Maximum ID Number Class Attributes	0
7	UINT	Maximum ID Number Instance Attributes	0

At the **instance level**, the order of the attributes returned in the "Attribute Data" parameter of the Get_Attributes_All response shall be as specified in Table 101.

Table 101 – Instance level object/service specific response data of Get_Attributes_All

Attribute ID	Data type	Name	Default Value (if not implemented)
1	STRUCT of	Object_List	
	UINT	Number	0
	ARRAY of UINT	Classes	(null)
2	UINT	Number available	0
3	UINT	Number active	0
4	ARRAY of UINT	Active connections	(null)

4.1.8.3.3 Object specific services

4.1.8.3.3.1 Symbolic_Translation

The Symbolic_Translation_RequestPDU body shall be as specified in Table 102.

Table 102 – Structure of Symbolic_Translation_RequestPDU body

Name	Data type
Symbolic Address	Padded EPATH

The Symbolic_Translation_ResponsePDU body shall be as specified in Table 103.

Table 103 – Structure of Symbolic_Translation_ResponsePDU body

Name	Data type
Logical Address	Padded EPATH

The service response may return a status from the list of status codes in Table 104.

Table 104 – Object specific status for Symbolic_Translation service

General Status Code	Extended Status Code	Error Name	Status description
0x20	0x00	Symbolic Path unknown	The Symbolic path is not recognized by the processing node
0x20	0x01	Symbolic Path destination not assigned	The Symbolic path, although recognized, is not presently associated with a Logical path equivalent.
0x20	0x02	Symbolic Path segment error	The symbol identifier or the symbol segment syntax was not understood by the processing node.

4.1.8.3.3.2 Send_Receive_Fragment

The Send_Receive_Fragment_RequestPDU body for phase 1 shall be as specified in Table 105.

Table 105 – Structure of Send_Receive_Fragment_RequestPDU body – Phase 1

Name		Data type	Semantics of values
Fragmentation Request Header	Fragmentation Version	USINT	Currently only version 1 is defined.
	Request Fragmentation Flags	SWORD	See Table 108 and Table 109.
	Reserved	UINT	Shall be set to 0.
	Request Info	UDINT	
Embedded Service Request Fragment		Array of octet	The format of the reassembled Embedded Service Request Fragment parameters is identical to the Message Router request format.

When a request with the Last flag set is received and the reassembled embedded service request is determined to be valid, the request is sent to the target object, and the session transitions to phase 2.

The Send_Receive_Fragment_RequestPDU body for phase 2 shall be as specified in Table 106.

Table 106 – Structure of Send_Receive_Fragment_RequestPDU body – Phase 2

Name		Data type	Semantics of values
Fragmentation Request Header	Fragmentation Version	USINT	Currently only version 1 is defined.
	Request Fragmentation Flags	SWORD	See Table 108 and Table 109. For requests to get the next fragment response, this parameter shall always specify Middle fragment.
	Reserved	UINT	Shall be set to 0.
	Request Info	UDINT	For requests to get the next fragment response, this parameter shall be 0.

The Send_Receive_Fragment_ResponsePDU body for phase 1 is empty.

The Send_Receive_Fragment_ResponsePDU body for phase 2 shall be as specified in Table 107.

Table 107 – Structure of Send_Receive_Fragment_ResponsePDU body – Phase 2

Name		Data type	Semantics of values
Fragmentation Request Header	Fragmentation Version	USINT	Currently only version 1 is defined.
	Response Fragmentation Flags	SWORD	See Table 108 and Table 109.
	Reserved	UINT	Shall be set to 0.
	Response Info	UDINT	
Embedded Service Response Fragment		Array of octet	The format of the combined Embedded Service Response Fragment parameters is identical to the Message Router Response Format.

If the Message Router in the target detects an error during a fragmentation session, the Send_Receive_Fragment_ResponsePDU body is empty (no Fragmentation Response Header and Embedded Service Response Fragment).

If the target object servicing the embedded request detects an error, the response message returns General Status Code 0x1E (Embedded Service Error). This error response contains response data consisting of the Fragmentation Response Header and Embedded Service Response Fragment. The Embedded Service Response Fragment uses the Message Router response format which includes the General Status Code and Extended Status Code, along with potential response data from the target object.

The Request/Response Fragmentation Flags fields contain flags that control the fragmentation of the request or response as shown in Table 108. The usage of the combined Request/Response Fragmentation Flag values are defined in Table 109.

Table 108 – Request/Response Fragmentation Flags

Bit(s)	Name	Description
0	First	Set in the first fragment of a fragmented request or response message.
1	Last	Set in the last fragment of a fragmented request or response message.
2	Abort	Only valid in request messages, reserved in response messages. Terminate an ongoing fragmentation session. When set, First and Last Flags are ignored.
3-7	Reserved	

Table 109 – Fragmentation Flags Usage

Last	First	Description
0	0	Middle fragment of a fragmented request or response message.
0	1	First fragment of a fragmented request or response message.
1	0	Last fragment of a fragmented request or response message.
1	1	Single fragment in a fragmented message, i.e. the embedded service request or response fits in one fragment.

The service response may return a status from the list of status codes in Table 110.

Table 110 – Object specific status for Send_Receive_Fragment service

<table>
<tr><th>General Status Code</th><th>Extended Status Code</th><th>Error Name</th><th>Status description</th></tr>
<tr><td>0x02</td><td>0x0001</td><td>Request Info Too Large</td><td>The Request Info (total request size) that the client requested is larger than the target can handle.</td></tr>
<tr><td>0x02</td><td>0x0002</td><td>Out Of Fragmentation Sessions</td><td>The target is out of available fragmentation sessions.</td></tr>
<tr><td>0x02</td><td>0x0003</td><td>Assembled Response Too Large</td><td>The total assembled response is too large for the target to handle.
For this error, the extended status size is formatted as follows.
<table>
<tr><th>Data type</th><th>Value</th><th>Explanation</th></tr>
<tr><td>UINT</td><td>0x0003</td><td>Extended status code</td></tr>
<tr><td>UDINT</td><td>Actual Response Size</td><td>Size of assembled response</td></tr>
<tr><td>UDINT</td><td>Max Size</td><td>Maximum assembled response the target can handle</td></tr>
</table></td></tr>
<tr><td>0x17</td><td>0x0001</td><td>No Active Fragmentation Session</td><td>A Middle or Last fragment was received before first having started a fragmentation session.</td></tr>
<tr><td>0x17</td><td>0x0002</td><td>Middle Fragment Received When Expecting a Last Fragment</td><td>A Middle fragment was received when expecting a Last fragment.</td></tr>
<tr><td>0x17</td><td>0x0003</td><td>Last Fragment Specified in Request When Expecting a Middle Fragment – Phase 1</td><td>A fragment with the Last bit set was received when expecting a Middle fragment during phase 1.</td></tr>
<tr><td>0x17</td><td>0x0004</td><td>Last Fragment Specified in Request When Expecting Middle Fragment – Phase 2</td><td>A fragment with the Last bit set was received when returning a fragmented response during phase 2.</td></tr>
<tr><td>0x17</td><td>0x0005</td><td>Request Info is Out of Sequence</td><td>The received offset (Request Info) doesn’t align with the expected offset (i.e. the received Request Info isn’t equal to the previously received Request Info plus the size of the previously Embedded Service Request).</td></tr>
<tr><td>0x17</td><td>0x0006</td><td>Fragment Received With Invalid Request Info</td><td>A fragment with an invalid Request Info parameter set was received. This can be due to either receiving a value of zero when expecting non-zero, or receiving a non-zero value when expecting zero.</td></tr>
<tr><td>0x17</td><td>0x0007</td><td>Invalid Size – Too Much Data</td><td>The received offset (Request Info) plus Embedded Service Request Fragment size is greater than the total request size.</td></tr>
<tr><td>0x17</td><td>0x0008</td><td>Invalid Size – Non-Fragmented Size Mismatch</td><td>The received total size in a non-fragmented request (First and Last bits set) does not match the Embedded Service Request Fragment size.</td></tr>
<tr><td>0x1E</td><td>N/A</td><td>Embedded Service Error</td><td>An embedded service resulted in an error</td></tr>
<tr><td>0x20</td><td>0x0001</td><td>Unsupported Version</td><td>The Fragmentation Version parameter contains an unsupported version.</td></tr>
</table>

4.1.8.4 Assembly object specific syntax elements

4.1.8.4.1 Attributes

4.1.8.4.1.1 Class attributes

The format of the Assembly object class attributes shall be as specified in Table 111.

Table 111 – Assembly object class attributes

Attribute ID	Name	Data type	Semantics of values
1	Revision	UINT	Revision of this object. Value = 3
2 – 7, 200, 201	These optional Class Attributes are specified in 4.1.10.2.2.		

4.1.8.4.1.2 Instance attributes

The format of the Assembly object instance attributes is as specified in Table 112.

Table 112 – Assembly object instance attributes

Attribute ID	Name	Data type	Semantics of values
1	Number of Members in List	UINT	Number of members in attribute 2
2	Member List	ARRAY of STRUCT	This attribute has a complex data type (array of paths)
	Member Data Size	UINT	Size of member data or pad in bits
	Member Path Size	UINT	Size in octets (0 = Empty Path)
	Member Path	Packed EPATH	Packed path to the member data. See 4.1.9 for definition of Path
3	Data	ARRAY of octet	Contain all of the member data packed into one array. This data may contain many different data types. For efficiency it is best to keep this data word aligned by packing it on word boundaries and adding padding as needed. This can be accomplished by using "empty paths" (Member Path Size = 0)
4	Size	UINT	
5	Member List Signature	UDINT	Used to indicate that the Member List (Attribute 2) has changed. Counter value that increments by one with each change to the Member List attribute and wraps around from 0xFFFFFFFF to 0x00000000. This value shall be retained through power cycles.

The following rules apply to the Member List attribute.

Members may represent either data elements or pad bits. The members shall be placed into the data block least significant bit first in the order they are listed. The sum of the Member Size value for all members shall be an integer number of octets.

When a member represents a data element, the Member Path field specifies the logical segments that point to the data element. If the Member Size field value is smaller than the defined size of the specified data element, the least significant bits of the corresponding element shall be included. If a Member Size field value is larger than the defined size of the specified data element, the entire data element shall be followed by N pad bits where N is equal to the Member Size minus the size of the data element. Producers shall set pad bits in the Data attribute to 0, consumers shall ignore pad bits.

When a member represents pad bits, the Member Path Size field shall be 0, the Member Path field shall be empty and the number of bits specified by the Member Size field shall specify the number of pad bits to include in the Data attribute. Producers shall set pad bits in the Data attribute to 0, consumers shall ignore pad bits.

4.1.8.4.1.3 Assembly Instance ID ranges

The Assembly Instance ID values shall be as shown in Table 113. Assembly Instance ID = 0x00 is reserved and shall not be used.

Table 113 – Assembly Instance ID ranges

Range (hex)	Range (decimal)	Meaning	Quantity
0x01 to 0x63	1 to 99	Open[a]	99
0x64 to 0xC7	100 to 199	Vendor Specific[b]	100
0xC8 to 0xD1	200 to 209	Open[a]	10
0xD2	210	Standard Network Diagnostic assembly[d]	1
0xD3 to 0xD7	211 to 215	Predefined diagnostic assemblies[d]	5
0xD8 to 0xEC	216 to 236	Reserved[c]	21
0xED[e]	237	Open – O2T Heartbeat for Listen Only	1
0xEE[e]	238	Open – O2T Heartbeat for Input Only	1
0xEF[e]	239	Open – T2O Heartbeat	1
0xF0 to 0xFF	240 to 255	Vendor Specific[b]	16
0x0100 to 0x02FF	256 to 767	Open[a]	512
0x0300 to 0x4FF	768 to 1 279	Vendor Specific[b]	512
0x0500 to 0x7FFF	1 280 to 32 767	Open[a]	31 488
0x8000 to 0xFFFF	32 768 to 65 535	Vendor Specific[b]	32 768
0x00010000 to 0x000FFFFF	65 536 to 1 048 575	Open[a]	983 040
0x00100000 to 0xFFFFFFFF	1 048 576 to 4 294 967 295	Reserved[c]	4 293 918 720

[a] Static assemblies defined in device profiles.

[b] Static assemblies and dynamic assemblies

[c] Reserved ranges may be further defined by the ODVA, Inc. organization

[d] Variable assemblies

[e] See 4.1.6.12 for usage definition.

4.1.8.4.1.4 Standard Network Diagnostic assembly – Instance 0xD2 (210)

The object class structures permitted in the Standard Network Diagnostic assembly are specified in Table 114.

Table 114 – Standard Network Diagnostic assembly content and ordering

Diagnostic structure members	Placement in the assembly	Number of instances required
Member List Signature	1	1, indicates whether Member List has changed
Pad	2	32 bits, shall be zeros
Connection Manager Connection Point	3	1 instance
Ethernet Link Connection Point	4	1 instance per Type 2 Ethernet capable port on the device.
TCP/IP Interface Connection Point	5	1 instance per Type 2 Ethernet port that has individually configured IP address settings.
Device Level Ring Connection Point	6	1 instance per pair of ports configured for DLR, omitted if no ports are configured for DLR operation.
PRP/HSR Protocol Connection Point	7	1 instance per pair of ports configured for PRP, omitted if no ports are configured for PRP.
Time Sync Connection Point	8	1 instance if the device is configured to support Type 2 Time Synchronization, omitted if the device is not configured to support Type 2 Time Synchronization.
RSTP Bridge Connection Point	9	1 instance per RSTP Bridge, omitted if no RSTP Bridges are configured.
RSTP Port Connection Point	10	1 instance per RSTP Port, omitted if no RSTP Ports are configured.

When a device has multiple instances of the same Connection Point, they shall be in instance number order.

NOTE Other content can be added over time to expand this structure.

Position 1 is padded to provide 64-bit alignment. All Connection Point structures are defined to be 64-bit aligned, which ensures that regardless of the quantity of each present (0 to n), the entire assembly structure will maintain 64-bit alignment.

4.1.8.4.2 Common services

Create service

The Create common service shall have the object-specific request parameter specified in Table 115.

Table 115 – Object-specific request parameter for Create

Name	Data type	Semantics of values
Member List Signature Flag	BOOL	Indicates if the newly created instance will support the Member List Signature attribute: 0 = Omit Member List Signature, default 1 = Include Member List Signature, recommended This parameter is optional. If this parameter is omitted, the default value of 0 (Omit Member List Signature) is used.

The Create common service shall have the object-specific response parameter specified in Table 116.

Table 116 – Object-specific response parameter for Create

Name	Data type	Semantics of values
Instance ID	UINT or UDINT[a]	The Instance ID of the instance that was created The instance ID shall be assigned from one of the vendor specific ranges supported by the device. See Table 113 for the vendor specific ranges allowed.

[a] UDINT if dynamic instances can be created with Instance IDs greater than 65 535, UINT otherwise.

4.1.8.5 Acknowledge Handler object specific syntax elements

4.1.8.5.1 Attributes

4.1.8.5.1.1 Class attributes

The format of the Acknowledge Handler object class attributes shall be as specified in Table 117.

Table 117 – Acknowledge Handler object class attributes

Attribute ID	Name	Data type	Semantics of values
1	Revision	UINT	Revision of this object. Value = 1
2 – 7, 200, 201	These optional Class Attributes are specified in 4.1.10.2.2.		

4.1.8.5.1.2 Instance attributes

The format of the Acknowledge Handler object instance attributes is as specified in Table 118.

Table 118 – Acknowledge Handler object instance attributes

Attribute ID	Name	Data type	Semantics of values
1	Acknowledge Timer	UINT	Range 1 to 65 535 ms (0 invalid) Default = 16
2	Retry Limit	USINT	Range 0 to 255 Default = 1
3	COS Producing Connection Instance	UINT	Connection Instance ID
4	Ack List Size	SWORD	0 = Dynamic > 0 = Max number of members
5	Ack List	STRUCT of	
		SWORD	Number of members in the array
		ARRAY of UINT	List of Connection Instance IDs
6	Data with Ack Path List Size	SWORD	0 = Dynamic > 0 = Max number of members
7	Data with Ack Path List	STRUCT of	
		SWORD	Number of members in the array
		ARRAY of	
		UINT	Connection Instance ID
		USINT	Path length
		Padded EPATH	Path

4.1.8.5.2 Object specific services

4.1.8.5.2.1 Add_AckData_Path

The Add_AckData_Path_RequestPDU body shall be as specified in Table 119.

Table 119 – Structure of Add_AckData_Path_RequestPDU body

Name	Data type
Connection Instance ID	UINT
Consumer Path Size	USINT
Consumer Path	Padded EPATH

The Add_AckData_Path_ResponsePDU body is empty.

4.1.8.5.2.2 Remove_AckData_Path

The Remove_AckData_Path_RequestPDU body shall be as specified in Table 120.

Table 120 – Structure of Remove_AckData_Path_RequestPDU body

Name	Data type
Connection Instance ID	UINT

The Remove_AckData_Path_ResponsePDU body is empty.

4.1.8.6 Time Sync object specific syntax elements

4.1.8.6.1 Attributes

4.1.8.6.1.1 Class attributes

The format of the Time Sync object class attributes shall be as specified in Table 121.

Table 121 – Time Sync object class attributes

Attribute ID	Name	Data type	Semantics of values
1	Revision	UINT	Revision of this object. Value = 3, 4 or 5 [a]
2 – 7, 200, 201	These optional Class Attributes are specified in 4.1.10.2.2.		

[a] Revision 4 is required for master capable devices; revision 5 is required for conditional attribute 29 and 31; others may use revision 3, 4 or 5.

4.1.8.6.1.2 Instance attributes

The format of the Time Sync object instance attributes shall be as specified in Table 122.

Table 122 – Time Sync object instance attributes

Attribute ID	Name	Data type	Semantics of values
1	PTPEnable	BOOL	PTP enabled for this device: 0 = PTP disabled 1 = PTP enabled
2	IsSynchronized	BOOL	Local clock synchronized with master reference clock: 0 = local clock not synchronized 1 = local clock synchronized
3	SystemTimeMicroseconds	UTIME	Current value of system_time in microseconds
4	SystemTimeNanoseconds	STIME	Current value of system_time in nanoseconds
5	OffsetFromMaster	NTIME	Offset between local clock and master clock in nanoseconds
6	MaxOffsetFromMaster	ULINT	Maximum offset between local clock and master clock in nanoseconds
7	MeanPathDelayToMaster	NTIME	Mean path delay to master in nanoseconds
8	GrandMasterClockInfo	STRUCT of	Grandmaster Clock information
	ClockIdentity	USINT[8]	Unique identifier of the clock. See Table 123 for ClockIdentiy encoding
	ClockClass	UINT	Class of the clock quality. Table 124 shows the values most likely to be used by the Time sync object. See IEC 61588 for a complete list of values
	TimeAccuracy	UINT	Expected absolute accuracy of the clock relative to the PTP epoch. See Table 125 for TimeAccuracy values
	OffsetScaledLogVariance	UINT	Measure of the inherent stability properties of the clock
	CurrentUtcOffset	UINT	Current UTC offset in seconds from International Atomic Time (TAI) of the clock. As of 2006-01-01 at 00:00:00 UTC, the offset was 33 seconds
	TimePropertyFlags	WORD	For the value of the TimePropertyFlags see Table 126
	TimeSource	UINT	For the possible TimeSource values see Table 127
	Priority1	UINT	Relative priority of the grandmaster clock to other clocks in the system. See Priority1 attribute 16
	Priority2	UINT	Relative priority of the grandmaster clock to other clocks in the system. See Priority2 attribute 17
9	ParentClockInfo	STRUCT of	Parent Clock information
	ClockIdentity	USINT[8]	Unique identifier of the clock. See Table 123 for ClockIdentiy encoding
	PortNumber	UINT	PTP Port number
	ObservedOffsetScaledLog Variance	UINT	Estimated measure of the parent clock's variance as observed by the slave clock
	ObservedPhaseChangeRate	UDINT	Estimated measure of the parent clock's drift as observed by the slave clock

Attribute ID	Name	Data type	Semantics of values
10	LocalClockInfo	STRUCT of	Local Clock information
	ClockIdentity	USINT[8]	Unique identifier of the clock See Table 123 for ClockIdentiy encoding
	ClockClass	UINT	Class of the clock quality. Table 124 shows the values most likely to be used by the Time sync object. See IEC 61588 for a complete list of values
	Time Accuracy	UINT	Expected absolute accuracy of the clock relative to the PTP epoch. See Table 125 for TimeAccuracy values
	OffsetScaledLogVariance	UINT	Measure of the inherent stability properties of the clock
	CurrentUtcOffset	UINT	Current UTC offset in seconds from International Atomic Time (TAI) of the clock. As of 2006-01-01 at 00:00:00 UTC, the offset was 33 seconds
	TimePropertyFlags	WORD	For the value of the TimePropertyFlags see Table 126
	TimeSource	UINT	For the possible TimeSource values see Table 127
11	NumberOfPorts	UINT	Number of PTP ports on the device
12	PortStateInfo	STRUCT of	PTP port state information
	NumberOfPorts	UINT	Number of PTP ports on the device
		ARRAY of STRUCT of	
	PortNumber	UINT	PTP port number
	PortState	UINT	Current state of the PTP port: 1 = Initializing 2 = Faulty 3 = Disabled 4 = Listening 5 = Pre_Master 6 = Master 7 = Passive 8 = Uncalibrated 9 = Slave All other = Reserved
13	PortEnableCfg	STRUCT of	PTP port enable configuration
	NumberOfPorts	UINT	Number of PTP ports on the device
		ARRAY of STRUCT of	
	PortNumber	UINT	PTP port number
	PortEnable	UINT	PortEnable has the following values (default is "enabled"): 1 = PTP port enabled 0 = PTP port disabled
14	PortLogAnnounceIntervalCfg	STRUCT of	PTP port log announce interval configuration
	NumberOfPorts	UINT	Number of PTP ports on the device
		ARRAY of STRUCT of	PTP port log announce interval of each port
	PortNumber	UINT	PTP port number
	PortLogAnnounceInterval	UINT	PTP announce interval between successive "Announce" messages issued by a master clock

Attribute ID	Name	Data type	Semantics of values
15	PortLogSyncIntervalCfg	STRUCT of	PTP port log sync interval configuration
	NumberOfPorts	UINT	Number of PTP ports on the device
		ARRAY of STRUCT of	PTP port log sync interval of each port
	PortNumber	UINT	PTP port number
	PortLogSyncInterval	UINT	PTP sync interval between successive "Sync" messages issued by a master clock
16	Priority1	USINT	Best Master ranking of this clock and superseeds the clock quality (class, accuracy, and variance). Values are between 0 and 255, wih 0 for the highest priority
17	Priority2	USINT	Best Master ranking of this clock after clock quality (class, accuracy, and variance) has been evaluated and superseeds the tie-breaker. Values are between 0 and 255, wih 0 for the highest priority
18	DomainNumber	USINT	PTP clock domain
19	ClockType	WORD	For ClockType values see Table 128
20	ManufactureIdentity	USINT[4]	Manufacturer identity of the clock. The first 3 octets specify the IEEE OUI (Organization Unique Id) for the manufacturer. The last octet is reserved
21	ProductDescription	STRUCT of	Product description of the device that contains the clock, formatted as UTF-8 Unicode with a maximum number of symbols of 64.
	Size	UDINT	Size of product description (total number of octets for the Description field) [a]
	Description	ARRAY of USINT	Product description
22	RevisionData	STRUCT of	Revision data of the device that contains the clock, formatted as UTF-8 Unicode with a maximum number of symbols of 32.
	Size	UDINT	Size of revision data (total number of octets for the Revision field) [a]
	Revision	ARRAY of USINT	Revision data
23	UserDescription	STRUCT of	User description of the device that contains the clock, formatted as UTF-8 Unicode with a maximum number of symbols of 128.
	Size	UDINT	Size of user description (total number of octets for the Description field) [a]
	Description	ARRAY of USINT	User description
24	PortProfileIdentityInfo	STRUCT of	PTP port profile identity information
	NumberOfPorts	UINT	Number of PTP ports on the device
		ARRAY of STRUCT of	
	PortNumber	UINT	PTP port number
	PortProfileIdentity	USINT[8]	PTP port profile identity. The profile identifier is contained in the first 6 octets of the array. The last two octets shall be set to zero.

Attribute ID	Name	Data type	Semantics of values
25	PortPhysicalAddressInfo	STRUCT of	PTP port physical address information
	NumberOfPorts	UINT	Number of PTP ports on the device
		ARRAY of STRUCT of	
	PortNumber	UINT	PTP port number
	PhysicalProtocol	USINT[16]	Physical protocol, expressed in ASCII characters. The maximum number of characters is 16. Unused array elements shall be set to zero. See Table 129 for a list of recommended values. EXAMPLE "IEEE 802.3" = 49 45 45 45 20 38 30 32 2E 33 00 00 00 00 00 00
	SizeOfAddress	UINT	Size of the PortPhysicalAddress
	PortPhysicallAddress	USINT[16]	PTP port physical address, expressed as an array of octets. The maximum number of octets is 16. Unused array elements shall be set to zero. EXAMPLE MAC address "01 02 03 04 05 06" = 01 02 03 04 05 06 00 00 00 00 00 00 00 00 00 00 (and size is 6 octets)
26	PortProtocolAddressInfo	STRUCT of	PTP port protocol address information
	NumberOfPorts	UINT	Number of PTP ports on the device
		ARRAY of STRUCT of	
	PortNumber	UINT	PTP port number
	NetworkProtocol	UINT	NetworkProtocol values 1 = UDP/Ipv4 (e.g. Type 2 Ethernet) 2 = UDP/Ipv6 3 = ISO/IEC/IEEE 8802-3 4, 5 = reserved for Type 2 networks 0xFFFE = local or unknown protocol all other = reserved
	SizeOfAddress	UINT	Size of the PortProtocolAddress
	PortProtocolAddress	USINT[16]	PTP port protocol address (e.g. IP address). The maximum number of octets is 16. Unused array elements shall be set to zero. EXAMPLE IP protocol address "192.168.1.2" = C0 A8 01 02 00 00 00 00 00 00 00 00 00 00 00 00 (and size is 4 octets)
27	StepRemoved	UINT	Number of communication paths traversed between the local clock and the grandmaster clock
28	SytemTimeAndOffset	STRUCT of	System time and offset in microseconds
	SystemTime	UTIME	System time in microseconds
	SystemOffset	LTIME	Offset to the local clock value

Attribute ID	Name	Data type	Semantics of values
29	AssociatedInterfaceObjects	STRUCT of	Objects associated with PTP ports
	NumberOfPorts	UINT	Number of PTP Ports
		ARRAY of STRUCT of	
	PortNumber	UINT	PTP port number
	AssociatedObjectPathSize	USINT	Number of 16-bit words in the following EPATH
	AssociatedObject	Padded EPATH	Logical path segments that identify the associated object instance
30	DefaultLeapSeconds	UINT	Default leap seconds
31	AssociatedInterfaceLabels	STRUCT of	Interface labels associated with PTP ports
	NumberOfPorts	UINT	Number of PTP Ports
		ARRAY of STRUCT of	
	PortNumber	UINT	PTP port number
	AssociatedInterfaceLabelPathSize	USINT	Number of 16-bit words in the following EPATH
	AssociatedInterfaceLabel	Padded EPATH	Logical path segments that identify the associated object interface labels

[a] The number of symbols in the description shall be converted to octets.

Table 123 – ClockIdentity encoding for different network implementations

Network	Octet 0	Octet 1	Octet 2	Octet 3	Octet 4	Octet 5	Octet 6	Octet 7
Type 2 network	Encoding is specified by the Type 2 network communication profile							
Local or closed	0xFF	0xFF	Vendor ID [a]		Serial Number [a]			
All others	See IEC 61588							

[a] The Vendor ID and Serial Number are formatted as big endian in the ClockIdentity. For example, a Vendor ID of "0809" and a Serial Number of "03040506" results in a ClockIdentity for a local network of "FF FF 08 09 03 04 05 06".

Table 124 – ClockClass values

ClockClass	Value
Primary reference	6
Primary reference (Hold)	7
Degraded reference A (Master only)	52
Degraded reference B (Master / Slave)	187
Default	248
Slave only	255
See IEC 61588	all other

Table 125 – TimeAccuracy values

Clock accuracy	Value
Reserved	0x00 to 0x1F
± 25 ns	0x20
± 100 ns	0x21
± 250 ns	0x22
± 1 µs	0x23
± 2,5 µs	0x24
± 10 µs	0x25
± 25 µs	0x26
± 100 µs	0x27
± 250 µs	0x28
± 1 ms	0x29
± 2,5 ms	0x2A
± 10 ms	0x2B
± 25 ms	0x2C
± 100 ms	0x2D
± 250 ms	0x2E
± 1 s	0x2F
± 10 s	0x30
> ± 10 s	0x31
Reserved	0x32 to 0x7F
For use by alternate PTP profiles	0x80 to 0xFD
Unknown	0xFE
Reserved	0xFF

Table 126 – TimePropertyFlags bit values

TimePropertyFlags	Bit index
Leap indicator 61	0
Leap indicator 59	1
Current UTC offset valid	2
PTP timescale	3
Time traceable	4
Frequency traceable	5

Table 127 – TimeSource values

TimeSource	Value
ATOMIC CLOCK	0x10
GPS	0x20
TERRESTRIAL RADIO	0x30
PTP	0x40
NTP	0x50
HAND SET	0x60
OTHER	0x90
INTERNAL OSCILLATOR	0xA0
For use by alternate PTP profiles	0xF0 to 0xFE
Reserved	0xFF

Table 128 – Types of Clock

Bit Index [b]	Configured clock type
0	Reserved [a]
1	Reserved [a]
2	Reserved [a]
3	Management node
4	End-to-end transparent clock
5	Reserved [a]
6	Boundary clock
7 [c]	Ordinary clock
8 [c]	Slave only
9 to 15	Reserved [a]

[a] Reserved bits shall be set to 0.

[b] A value of 1 for a bit indicates that the capability applies to this node.

[c] When bit 8 is set, bit 7 shall also be set, as Slave Only functionality is a subset of the Ordinary Clock function.

Table 129 – Network protocol to PortPhysicalAddressInfo mapping

Network protocol	PhysicalProtocol	PortPhysicalAddress
UDP/IPv4	"IEEE 802.3"	Use MAC address
UDP/IPv6	"IEEE 802.3"	Use MAC address
IEEE Std 802.3-2018	"IEEE 802.3"	Use MAC address
Type 2 network	Specified by the Type 2 network communication profile	
Local or unknown protocol	Vendor specific	Use vendor specific

4.1.8.6.1.3 Diagnostic connection points

One diagnostic connection point is defined for the Time Sync object class at the instance level. This connection point is required if the Standard Network Diagnostic Assembly (Instance 0xD2) is implemented (see 4.1.8.4.1.4).

The format of the Time Sync diagnostic connection point is as specified in Table 130.

Table 130 – Time Sync connection point 1, Standard Network Diagnostics

Attribute ID	Name	Data type	Attribute size	Size of structure
2	IsSynchronized	BOOL	1 bit	24 octets
n/a	63 bits pad, shall be zeros		63 bits	
5	OffsetFromMaster	NTIME	8 octets	
8	GrandMasterClockInfo.ClockIdentity	SINT[8]	8 octets	

4.1.8.6.2 Common services

Get_Attributes_All Response

At the **class level**, the order of the attributes returned in the "Attribute Data" parameter of the Get_Attributes_All response shall be as defined in Table 131.

Table 131 – Class level object/service specific response data of Get_Attributes_All

Attribute ID	Data type	Attribute Name	Default Value (if not implemented)
1	UINT	Revision	
2	UINT	Max Instance	0
3	UINT	Number of Instances	0
4	STRUCT of	Optional attribute list	
	UINT	Number of attributes	0
	ARRAY of UINT	Optional attributes	(null)
5	STRUCT of	Optional service list	
	UINT	Number services	0
	ARRAY of UINT	Optional services	(null)
6	UINT	Maximum ID Number Class Attributes	0
7	UINT	Maximum ID Number Instance Attributes	0

4.1.8.7 Parameter object specific syntax elements

4.1.8.7.1 Attributes

4.1.8.7.1.1 Class attributes

The format of the Parameter object class attributes shall be as specified in Table 132.

Table 132 – Parameter object class attributes

Attribute ID	Name	Data type	Semantics of values
1	Revision	UINT	Revision of this object. Value = 1
2	Max Instance	UINT	The largest instance number of a created object at this class hierarchy level
3 – 7	These optional Class Attributes are specified in 4.1.10.2.2.		
8	Parameter Class Descriptor	WORD	See Table 133
9	Configuration Assembly Instance	UINT	This attribute shall be set to zero if a configuration assembly is not supported
10	Native Language	USINT	0 = English 1 = French 2 = Spanish 3 = Italian 4 = German 5 = Japanese 6 = Portuguese 7 = Mandarin Chinese
200, 201	These optional Class Attributes are specified in 4.1.10.2.2.		

The Parameter Class Descriptor attribute contains bits to describe parameter characteristics. The bits are supported are specified in Table 133.

Table 133 – Parameter Class Descriptor bit values

Bit	Definition
0	Supports Parameter instances 1 = Individual Parameter instances ARE supported. 0 = NO Parameter instances are supported. Only configuration assembly instance used
1	Supports Full attributes 1 = All Full Parameter attributes ARE supported 0 = Only Parameter instance stub attributes are supported
2	Shall do non-volatile storage save command 1 = Shall execute non–volatile storage save command. The Save service of the parameter class is used to save instance parameter values 0 = Need not execute non–volatile storage save command
3	Params are stored in Non-Volatile storage 1 = All Full parameters are stored in non–volatile storage 0 = Parameters are not stored in non–volatile storage

4.1.8.7.1.2 Instance attributes

The format of the Parameter object instance attributes is as specified in Table 134.

Table 134 – Parameter object instance attributes

Attribute ID	Name	Data type	Semantics of values
1	Parameter Value	Specified by Data Type (attribute 5)	
2	Link Path Size	USINT	Number of octets. If this attribute is 0, then no link is specified.
3	Link Path	Packed EPATH	The Link Path is limited to 255 octets
4	Descriptor	WORD	See Table 135
5	Data Type	USINT	See 5.2.2
6	Data Size	USINT	
7	Parameter Name String	SHORT_STRING	The maximum number of characters is 16
8	Units String	SHORT_STRING	The maximum number of characters is 4
9	Help String	SHORT_STRING	The maximum number of characters is 64
10	Minimum Value	Specified by Data Type (attribute 5)	See Table 137
11	Maximum Value	Specified by Data Type (attribute 5)	See Table 137
12	Default Value	Specified by Data Type (attribute 5)	Actual value the parameter should be set to when the user wants the default for the parameter
13	Scaling Multiplier	UINT	See Table 138
14	Scaling Divisor	UINT	See Table 138
15	Scaling Base	UINT	See Table 138
16	Scaling Offset	INT	See Table 138
17	Multiplier Link	UINT	See Table 139
18	Divisor Link	UINT	See Table 139
19	Base Link	UINT	See Table 139
20	Offset Link	UINT	See Table 139
21	Decimal Precision	USINT	Specifies number of decimal places to use when displaying the scaled engineering value. Also used to determine actual increment value so that incrementing a value causes a change in scaled engineering value to this precision
22	International Parameter Name	STRINGI	Human readable string representing the parameter name
23	International Engineering Units	STRINGI	Engineering units associated with the parameter
24	International Help String	STRINGI	Human readable string representing the help string

Table 135 – Semantics of Descriptor Instance attribute

Bit	Definition	Meaning
0	Supports settable path	Indicates that link path can be set
1	Supports Get_Enum_String	Indicates that enumerated strings can be read with the Get_Enum_String service. If descriptor bit 8 is set, enumerated values outside the min/max range may exist
2	Supports scaling	See Table 136
3	Supports scaling links	See Table 136
4	Read only parameter	Indicates that the Parameter Value attribute can only be read, and not set
5	Monitor parameter	Indicates that the Parameter Value attribute is updated in real time by the device
6	Supports extended precision scaling	See Table 136
7	Supports non-consecutive enumerated strings	Obsolete
8	Allows both enumeration and min/max range values	Valid for integer data types only. Enumerated values and values in the min/max range are valid. Enumerated values may be inside or outside of the min/max range. If an enumerated value is inside the range, the enumerated string takes precedence over the value
9	Non-displayed parameter	The configuration tool shall not display this parameter
10	Indirect parameter reference	The parameter value represents the instance number of another parameter. The referenced parameter instance shall not be an additional indirect reference. A parameter value of 0 shall indicate no reference. The data type for this parameter shall be USINT, UINT or UDINT
11	Not addressable	The parameter is not directly addressable from the network by any of the Set_Attribute or Get_Attribute services
12	Save supported	This bit, when set, indicates that this parameter can be individually saved by sending the Save service to this parameter instance
13	Apply supported	This bit, when set, indicates the execution of the Apply service to this parameter instance is required before attribute changes affect instance behavior
14	Write only parameter	Indicates that the Parameter Value attribute can only be set, and not read
15	Reserved	This shall be set to zero

Table 136 – Descriptor Scaling bits usage

Supports extended precision scaling (bit 6)	Supports scaling (bit 2)	Supports scaling links (bit 3)	Meaning
0	0	n/a	No Scaling
0	1	0	Supports scaling using Formula (1) and Formula (2). The scaling attributes (13-16) values are used.
0	1	1	Supports scaling using Formula (1) and Formula (2). For non-zero link attributes (17-20), the indicated parameter value will be used. Otherwise the corresponding scaling attribute (13-16) value is used.
1	n/a	0	Supports extended scaling using Formula (3) and Formula (4). The scaling attribute (13-16) values are used.
1	n/a	1	Supports extended scaling using Formula (3) and Formula (4). For non-zero link attributes (17-20), the indicated parameter value will be used. Otherwise the corresponding scaling attribute (13-16) value is used.

Table 137 – Minimum and Maximum Value semantics

Data type	Description and semantics	Minimum Value semantics	Maximum Value semantics	Required/ Optional/Not allowed
OCTET	Bit String – 8 bit length	The least significant bit that is set in the minimum value is the lowest valid bit to be enumerated. The most significant bit that is set in the maximum value is the highest valid bit to be enumerated. A minimum value of zero means that bit 0 is the lowest valid bit to be enumerated. A maximum value of zero is not valid. Example 1 (OCTET type): Min value = 0b00000001 Max value = 0b00001000 Bits 0 to 3 are enumerated Example 2 (WORD TYPE): Min value = 0b0000000000000001 Max value = 0b0000000000001011 Bits 0 to 3 are enumerated, bits 0 and 1 in max value are ignored, bit 3 in min value is ignored Example 3 (DWORD TYPE): Min value= 0b00000000000000000000000000000000 Max value= 0b00000000000000000000000000001000 Bits 0 to 3 are enumerated, 0 min value implies bit 0		Optional
WORD	Bit String – 16 bit length			
DWORD	Bit String – 32 bit length			
LWORD	Bit String – 64 bit length			
STRING[a]	String (2 octet length indicator, 1 octet per character)	Minimum string length	Maximum string length	Required
STRING2[a]	String (2 octet length indicator, 2 octets per character)	Minimum string length	Maximum string length	Required
STRINGN[a]	String (2 octet length indicator, N octets per character)	Minimum string length	Maximum string length	Required
SHORT_ STRING[a]	Character string (1 octet length indicator, 1 octet characters)	Minimum string length	Maximum string length	Required
STRINGI[a]	International character string	Minimum length (in characters) of the "stringcontents" component of the string's implicit sequence	Maximum length (in characters) of the "stringcontents" component of the string's implicit sequence	Required
EPATH[a]	Encoded Path	Minimum string length	Maximum string length	Optional
ENGUNIT	Engineering Units	The minimum value for this data type is not defined and shall not be specified in the EDS file or the parameter object instance	The maximum value for this data type is not defined and shall not be specified in the EDS file or the parameter object instance	Optional
All other data types		The minimum numeric value that may be assigned to the data value	The maximum numeric value that may be assigned to the data value	Optional[b]

[a] The STRING, STRING2, STRINGN, SHORT_STRING, STRINGI and EPATH data types do not have a minimum or maximum value specification. The minimum and maximum value fields are used to present the minimum and maximum string or path lengths. In these cases, the Data Size parameter is used to represent the number of octets required per character or encoding entry.

[b] If the Minimum Value and/or Maximum Value is not specified then the minimum and/or maximum value for the parameter data value are as defined in IEC 61158-5-2.

Table 138 – Scaling Formula attributes

Attribute	Meaning
Multiplier Value	(Mult) Multiplier value for the scaling formula. This value can be based on another parameter
Divisor Value	(Div) Divisor value for the scaling formula. This value can be based on another parameter specified in the Divisor Link
Base Value	(Base) Base value for the scaling formula. This value can be based on another parameter specified in the Base Link
Offset Value	(Offset) Offset value for the scaling formula. This value can be based on another parameter specified in the Offset Link. This attribute is an INT and can be negative
Decimal Precision	(Precision) Precision value for the scaling formula. This value cannot be based on another parameter

Scaling Links

Scaling values (multiplier, divisor, base, and offset) can also be based on other parameters. Scaling Links specify from which instance that scaling value is to be retrieved. If the scaling link attribute is set to 0, then that scaling value is a constant and not linked to another parameter. Table 139 specifies the scaling links.

Table 139 – Scaling links

Attribute	Meaning
Multiplier Link	Specifies the parameter instance from where the Multiplier Value is retrieved
Divisor Link	Specifies the parameter instance from where the Divisor Value is retrieved
Base Link	Specifies the parameter instance from where the Base Value is retrieved
Offset Link	Specifies the parameter instance from where the Offset Value is retrieved

Scaling Factor Attributes

The Scaling Factor represents actual UINT and INT parameter values in other formats. Formula (1) shall be used to determine the engineering value from the actual value using scaling.

$$\text{EngValue} = \frac{(\text{ActualValue} + \text{Offset}) \times \text{Mult} \times \text{Base}}{\text{Div}} \quad (1)$$

The engineering value can then be displayed to the user in the terms specified within the Decimal Precision Instance Attribute. The inverse of the Scaling Formula shall be used to determine the actual value from the engineering value using scaling (see Formula (2)).

$$\text{ActualValue} = \frac{(\text{EngValue} \times \text{Div})}{\text{Mult} \times \text{Base}} - \text{Offset} \quad (2)$$

The extended precision scaling factor adds extended precision to the standard scaling factor. Formula (3) shall be used to determine the engineering value from the actual value using extended precision scaling.

$$\text{EngValue} = \frac{(\text{ActualValue} + \text{Offset}) \times \text{Mult} \times \text{Base}}{\text{Div} \times 10^{\text{Precision}}} \quad (3)$$

The engineering value can then be displayed to the user in the terms specified within the Decimal Precision attribute. The inverse of the extended precision scaling formula shall be used to determine the actual value from the engineering value using extended precision scaling (see Formula (4)).

$$\text{ActualValue} = \frac{(\text{EngValue} \times \text{Div} \times 10^{\text{Precision}})}{\text{Mult} \times \text{Base}} - \text{Offset} \quad (4)$$

4.1.8.7.2 Common services

Get_Attributes_All Response

At the **class level**, the order of the attributes returned in the "Attribute Data" parameter of the Get_Attributes_All response shall be as defined in Table 140. A device is only required to include data in the response data array up to the last implemented attribute.

Table 140 – Class level object/service specific response data of Get_Attributes_All

Attribute ID	Data type	Attribute name	Default value (if not implemented)
1	UINT	Revision	1
2	UINT	Max Instance	
8	WORD	Parameter Class Descriptor	
9	UINT	Configuration Assembly Instance	
10	USINT	Native Language	0

At the **instance level**, the setting of the Parameter Class Descriptor attribute dictates what attributes are returned by the Get_Attributes_All service, as follows:

- if this attribute does not have the "Supports Full Attributes" bit set, only the implemented attributes marked Stub (attribute numbers 1 to 6) are returned by the Get_Attributes_All service;
- if this attribute does have the "Supports Full Attributes" bit set,the Get_Attributes_All service returns all implemented attributes (numbers 1 to 24).

For Parameter object stubs, the order of the attributes returned in the "Attribute Data" parameter of the Get_Attributes_All response shall be as defined in Table 141.

Table 141 – Instance level object/service specific response data of Get_Attributes_All (Parameter object stub)

Attribute ID	Data type	Attribute name	Default value (if not implemented)
1	Specified by Data Type attribute (5)	Parameter Value	
2	USINT	Link Path Size	
3	Packed EPATH	Link Path	
4	WORD	Descriptor	
5	USINT	Data Type	
6	USINT	Data Size	

For full Parameter objects, the order of the attributes returned in the "Attribute Data" parameter of the Get_Attributes_All response shall be as defined in Table 142. A device is only required to include data in the response data array up to the last implemented attribute.

Table 142 – Instance level object/service specific response data of Get_Attributes_All (full Parameter object)

Attribute ID	Data type	Attribute name	Default value (if not implemented)
1	Specified by Data Type attribute (5)	Parameter Value	
2	USINT	Link Path Size	
3	Packed EPATH	Link Path	
4	WORD	Descriptor	
5	USINT	Data Type	
6	USINT	Data Size	
7	SHORT_STRING	Parameter Name String	
8	SHORT_STRING	Units String	
9	SHORT_STRING	Help String	
10	Specified by Data Type attribute (5)	Minimum Value	
11	Specified by Data Type attribute (5)	Maximum Value	
12	Specified by Data Type attribute (5)	Default Value	
13	UINT	Scaling Multiplier	
14	UINT	Scaling Divisor	
15	UINT	Scaling Base	
16	INT	Scaling Offset	
17	UINT	Multiplier Link	
18	UINT	Divisor Link	
19	UINT	Base Link	
20	UINT	Offset Link	
21	USINT	Decimal Precision	
22	STRINGI	International Name Parameter [a]	0
23	STRINGI	International Engineering Units [a]	0
24	STRINGI	International Help String [a]	0

[a] For a device that has implemented the International String attributes, the Parameter Name String character count, the Units String character count and the Help String character count shall be reported as zero. For devices that do not support the International String attributes, each (and every) International String attribute shall be reported as a single octet of zero, or may be missing from the response. If any International String attribute is supported, all three attributes shall be reported in the response.

4.1.8.7.3 Object specific service

Get_Enum_String

The Get_Enum_String_RequestPDU body shall be as specified in Table 143.

Table 143 – Structure of Get_Enum_String_RequestPDU body

Name	Data type	Semantics of values
Enumerated String Number	USINT	Number of enumerated strings to retrieve. Maximum possible range of values = 0 to 255. Value indicates bit offset (relative to zero) for bit enumerations, actual value (relative to zero) for value enumerations

The Get_Enum_String_ResponsePDU body shall be as specified in Table 144.

Table 144 – Structure of Get_Enum_String_ResponsePDU body

Name	Data type	Semantics of values
Enumerated String	SHORT_STRING	Enumerated strings. Maximum number of characters = 16

Enumerated strings are human–readable strings that describe either a bit or a value, depending on the parameter's data type. The relationship of the string type with the parameter data type is shown in Table 145.

Table 145 – Enumerated strings Type versus Parameter data type

If the parameter's data type is:	Then the enumerated strings returned are:
OCTET, WORD, DWORD, LWORD	Bit enumerated strings
USINT, SINT, UINT, INT, BOOL	Value enumerated strings
All Other data types	Invalid for enumeration

If the parameter's data type is OCTET, WORD, DWORD or LWORD, requesting a Get_Enum_String service with an enumerated string number of 0 on a parameter returns a SHORT_STRING that describes bit 0. Requesting a Get_Enum_String service with an enumerated string number of 1 on a parameter returns a SHORT_STRING that describes bit 1. This continues up to the maximum bit number supported by the parameter.

If the parameter's data type is SINT, USINT, INT, UINT or BOOL, requesting a Get_Enum_String service with an enumerated string number of 0 on a parameter returns a SHORT_STRING that describes the value of 0. Requesting a Get_Enum_String service with an enumerated string number of 1 returns a SHORT_STRING that describes the value of 1.

4.1.8.8 Connection Manager object specific syntax elements

4.1.8.8.1 Attributes

4.1.8.8.1.1 Class attributes

The format of the Connection Manager object class attributes shall be as specified in Table 146.

Table 146 – Connection Manager object class attributes

Attribute ID	Name	Data type	Semantics of values
1	Revision	UINT	Revision of this object. Value = 1
2 – 7	These optional Class Attributes are specified in 4.1.10.2.2.		
8, 9	These attributes are used for safety (see IEC 61784-3-2). They shall not be used if the device is not a safety device.		
200, 201	These optional Class Attributes are specified in 4.1.10.2.2.		

4.1.8.8.1.2 Instance attributes

The format of the Connection Manager object instance attributes is as specified in Table 147.

Table 147 – Connection Manager object instance attributes

Attribute ID	Name	Data type	Semantics of values
1	OpenReqs	UINT	
2	OpenFormat Rejects	UINT	
3	OpenResource Rejects	UINT	
4	OpenOther Rejects	UINT	
5	CloseReqs	UINT	
6	CloseFormat Rejects	UINT	
7	CloseOther Rejects	UINT	
8	ConnTimeouts	UINT	Total number of connection timeouts that have occurred in connections controlled by this Connection Manager.
9	Connection Entry List	STRUCT of	
	NumConnEntries	UINT	Number of bits used in the ConnOpenBits element. This attribute, divided by 8 and incremented for any remainder, gives the length in octets of the array in the ConnOpenBits field.
	ConnOpenBits	ARRAY of BOOL	Bit field. List of connection data. Each bit represents a possible connection. 0 = No Connection. 1 = Connection Established.
10	Reserved / Obsolete		
11	CpuUtilization	UINT	CPU Utilization in tenths of a percent. Range of 0 to 1 000 representing 0,0 % to 100,0 %.
12	MaxBuffSize [a]	UDINT	Amount of buffer space is in octets.
13	BufSize Remaining [a]	UDINT	Amount of buffer space is in octets.
14	Max Connection Establishment Time	UINT	Number of milliseconds (1 to 65 535)
15	I/O Packets per second	UDINT	Current I/O packets per second for I/O traffic
16	Percent I/O Utilization	UINT	Current I/O communications utilization for I/O traffic. Percentage in units of 0,1 %, with 1 100 representing 110,0 % utilization.

Attribute ID	Name	Data type	Semantics of values
17	Explicit Packets per second	UDINT	Total number of explicit packets sent and received by this device over the last second
18	Missed I/O Packets	UDINT	Running total of missed I/O packets
19	Type 2 I/O Connections	UDINT	Total number of Type 2 I/O connections in use
20	Type 2 Explicit Connections	UDINT	Total number of Type 2 Explicit Messaging connections in use

[a] The meaning of, and method of calculating, these values are vendor specific.

4.1.8.8.1.3 Diagnostic connection points

One diagnostic connection point is defined for the Connection Manager object class at the instance level. This connection point is required if the Standard Network Diagnostic Assembly (Instance 0xD2) is implemented (see 4.1.8.4.1.4).

The format of the Connection Manager diagnostic connection point is as specified in Table 148.

Table 148 – Connection Manager connection point 1, Standard Network Diagnostics

Attribute ID	Name	Data type	Attribute size	Size of structure
19	Type 2 I/O Connections	UDINT	4 octets	32 octets
18	Missed I/O Packets	UDINT	4 octets	
17	Explicit Packets per second	UDINT	4 octets	
15	I/O Packets per second	UDINT	4 octets	
20	Type 2 Explicit Connections	UDINT	4 octets	
8	Connection Timeouts	UINT	2 octets	
11	CPU_Utilization	UINT	2 octets	
16	Percent I/O Utilization	UINT	2 octets	
n/a	48 bits pad	n/a	6 octets	

4.1.8.8.2 Common services

4.1.8.8.2.1 Get_Attributes_All Response

At the **class level**, the order of the attributes returned in the "Attribute Data" parameter of the Get_Attributes_All response shall be as defined in Table 149.

Table 149 – Class level object/service specific response data of Get_Attributes_All

Attribute ID	Data type	Attribute name	Default value (if not implemented)
1	UINT	Revision	1
2	UINT	Max Instance	1
6	UINT	Maximum ID Number Class Attributes	0
7	UINT	Maximum ID Number Instance Attributes	0

Important: A device is only required to include data in the response data array up to the last implemented attribute as defined in 3.5.3.2.1.

At the **instance level**, the order of the attributes returned in the "Attribute Data" parameter of the Get_Attributes_All response shall be as defined in Table 150. This service shall only return values of supported attributes. Therefore, a device can only return values up to the last consecutive supported attribute starting from the first attribute (Attribute 1). Values from any attributes supported beyond these shall be acquired via a Get_Attribute_Single service.

Table 150 – Instance level object/service specific response data of Get_Attributes_All

Attribute ID	Data type	Attribute name	Default value (if not implemented) [b]
1	UINT	Open Requests	
2	UINT	Open Format Rejects	
3	UINT	Open Resource Rejects	
4	UINT	Open Other Rejects	
5	UINT	Close Requests	
6	UINT	Close Format Rejects	
7	UINT	Close Other Rejects	
8	UINT	Connection Timeouts	
9	STRUCT of:	Connection Entry List	
	UINT	NumConnEntries [a]	
	ARRAY of BOOL	ConnOpenBits	
11	UINT	CPU_Utilization	
12	UDINT	MaxBuffSize	
13	UDINT	BufSize Remaining	
14	UINT	Max Connection Establishment Time	

[a] This field, divided by 8 and rounded up for any remainder, gives the length of the array (in octets) of the ConnOpenBits field of this structure.

[b] No default values are provided because no unsupported attributes are allowed as described above.

4.1.8.8.2.2 Set_Attributes_All Request

At the **instance level**, the order of the attributes returned in the "Attribute Data" parameter of the Set_Attributes_All request shall be as defined in Table 151.

Table 151 – Instance level object/service specific request data of Set_Attributes_All

Attribute ID	Data type	Attribute name	Default values (if not implemented)
1	UINT	Open Requests [a]	0
2	UINT	Open Format Rejects [a]	0
3	UINT	Open Resource Rejects [a]	0
4	UINT	Open Other Rejects [a]	0
5	UINT	Close Requests [a]	0
6	UINT	Close Format Rejects [a]	0
7	UINT	Close Other Rejects [a]	0
8	UINT	Connection Timeouts [a]	0

[a] If this attribute is not supported, the value sent shall be ignored. This condition does not cause the service request to fail.

4.1.8.9 Connection object specific syntax elements

4.1.8.9.1 Attributes

4.1.8.9.1.1 Class attributes

The format of the Connection object class attributes shall be as specified in Table 152.

Table 152 – Connection object class attributes

Attribute ID	Name	Data type	Semantics of values
1	Revision	UINT	Revision of this object. Value = 1
2 – 7, 200, 201	These optional Class Attributes are specified in 4.1.10.2.2.		

4.1.8.9.1.2 Instance attributes

The format of the Connection object instance attributes is as specified in Table 153.

Table 153 – Connection object instance attributes

Attr ID	Name	Data type	Semantics of values
1	State	USINT	State of the object.
2	Instance_type	USINT	Indicates either I/O or Messaging Connection.
3	TransportClass_trigger	SWORD	Defines behavior of the Connection.
4	DN_produced_ connection_id	UINT	Placed in ISO 11898-1 CAN Identifier Field when the Connection transmits on a CAN-based subnet.
5	DN_consumed_ connection_id	UINT	ISO 11898-1 CAN Identifier Field value that denotes message to be received on a CAN-based subnet.
6	DN_initial_comm_ characteristics	SWORD	Defines the Message Group(s) across which productions and consumptions associated with this Connection occur on a CAN-based subnet.
7	Produced_connection_size	UINT	Maximum number of octets transmitted across this Connection.
8	Consumed_connection_size	UINT	Maximum number of octets received across this Connection.
9	Expected_packet_rate	UINT	Defines timing associated with this Connection.
10	MSG_produced_connection_id	UDINT	Identifies the message sent on the subnet by this connection.
11	MSG_consumed_connection_id	UDINT	Identifies the message received from the subnet for this connection.
12	Watchdog_timeout_action	USINT	Defines how to handle Inactivity/Watchdog timeouts.
13	Produced_connection_path_ length	UINT	Number of octets in the produced_connection_path attribute.
14	Produced_connection_path	Packed EPATH	Specifies the application object(s) whose data is to be produced by this Connection object. See 4.1.9.
15	Consumed_connection_path_ length	UINT	Number of octets in the consumed_connection_path attribute.
16	Consumed_connection_path	Packed EPATH	Specifies the application object(s) that are to receive the data consumed by this Connection object. See 4.1.9.
17	Production_inhibit_time	UINT	Defines minimum time between new data production.

Attr ID	Name	Data type	Semantics of values
18	Connection_timeout_multiplier	USINT	Specifies the multiplier applied to the expected_packet_rate value to derive the value for the Inactivity/Watchdog Timer.
19	Connection_binding_list	STRUCT UINT Array of UINT	List of I/O connection instances bound to this instance.

Detailed descriptions of the Connection object instance attributes are provided below. The defined default attribute values shall be used when no other internal and/or system-defined rules exist.

State

This attribute defines the current state of the Connection instance. Table 154 defines the possible states and assigns a value used to indicate that state.

Table 154 – Values assigned to the state attribute

Value	State Name	Description
00	Non-existent	The Connection has yet to be instantiated.
01	Configuring	The Connection has been instantiated and is waiting for the following events to occur: (1) to be properly configured and (2) to be told to apply the configuration.
02	Waiting For Connection ID[a]	See definition in Type 2 network communication profile.
03	Established	The Connection has been validly/fully configured and the configuration has been successfully applied.
04	Timed Out	If a Connection object experiences an Inactivity/Watchdog timeout, then a transition may be made to this state. See the watchdog_timeout_action attribute description and the description of the Inactivity/Watchdog Timer in IEC 61158-5-2, 6.2.3.2.1.7 (Connection Timing) for more details.
05	Deferred Delete[a]	See definition in Type 2 network communication profile.
06	Closing	A Bridged Connection object has received, and is processing, a Forward Close from the Connection Manager. The deletion of the connection does not occur until after a successful Forward Close response has been received from the target node.

[a] This value is only used by a specific Type 2 network communication profile.

Important: A dynamically created connection instance is the child of the Explicit Messaging connection across which it was created. Different subnet types may provide other mechanisms for creating a connection that imply a particular parent-child relationship. See network-specific specifications for details.

Important: All resources associated with a Connection Instance (*A)* that has been dynamically created across an Explicit Messaging Connection (*B*) shall be released if the Explicit Messaging Connection (*B)* times out prior to the dynamically created Connection Instance (*A)* transitioning to the Established state.

Important: When a transition is made to the Established state, all timers associated with the Connection object are activated (see Connection Timing in IEC 61158-5-2, 6.2.3.2.1.7)

Instance_type

This attribute defines the instance type (see Table 155).

Table 155 – Values assigned to the instance_type attribute

Value	Meaning
00	Explicit Messaging. This Connection Instance represents one of the end-points of an Explicit Messaging Connection. An Explicit Messaging Connection is dynamically created by sending the *Open Explicit Messaging Connection Request* to the Connection Class.
01	I/O. This Connection Instance represents one of the end-points of an I/O Connection. An I/O Connection is dynamically created by sending a *Create Request* to the Connection Class.
02	Bridged. This Connection Instance represents an intermediate 'hop' of a bridged I/O or Explicit Messaging connection. A pair of Bridged Connection objects (one for each subnet bridged between) are dynamically created by a node after successfully receiving a Forward Open service to the Connection Manager object when this node is not the end point (target).

TransportClass_trigger

Defines whether this is a producing only, consuming only, or both producing and consuming connection. If this end point is to perform a data production, this attribute also defines the event that triggers the production. The eight (8) bits are divided as shown in Figure 7.

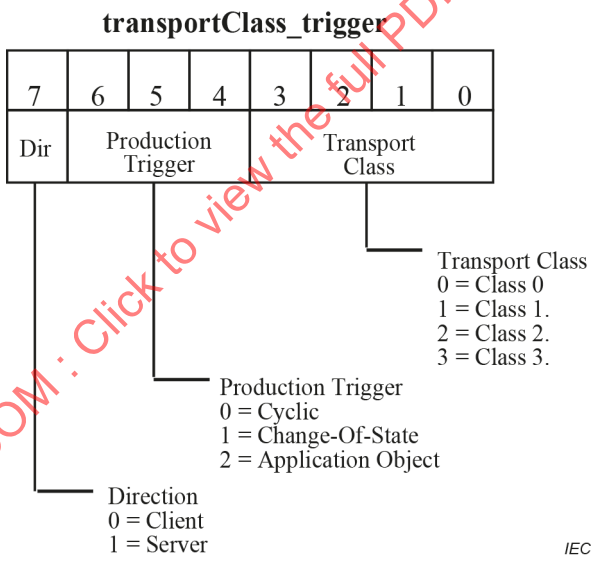


Figure 7 – Transport Class Trigger attribute

The **Direction bit** of the transportClass_trigger octet indicates whether the end-point is to act as the Client or the Server on this connection (see Table 156).

Table 156 – Possible values within Direction Bit

Value	Meaning	
0	Client	This end-point provides the Client behavior associated with this Connection. Additionally, this value indicates that the *Production Trigger* bits within the transportClass_trigger octet contain the description of when the Client is to produce the message associated with this connection. Client connections with production trigger value of 0 or 1 (Cyclic or Change-of-State) shall produce immediately after transitioning to the Established state.
1	Server	This end-point provides the Server behavior associated with this Connection. In addition, this value indicates that the *Production Trigger* bits within the transportClass_trigger octet are to be IGNORED. The *Production Trigger* bits are ignored due to the fact that a Server end-point *reacts* to the transmission from the Client. The only means by which a Server end-point is triggered to transmit is when this *reaction* calls for the production of a message (Transport Classes 2 or 3).

Table 157 lists the values that are possible within the **Production Trigger** bits of the **transportClass_trigger** attribute.

Table 157 – Possible values within Production Trigger Bits

If the value is:	Then the Production of a message is:	
0	Cyclic	The expiration of the Transmission Trigger Timer triggers the data production. See IEC 61158-5-2, 6.2.3.2.1.7 Connection Timing for a detailed description of the Transmission Trigger Timer.
1	Change-Of-State	Production occurs when a change-of-state is detected by the application object. The term used to describe this production is "new data". NOTE The consuming end-point could have been configured to expect the packet at a certain rate, regardless of the triggering mechanism at the producing end-point. See the description of the expected_packet_rate attribute of a Connection object and the description of Connection Timing in IEC 61158-5-2, 6.2.3.2.1.7 for more information.
2	Application Object Triggered	The application object decides when to trigger the production. The term used to describe this production is "new data". NOTE The consuming end-point could have been configured to expect the packet at a certain rate, regardless of the triggering mechanism at the producing end-point. See the description of the expected_packet_rate attribute of a Connection object and the description of Connection Timing in IEC 61158-5-2, 6.2.3.2.1.7 for more information.
3 - 7	Reserved	

Table 158 lists possible values within the **Transport Class** nibble of the **transportClass_trigger** attribute. Behaviors resulting from these particular values are illustrated in the series of figures that follow the table.

Table 158 – Possible values within Transport Class Bits

Value	Meaning	
0	Transport Class 0	Based on the value within the *Dir* bit, this connection end-point will be a producing only OR consuming only end-point. Upon application of this Connection instance, the module instantiates either a Link Producer (*Dir* bit = Client, producing only) or a Link Consumer (*Dir* bit = Server, consuming only) to be associated with this Connection.
1	Transport Class 1	
2	Transport Class 2	Indicates that the module will both produce AND consume across this connection. The Client end-point generates the first data production that is consumed by the Server, which causes the Server to return a production that is consumed by the Client.
3	Transport Class 3	
4 – 6	Reserved (obsoleted)	
7 – 15	Reserved	

A 16-bit sequence count value is prepended to all Class 1, 2, and 3 transports. This value is used to detect delivery of duplicate data packets. Sequence count values are initialized on the first message production and determined by the transport and trigger type on subsequent message productions. A resend of old data to maintain the connection shall not cause the sequence count to change and a consumer shall ignore data when it is received with a duplicate sequence count. Consuming applications can use this mechanism to distinguish between new samples and old samples that were sent to maintain the connection.

For Class 2 and 3 transports, when a request is received with a duplicate sequence count the receiving device shall respond with the original response. This mechanism can be used to keep Class 2 and 3 transports alive and to deal with cases of dropped packets.

Table 159, Table 160 and Table 161 summarize the valid combinations of **Production Trigger** and **Transport Class** and the associated Client and Server behaviors. See IEC 61158-5-2, 6.2.3.2.1.7 for a description of the **Transmission Trigger Timer**.

Table 159 summarizes the valid values for the **transportClass_trigger** attribute of a Connection Instance:

Table 159 – TransportClass_Trigger attribute values summary

TransportClass_trigger bits	Meaning
1 xxx 0000	Direction = Server, Production Trigger = IGNORED, Transport Class = 0.
1 xxx 0001	Direction = Server, Production Trigger = IGNORED, Transport Class = 1.
1 xxx 0010	Direction = Server, Production Trigger = IGNORED, Transport Class = 2.
1 xxx 0011	Direction = Server, Production Trigger = IGNORED, Transport Class = 3. This is the value assigned to this attribute within the Server end-point of an Explicit Messaging Connection.
0 000 0000	Direction = Client, Production Trigger = Cyclic, Transport Class = 0.
0 000 0001	Direction = Client, Production Trigger = Cyclic, Transport Class = 1.
0 000 0010	Direction = Client, Production Trigger = Cyclic, Transport Class = 2.
0 000 0011	Direction = Client, Production Trigger = Cyclic, Transport Class = 3.
0 001 0000	Direction = Client, Production Trigger = Change-Of-State, Transport Class = 0.
0 001 0001	Direction = Client, Production Trigger = Change-Of-State, Transport Class = 1.
0 001 0010	Direction = Client, Production Trigger = Change-Of-State, Transport Class = 2.
0 001 0011	Direction = Client, Production Trigger = Change-Of-State, Transport Class = 3.
0 010 0000	Direction = Client, Production Trigger = Application object, Transport Class = 0.
0 010 00001	Direction = Client, Production Trigger = Application object, Transport Class = 1

TransportClass_trigger bits	Meaning
0 010 0010	Direction = Client, Production Trigger = Application object, Transport Class = 2.
0 010 0011	Direction = Client, Production Trigger = Application object, Transport Class = 3. This is the value assigned to this attribute within the Client end-point of an Explicit Messaging Connection.
1 111 1111	Default value assigned to this attribute within an I/O Connection.

Table 160 summarizes client behavior for Class 0 in regards to message production for the different trigger types.

Table 160 – Transport Class 0 client behavior summary

Trigger type	Production triggered by	Repeated production to maintain connection
Cyclic	Transmission Timer (API)	n/a
Change of State	Detected data change	Transmission Timer (API)
Application	Application update of data	Transmission Timer (API)

Table 161 summarizes client behavior for Classes 1, 2 and 3 in regards to message production and sequence count for the different trigger types.

Table 161 – Transport Class 1, 2 and 3 client behavior summary

Trigger type	Sequence count incremented by	Production triggered by	Repeated production to maintain connection
Cyclic	Application update of data	Transmission Timer (API)	n/a
Change of State	Detected data change	Detected data change	Transmission Timer (API)
Application	Application update of data	Application update of data	Transmission Timer (API)

DN_produced_connection_id

This attribute shall not be used, unless otherwise specified in the network communication profile of the subnet.

It contains the Connection ID to be associated with transmissions sent across this connection (if any), i.e. the value that will be specified in the CAN Identifier Field of ISO 11898-1 when this Connection transmits. See IEC 62026-3:2014, 5.1.2 for a description of how the CAN Identifier Field is used. This value is loaded directly into the associated Link Producer's connection_id attribute. Values are defined in Table 162.

Table 162 – Values defined for the DN_produced_connection_id attribute

Value	Meaning
0x0000 - 0x07F0	The value to be placed in the CAN Identifier Field when this Connection transmits.
0x0800 - 0xFFFE	Reserved
0xFFFF	Default value assigned to this attribute within an I/O Connection. This attribute will retain this value if this Connection instance is not producing any data (consumer only).

DN_consumed_connection_id

This attribute shall not be used, unless otherwise specified in the network communication profile of the subnet.

It contains the Connection ID which identifies messages to be received across this connection (if any), i.e. the CAN Identifier Field value that is associated with messages this Connection object receives. See IEC 62026-3:2014, 5.1.2 for a description of how the CAN Identifier Field is used. This value is loaded directly into the associated Link Consumer's connection_id attribute. Values are defined in Table 163.

Table 163 – Values defined for the DN_consumed_connection_id attribute

Value	Meaning
0x0000 - 0x07F0	The value that identifies messages to be consumed. This will be specified in the CAN Identifier Field of messages that are to be consumed.
0x0800 - 0xFFFE	Reserved
0xFFFF	Default value assigned to this attribute within an I/O Connection. This attribute will retain this value if this Connection instance is not consuming any data (producer only).

DN_initial_comm_characteristics

This attribute shall not be used, unless otherwise specified in the network communication profile of the subnet.

It defines the Message Group(s) across which productions and consumptions associated with this Connection occur.

This octet is divided into two nibbles, as show in Figure 8.

7	6	5	4	3	2	1	0
Initial Production Characteristics				Initial Consumption Characteristics			

Figure 8 – DN_initial_comm_characteristics attribute format

Table 164 lists the values that are possible within the Initial Production Characteristics nibble (upper nibble) of the DN_initial_comm_characteristics attribute.

Table 164 – Values for the Initial Production Characteristics nibble

Value	Meaning	
0x0	Produce across Message Group 1	The production associated with this Connection is to take place across Message Group 1. The producing module generates the Connection ID value and loads it into the Connection object's DN_produced_connection_id attribute. The producing module allocates a Message ID from its Group 1 Message ID pool and combines this with its Source MAC ID to generate the Connection ID. The numerically lowest available Group 1 Message ID is to be used in generating the DN_produced_connection_id attribute value. This value shall also be loaded into the corresponding DN_consumed_connection_id attribute(s) associated with the consuming Connection object(s).
0x1	Produce across Message Group 2 (Destination)	The production associated with this Connection is to take place across Message Group 2. Additionally, the intended recipient's MAC ID (Destination MAC ID) is to be placed within the MAC ID component of the Group 2 Identifier Field. In this case, the consuming module generates the Connection ID value to be associated with transmissions across this connection. When the consuming module has generated this value and loaded it into the appropriate Connection object's DN_consumed_connection_id attribute, it can be read and subsequently loaded into the producing Connection object's DN_produced_connection_id attribute.
0x2	Produce across Message Group 2 (Source)	The production associated with this Connection is to take place across Message Group 2. In addition, the producing module's MAC ID (Source MAC ID) is to be placed within the MAC ID component of the Group 2 Identifier. In this case, the producing module generates the Connection ID value and loads it into the Connection object's DN_produced_connection_id attribute. The numerically lowest available Group 2 Message ID is to be used in generating the DN_produced_connection_id attribute value. This value shall also be loaded into the corresponding DN_consumed_connection_id attribute(s) associated with the consuming Connection object(s).
0x3	Produce across Message Group 3	The production associated with this Connection is to take place across Message Group 3. The producing module generates the Connection ID value and loads it into the Connection object's DN_produced_connection_id attribute. The producing module allocates a Message ID from its Group 3 Message ID pool and combines this with its Source MAC ID to generate the Connection ID. The numerically lowest available Group 3 Message ID is to be used in generating the DN_produced_connection_id attribute value. This value shall also be loaded into the corresponding DN_consumed_connection_id attribute(s) associated with the consuming Connection object(s).
0x4 - 0xE	Reserved	
0xF	Default value	The default value assigned to the Initial Production Characteristics nibble within an I/O Connection. NOTE If this is a consuming only I/O Connection, then the default value remains in this nibble. Explicit Messaging Connection objects automatically configure this attribute when the Connection is established.

Table 165 lists the possible values within the Initial Consumption Characteristics nibble (lower nibble) of the DN_initial_comm_characteristics attribute.

Table 165 – Values for the Initial Consumption Characteristics nibble

Value	Meaning	
0x0	Consume a Group 1 Message	The message to be consumed will be transmitted across Message Group 1. The producing module generates the Connection ID value. This value shall be loaded into the DN_consumed_connection_id attribute associated with the consuming Connection object(s).
0x1	Consume a Group 2 Message (Destination)	The message to be consumed will be transmitted across Message Group 2. The intended recipient's MAC ID (Destination MAC ID) is specified within the Group 2 Identifier. The consuming module generates the Connection ID value and loads it into the DN_consumed_connection_id attribute associated with this Connection object. The numerically lowest available Group 2 Message ID is to be used in generating the DN_consumed_connection_id attribute value. This value shall be loaded into the producing Connection object's DN_produced_connection_id attribute.
0x2	Consume a Group 2 Message (Source)	The message to be consumed will be transmitted across Message Group 2. The transmitting module's MAC ID (Source MAC ID) is specified within the Group 2 Identifier. In this case, the producing module generates the Connection ID value and loads it into the Connection object's the DN_produced_connection_id attribute. This value shall be loaded into the DN_consumed_connection_id attribute associated with the consuming Connection object(s).
0x3	Consume a Group 3 Message	The message to be consumed will be transmitted as a Group 3 Message. The producing module generates the Connection ID value. The Connection ID value shall be loaded into this Connection object's DN_consumed_connection_id attribute.
0x4 - 0xE	Reserved	
0xF	Default value	The default value assigned to the Initial Consumption Characteristics nibble within an I/O Connection. NOTE If this is a producing only I/O Connection, then the default value remains in this nibble. Explicit Messaging Connections automatically configure this attribute when the Connection is established.

Important: The module that generates a Connection ID shall guarantee that it does not allocate the Message ID/MAC ID pair in such a way that two separate modules are capable of transmitting identical bit patterns within the Identifier Field.

Produced_connection_size

The meaning of this attribute is different for Explicit Messaging Connections than it is for I/O Connections. If the subnet defines a fragmentation protocol and the device supports fragmentation, this size may be larger than the largest frame size.

For Explicit Messaging Connections:

This attribute signifies the maximum number of Message Router Request/Response Data octets (see 4.1.8) that a device is able to transmit across this Connection. Devices that place a known limit on the maximum amount of Message Router Request/Response Data that can be transmitted in a single message, or single fragmented series initialize this attribute accordingly. Devices that cannot or do not predefine an up-front transmit limit place the value 0xffff into this attribute (there may still be a limit, however, it is not known in advance).

Important: Due to the nature of Explicit Messaging, the length of Explicit Messages will fluctuate over the lifetime of a connection. Explicit Messaging Connections perform fragmentation based on the length of the current message to transmit where the subnet type may define a fragmentation protocol.

For I/O Connections:

If the transportClass_trigger indicates that this Connection instance is to produce, then this attribute defines the maximum amount of I/O data that may be produced as a single unit across this connection. The amount of I/O to be transmitted at any given point in time can be less than or equal to the connection_size attribute.

This attribute defaults to zero (0) within an I/O Connection. If the subnet type supports fragmentation and this attribute is set to a value greater than the largest payload in an I/O Connection, then the Connection will break up the data into multiple fragments.

Important: Fragmentation within I/O Connections is performed based on the value within this attribute, regardless of the current amount of data to transmit.

Important: I/O Messages that contain no Application I/O Data and were configured to contain data (via produced_connection_size being greater than zero (0)) are defined to indicate a No Data event for the receiving application object(s). The behavior of an application object upon detection of the No Data event is application object specific.

Consumed_connection_size

The meaning of this attribute is different for Explicit Messaging Connections than it is for I/O Connections. If the subnet defines a fragmentation protocol and the device supports fragmentation, this size may be larger than the largest frame size. See the network specific adaptation specifications for more details.

For Explicit Messaging Connections:

This attribute signifies the maximum number of Message Router Request/Response Data octets that a device is able to receive across this Connection.

Devices that place a known limit on the maximum amount of Message Router Request/Response Data that can be received in a single message, or single fragmented series initialize this attribute accordingly. Devices that cannot or do not predefine an up-front receive limit place the value 0xffff into this attribute (there may still be a limit, however, it is not known in advance). Because of the nature of Explicit Messaging, the length of Explicit Messages will fluctuate over the lifetime of a connection.

For I/O Connections:

If the transportClass_trigger attribute indicates that this Connection is to consume, then this attribute defines the maximum amount of data that may be received as a single unit across this connection. The actual amount of I/O data received at any given time can be less than or equal to the connection_size attribute.

This attribute defaults to zero (0) within an I/O Connection. If the subnet type supports fragmentation and this attribute is set to a value greater than the largest payload in an I/O Connection, then the Connection will process the fragmentation protocol. See the network specific adaptation specifications for more details.

The length of an I/O Message shall be less than or equal to this attribute for an I/O Connection object to receive it as a valid message. If an I/O Connection object receives a message whose length is greater than this attribute, then it immediately discards the message and discontinues any subsequent processing.

NOTE With respect to the Server end-point of a Transport Class 2 or 3 Connection, this error condition (too much data) results in no response being transmitted and the watchdog timer is not kicked.

Expected_packet_rate

This attribute is used to generate the values loaded into the **Transmission Trigger Timer** and the **Inactivity/Watchdog Timer**. See IEC 61158-5-2, 6.2.3.2.1.7 for a description of the Transmission Trigger and Inactivity/Watchdog timers.

The resolution of this attribute is in milliseconds. A request to configure this attribute can result in the specification of a time value that a product cannot meet. In addition to performing product specific range checking when a request to modify this attribute is received, the following steps are performed:

- If the specified value is not equal to an increment of the available clock resolution, then the value is rounded up to the next serviceable value. For example: a Set_Attribute_Single request is received specifying the value 5 for the **expected_packet_rate** attribute and the product provides a 10 millisecond resolution on timers. In this case the product would load the value 10 into the **expected_packet_rate** attribute.
- The value that is actually loaded into the **expected_packet_rate** attribute is reported in the Service Data Field of a Set_Attribute_Single response message associated with a request to modify this attribute.
- If the requested value is equal to an increment of the clock resolution, then the requested value is loaded into the expected_packet_rate and reported in the response. For example: if the value 100 is requested and the clock resolution is 10 milliseconds, then of a value of 100 is loaded.
- When a Connection object is in the **Established** state, any modifications to the **expected_packet_rate** attribute have immediate effect on the Inactivity/Watchdog Timer. The following steps are performed by a Connection object in the **Established** state when a request is received to modify the **expected_packet_rate** attribute:
  - the current Inactivity/Watchdog Timer is canceled,
  - a new Inactivity/Watchdog Timer is activated based on the new value in the expected_packet_rate attribute.

This attribute defaults to 2500 (2 500 ms) within Explicit Messaging Connections, and to zero (0) within an I/O Connection.

MSG_produced_connection_id

This attribute is Required, unless otherwise specified in the network communication profile of the subnet. It contains the Connection ID, which identifies messages to be sent across this connection (if any).

MSG_consumed_connection_id

This attribute is Required, unless otherwise specified in the network communication profile of the subnet. It contains the Connection ID, which identifies messages to be received across this connection (if any).

Watchdog_timeout_action

This attribute defines the action the Connection object should perform when the Inactivity/Watchdog Timer expires. Table 166 defines the specifics of this attribute.

Table 166 – Values for the watchdog_timeout_action

Value	Meaning
0x00	*Transition to Timed Out*. The Connection transitions to the Timed Out state and remains in this state until it is Reset or Deleted. The command to Reset or Delete could come from an internal source (e.g., an application object) or could come from the network (e.g., a configuration tool). This is the default value for this attribute with respect to I/O Connections. This value is invalid for Explicit Messaging Connections.
0x01	*Auto Delete*. The Connection Class automatically deletes the Connection if it experiences an Inactivity/Watchdog timeout. This is the default value for this attribute with respect to Explicit Messaging Connections.
0x02	*Auto Reset*. The Connection remains in the Established state and immediately restarts the Inactivity/Watchdog timer. This value is invalid for Explicit Messaging Connections.
0x03	*Deferred Delete*. This value is only used by a specific Type 2 network communication profile.
0x04 - 0xFF	Reserved

Produced_connection_path_length

Specifies the number of octets of information within the **produced_connection_path** attribute. This is automatically initialized when the **produced_connection_path** attribute is configured. This attribute defaults to the value zero (0).

Produced_connection_path

The **produced_connection_path** attribute is made up of a octet stream which defines the application object(s) whose data is to be produced by this Connection object. The format of this octet stream is specified in 4.1.9. This attribute defaults to being empty upon instantiation of the Connection. It remains empty within Explicit Messaging Connections and within Connection objects that do not produce.

Consumed_connection_path_length

Specifies the number of octets of information within the **consumed_connection_path** attribute. This is automatically initialized when the **consumed_connection_path** attribute is configured. This attribute defaults to the value zero (0).

Consumed_connection_path

The **consumed_connection_path** attribute is made up of an octet stream which defines the application object(s) that are to receive the data consumed by this Connection object. The format of this octet stream is specified in 4.1.9. This attribute defaults to being empty upon instantiation of the Connection. It remains empty within Explicit Messaging Connections and within Connection objects that do not consume.

Production_inhibit_time

This attribute is used to configure the minimum delay time between new data production. This is required for all I/O Client connections, except those with a production trigger of Cyclic. The Set_Attribute_Single service shall be supported when this attribute is implemented. A value of zero (the default value for this attribute) indicates no inhibit time.

The resolution of this attribute is in milliseconds. A request to configure this attribute can result in the specification of time value that a product cannot meet. In addition to performing product specific range checking when a request to modify this attribute is received, the following steps are performed:

- If the specified value is not equal to an increment of the available clock resolution, then the value is rounded up to the next serviceable value. For example: a Set_Attribute_Single request is received specifying the value 5 for the **production_inhibit_time** attribute and the product provides a 10 millisecond resolution on times. In this case the product would load the value 10 into the **production_inhibit_time** attribute.
- The value that is actually loaded into the **production_inhibit_time** attribute is reported in the Service Data Field of a Set_Attribute_Single response message associated with a request to modify this attribute.
- If the requested value is equal to an increment of the clock resolution, then the requested value is loaded into the **production_inhibit_time** and reported in the response. For example: the value 100 is requested and the clock resolution is 10 milliseconds.

The Production Inhibit Timer shall be restarted each time new data production occurs. Data produced due to the expiration of the transmission trigger timer shall not result in the Production Inhibit Timer being restarted.

When a Connection object is in the **Established** state, any modifications to the **production_inhibit_time** attribute have no effect on a currently running Production Inhibit Timer. The new production_inhibit_time value is loaded into the Production Inhibit Timer on the following new data production.

When the apply_attributes service is received, the **production_inhibit_time** shall be verified against the **expected_packet_rate** attribute. If the **expected_packet_rate** value is greater than zero, but less than the **production_inhibit_time** value, then an error shall be returned. In this case, where two attribute values conflict use the **production_inhibit_time attribute** ID as the extended error code returned in the error response.

Connection_timeout_multiplier

The Connection_timeout_multiplier specifies the multiplier applied to the expected packet rate to obtain the value used by the Inactivity/Watchdog Timer. See the Connection Timeout Multiplier parameter description within the Connection Manager object Specific Service Parameters for the enumerated values of this attribute. The default value for this attribute is zero (specifying a multiplier of 4).

Connection_binding_list

The Connection_binding_list attribute identifies connection instances that are bound to this connection. The attribute structure provides a 16 bit count of bound connections, followed by a list of the bound instances. This attribute shall be supported if the Connection_Bind service is supported.

4.1.8.9.2 Common services

4.1.8.9.2.1 Apply_Attributes

The Apply_Attributes common service shall have the object-specific response parameters specified in Table 168.

Table 167 – Object-specific response parameters for Apply_Attributes

Name	Data type	Semantics of values
Produced Connection ID	UINT	Contains the value within the Connection Instance's produced_connection_id attribute for the relevant Type 2 network communication profile.
Consumed Connection ID	UINT	Contains the value within the Connection Instance's consumed_connection_id attribute for the relevant Type 2 network communication profile.

4.1.8.9.2.2 Set_Attribute_Single

The Set_Attribute_Single common service associated with the modification of the expected_packet_rate attribute shall have the object-specific response parameters specified in Table 168.

Table 168 – Object-specific response parameter for Set_Attribute_Single

Name	Data type	Semantics of values
Expected Packet Rate	UINT	Contains the actual value within the Connection Instance's expected_packet_rate attribute.

4.1.8.9.3 Object specific services

4.1.8.9.3.1 Connection_Bind Service

The Connection_Bind_RequestPDU body shall be as specified in Table 169.

Table 169 – Structure of Connection_Bind_RequestPDU body

Name	Data type	Semantics of values
Bound Instances	STRUCT of UINT UINT	Instance numbers of Connection objects to be bound.

The Connection_Bind_ResponsePDU body is empty.

The service response may return a status from the list of status codes in Table 170.

Table 170 – Object specific status for Connection_Bind service

General Status Code	Extended Status Code	Status Description
0x02	0x01	One or both of the connection instances is non-existent.
0x02	0x02	The connection class and/or instance is out of resources to bind instances.
0x0C	0x01	Both of the connection instances are existent, but at least one is not in the Established state.
0x20	0x01	Both connection instances are the same value.
0xD0	0x01	One or both of the connection instances is not a dynamically created I/O connection.
0xD0	0x02	One or both of the connection instances were created internally and the device is not allowing a binding to it.

4.1.8.9.3.2 Producing_Application_Lookup Service

The Producing_Application_Lookup_RequestPDU body shall be as specified in Table 171.

Table 171 – Structure of Producing_Application_Lookup_RequestPDU body

Name	Data type	Semantics of values
Producing Application Path	Packed EPATH	Connection path of producing application to be searched for within connections in the Established state. The path shall be a single Logical or Symbolic path.

The Producing_Application_Lookup_ResponsePDU body shall be as specified in Table 172.

Table 172 – Structure of Producing_Application_Lookup_ResponsePDU body

Name	Data type	Semantics of values
Instance Count	UINT	Number of Instances returned in the Connection Instance List parameter.
Connection Instance List	Struct of UINT	List of instance numbers of connection producing the data from the requested connection path within the node.

The service response may return a status from the list of status codes in Table 173.

Table 173 – Producing_Application_Lookup Service status codes

General Status Code	Extended Status Code	Status Description
0x02	0x01	The connection path was not found in any connection instance in the Established state.

4.1.8.9.3.3 SafetyOpen Service

See IEC 61784-3-2 for the definition of this service.

4.1.8.9.3.4 SafetyClose Service

See IEC 61784-3-2 for the definition of this service.

4.1.9 Message and connection paths

4.1.9.1 Contents

The path shall specify the object element that is either the target of a connection request, or the destination of a message request. The path shall contain multiple segments which can indicate the route to the next node (in the case of multiple links), what to connect to or where to send a message in the target device. Each segment shall be comprised of a segment descriptor octet which specifies the segment type and format, and segment information whose size is dependent on the segment type/format.

A path has a data type EPATH (Packed or Padded). The two types of path shall be

- padded paths (indicated as data type Padded EPATH);
- packed paths (indicated as data type Packed EPATH).

These two path formats (padded and packed) shall not be interchangeable. Usage of padded versus packed shall be specified, depending on the context of use.

Each segment of a padded path shall be 16 bit word aligned. If a pad octet is required to achieve the alignment, then the segment shall specify the location of the pad octet. A packed path shall not contain any pad octets.

The possible segment types shall be as follows:

Port segment (where);

Logical segment (what);

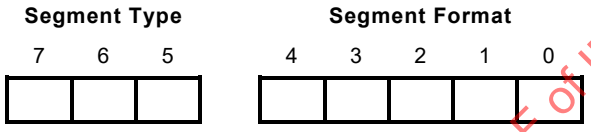
Network segment (when or how);

Symbolic segment;

Data segment.

4.1.9.2 Segment type

Each segment of the path shall contain a segment type/format octet to indicate how the segment is to be interpreted. The segment type/format is contained in the first octet of the segment. The bits of the first octet of a path segment shall be numbered 0 to 7, where bit 0 shall be the least significant bit of the octet. Bits of the segment type are defined in Figure 9.



0	0	0	Port Segment
0	0	1	Logical Segment
0	1	0	Network Segment
0	1	1	Symbolic Segment
1	0	0	Data Segment
1	0	1	Data Type (constructed, see 5.2.3)
1	1	0	Data Type (elementary, see 5.2.2)
1	1	1	Reserved for future use

Figure 9 – Segment type

The meaning of the Segment Format bits is based on the specified Segment Type.

4.1.9.3 Port segment

The port segment shall indicate

- communication port through which to leave the node (expressed as a 16-bit number);
- link address of the next device in the path.

Figure 10 shows the overall structure of the port segment.

Bits 5 to 7 of the first octet shall be zero to indicate the port segment type.

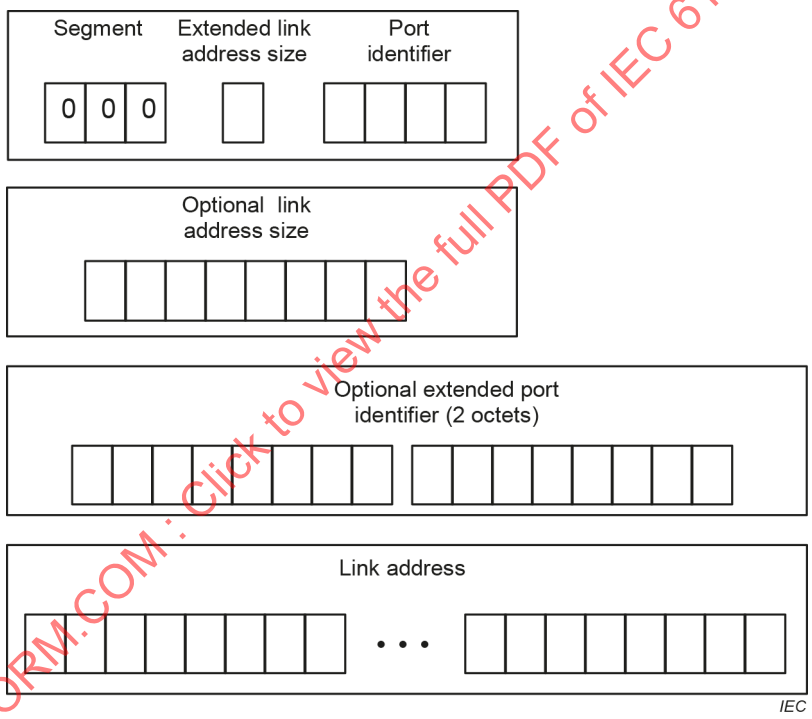
Bit 4, the extended link address size bit, shall be set to 0 if the link address is one octet. Bit 4 shall be set to 1 if the link address is larger than one octet. If the link address is larger than one octet, its size in octets shall be in the second octet of the port segment.

To support the Port Object instance attribute 7 (Port Number and Node Address, see IEC 61158-4-2, 7.11.4.6), a port segment with no link address can be specified by setting the Extended Link Address Size bit (Bit 4 set to 1) and setting the Optional Link Address Size octet to 0.

Bits 0 to 3, the port identifier, shall indicate through which port to leave the node. The port identifier shall specify a port number or an escape to an extended port identifier when the module can support more than 14 ports. Port number 0 shall be reserved. Port number 1 shall only be used to represent a back-plane port. If the port identifier is 15, then a 16-bit field, called the extended port identifier, shall be the next part of the port segment (following the optional link address size if present); otherwise, the value of the port identifier shall be the port number.

The port number shall be followed by a link address whose format depends on the type of network to which the port identifier refers. If the link address is greater than one octet, then it shall be padded so that the entire port segment is an even number of octets. The pad octet shall be set to 0 and shall not be included in the link address size.

NOTE 1 For the common port types, the link address is a single octet. Other port types, such as TCP/IP encapsulation, can use a larger link address (see 4.3 and Clause 11).



NOTE The bit representation is from high bit to low bit, left to right. The octet representation is from low octet to high octet, top to bottom and left to right.

Figure 10 – Port segment

The Extended Port Identifier format of the Port Segment shall only be used when there are more than 14 ports possible on the device. The Port Segment shall always be packed into the smallest Port Segment format possible with respect to the optional fields. Examples of possible port segments are as shown in Table 174 (values are hexadecimal).

Table 174 – Possible port segment examples

Port segment contents	Notes
[02][06]	Segment type = port segment, port number = 2, link address = 6
[0F][12][00][01]	Segment type = port segment. Port identifier is 15, indicating the port number is specified in the next 16 bit field [12][00] (18 decimal). Link address = 1
[15][0F][31][33][30][2E] [31][35][31][2E][31][33] [37][2E][31][30][35][00]	Segment type = port segment. Multi-octet address for TCP Port 5, link address 130.151.137.105 (IP address). The address is defined as a character array, length of 15 octets. The last octet in the segment is a pad octet

The link address portion of a TCP/IP connection path segment shall be encoded within the port segment as a string of ASCII characters. The string shall be one of the following forms:

- IP address in dotted decimal notation, for example "130.151.132.55" (see IETF RFC 1117 for the format of IP addresses);
- IP address in dotted decimal notation, followed by a ":" separator, followed by the TCP port number to be used at the specified IP address;
- host name, for example "plc.type2.org". The host name shall be resolved via a DNS request to a name server (see IETF RFC 1035 for information on host names and name resolution);
- host name, followed by a ":" separator, followed by the TCP port number to be used at the specified host.

The client generating the path shall specify all numbers supplied as parts in IP dotted decimal notation as decimal values with no leading "0x" or "0". Server handling of leading "0x" or "0" is implementation dependent.

The port number shall be represented in either hex or decimal. Hex shall be indicated by a leading "0x". When a port number is specified, it shall be used rather than the standard port number used for the encapsulation protocol (0xAF12). Only port 0xAF12 is guaranteed to be available in a Type 2 Ethernet compliant device.

Other TCP port numbers may be implemented; however, this specification does not provide a mechanism to determine which TCP port numbers are supported by a device. The use of other TCP port numbers is therefore discouraged.

NOTE 2 The guaranteed TCP port number, 0xAF12, has been reserved with the Internet Assigned Numbers Authority (IANA) for use by the encapsulation protocol.

Since port segments shall be word-aligned, a pad octet can be required at the end of the string. The pad octet shall be 0x00, and shall not be counted in the Optional Address Size field of the port segment.

NOTE 3 Examples of port segments for TCP/IP are shown in Table 175 below (values are hexadecimal).

Table 175 – TCP/IP link address examples

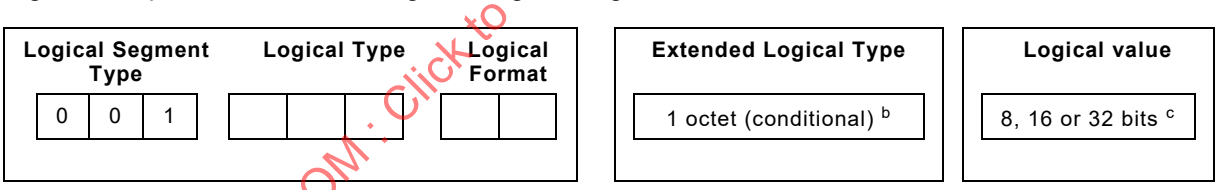
Port segment	IP address	Notes
[12][0D] [31][33][30][2E] [31][35][31][2E] [31][33][32][2E][31][00]	130.151.132.1	Multi-octet address for port 2, 13 octet string plus a pad octet
[13][0C] [70][6C][63][2E] [74][79][70][32][2E] [6F][72][67]	plc.typ2.org	Multi-octet address for port 3, 12 octet string, no pad octet
[16][15] [31][33][30][2E] [31][35][31][2E] [31][33][32][2E] [35][35][3A] [30][78][33][32][31][30][00]	130.151.132.55:0x3210	Multi-octet address for port 6, 21 octet string plus a pad octet
[15][11] [70][6C][63][2E] [74][79][70][32][2E] [6F][72][67][3A] [39][38][37][36][00]	plc.typ2.org:9876	Multi-octet address port 5, 17 octet string plus a pad octet

4.1.9.4 Logical segment

4.1.9.4.1 Logical segment structure

The logical segment selects a particular addressable entity within a device (for example, object class, object instance, and object attribute). When the logical segment is included within a Packed Path, the Logical Value shall be appended to the segment type octet with no pad in between.

Figure 11 specifies the encoding of a logical segment.



Class ID	0	0	0	0	0	8-bit logical value
Instance ID	0	0	1	0	1	16-bit logical value
Member ID	0	1	0	1	0	32-bit logical value
Connection Point	0	1	1	1	1	Reserved for future use
Attribute ID	1	0	0			
Special [a]	1	0	1			
Service ID [a]	1	1	0			
Extended Logical	1	1	1			

[a] The Special and Service ID Logical Types do not use the logical addressing definition for the Logical Format.

[b] Required when Logical Type is Extended Logical (1 1 1), not present otherwise. The Extended Logical Type values are defined in Table 176.

[c] Depends on value of Logical Format.

Figure 11 – Logical segment encoding

The Extended Logical Types are specified in Table 176.

Table 176 – Extended Logical Type

Value	Description
0	Reserved
1	Array Index
2	Indirect Array Index
3	Bit Index
4	Indirect Bit Index
5	Structure Member Number
6	Structure Member Handle
7 to 255	Reserved

The 8-bit and 16-bit logical address formats are allowed for use with all Logical Types.

The 32-bit logical address format is only allowed for the logical Instance ID, Member ID, Connection Point, Array Index, Bit Index, Structure Member Number and Structure Member Handle types. It is not allowed for any other Logical Type (reserved for future use).

The Class ID specifies a type of object within a device. The Instance ID is an integer assigned to an object when it is created. Instance 0, called the class instance, specifies the class itself. The attributes of an object are an enumerated list of externally visible values. The attribute ID specifies which attribute of an object is selected. Complex attributes are composed of members. The member ID specifies which member of the attribute.

When an extended logical segment is included within a Padded Path and the Logical Format is 8 bit, a pad octet shall be added after the Logical Value (the 16-bit and 32-bit formats are identical to the Packed Path) and shall be set to 0. For all other logical segments, when included within a Padded Path, the 16-bit and 32-bit logical formats shall have a pad inserted between the segment type octet and the Logical Value (the 8-bit format is identical to the Packed Path). The pad octet shall be set to zero.

When an Extended Logic Segment is specified the Extended Logical Segment Value octet shall be included between the Segment Type octet and the Logical Value.

An Array Index Extended Logical Segment is used to specify the 0-based index into the preceding item in the EPATH which shall be an array.

An Indirect Array Index Extended Logical Segment is used to specify the start of a nested application path, which resolves to a 0-based index into the preceding item in the EPATH which shall be an array. The Indirect Array Index Logical Segment Logical Value is the size of the nested application path, in 16-bit words.

A Bit Index Extended Logical Segment is used to specify the 0-based bit number into the preceding item in the EPATH (there is no restriction on type of the preceding item).

An Indirect Bit Index Extended Logical Segment is used to specify the start of a nested application path, which resolves to a 0-based bit number into the preceding item in the EPATH (there is no restriction on type of the preceding item). The Indirect Bit Index Logical Segment Logical Value is the size of the nested application path, in 16-bit words.

A Structure Member Number Extended Logical Segment is used to specify the 1-based member number into the preceding item in the EPATH which shall be a structure. The member number specifies the structure member, where the structure members are numbered starting with 1.

A Structure Member Handle Extended Logical Segment is used to specify the member handle into the preceding item in the EPATH which shall be a structure. The handle is a value that uniquely identifies a member and is provided by the target device when reporting constructed data type information using the Formal Encoding with Handles specified in 5.2.3.2.5.

The Connection Point Logical Type provides additional addressing capabilities beyond the standard Class ID/Instance ID/Attribute ID/Member ID object address. Object classes shall define when and how this addressing component is utilized (for example, a sub-instance of an Assembly object).

NOTE IEC 61158-5-2 describes the object model including the definition of class, instance, attribute, connection point, and members of a library of common objects.

The Service ID Logical Type has the following definition for the Logical Format:

- 0 0 8-Bit Service ID Segment (0x38)
- 0 1 Reserved for future use (0x39)
- 1 0 Reserved for future use (0x3A)
- 1 1 Reserved for future use (0x3B)

The Special Logical Type has the following definition for the Logical Format:

- 0 0 Electronic Key Segment (0x34)
- 0 1 Reserved for future use (0x35)
- 1 0 Reserved for future use (0x36)
- 1 1 Reserved for future use (0x37)

4.1.9.4.2 Electronic Key Segment

The electronic key segment shall be used to verify/identify a device. The key may be included as the first logical segment in a connection path and shall be checked by the Message Router of the receiving node against the values contained in instance 1 of its Identity object before any additional address checks are made. On a multi-hop message, sent to a remote link via routers, multiple electronic key segments may appear. The format of the electronic key segment shall be as shown in Table 177.

Table 177 – Electronic key segment format

Parameter	Format	Value
segment_type	USINT	always 0x34
electronic_key_type	USINT	0 to 3 – reserved 4 – REQUIRED (see Key Format in Table 178) 5 – OPTIONAL (see Serial Number Key Format in Table 179) 6 to 255 – reserved
electronic_key_data	ARRAY of octets	Depends on key format used

The `segment_type` for a key segment shall be 0x34. The `electronic_key_type` shall determine the format of a specific key segment: If `electronic_key_type` is equal to 0x04, the format of `electronic_key_data` is specified in Table 178. If `electronic_key_type` is equal to 0x05, the format of `electronic_key_data` is specified in Table 179. All other values for the `electronic_key_type` shall be reserved.

Table 178 – Key Format Table (key type 4)

Parameter	Format	Value
vendor_ID	UINT	these correspond to the values in instance 1 of the identity object
product_type	UINT	
product_code	UINT	
major_revision: 7	USINT	
compatible_match: 1	USINT	
minor_revision	USINT	

Table 179 – Serial Number Key Format Table (key type 5)

Parameter	Format	Value
vendor_ID	UINT	these correspond to the values in instance 1 of the identity object
product_type	UINT	
product_code	UINT	
major_revision: 7	USINT	
compatible_match: 1	USINT	
minor_revision	USINT	
serial_number	UDINT	

The `vendor_ID` shall specify the device vendor, or zero if no specific vendor is required.

The `product_type` shall specify a class of products such as digital input or analogue outputs. The `product_type` shall be ignored when it is set to zero. The `product_code` shall be vendor specific with each vendor having a unique code. The `product_code` shall be ignored when set to zero.

The `major_revision` and `compatible_match` fields shall be contained in the least significant 7 bits and most significant bit of the same octet, respectively.

The `major_revision` shall specify the functionality level of a device. The `major_revision` shall be ignored when set to zero.

The `minor_revision` shall specify the revision of a device that does not effect network-visible behavior. A value of zero shall specify that the originator of the request accepts any minor revision.

The `serial_number` shall specify the serial number of a device. When used in conjunction with the `vendor_ID`, it forms a unique identifier for each device on any Type 2 network. It shall not be set to zero.

If the `serial_number` received in the request is 0 or does not match the `serial_number` of the device, then the request shall be rejected. If the request was directed at the Message Router object, then general status 0x25, extended status 0x013A shall be returned (see Table 205). If the request was directed at the Connection Manager object, then general status 0x01, extended status 0x013A shall be returned (see Table 203).

The `compatible_match` shall modify the key matching function.

If the bit is clear (= 0), then any non-zero `vendor_ID`, `product_type`, `product_code`, `major_revision`, and `minor_revision` shall match exactly.

If the bit is set (=1), any key which a device can emulate may be accepted.

The `vendor_ID`, `product_type`, `product_code`, and `revision` are used to identify the device the recipient is being requested to emulate; therefore 0 is an invalid value for the `vendor_ID`, `product_type`, `product_code`, `major_revision` and `minor_revision` fields.

If the `vendor_ID`, `product_type`, `product_code`, `major_revision` and/or `minor_revision` is 0 or the device cannot emulate the requested device, the request shall be rejected. If the compatible key was included in a request directed at the Message Router object, then one of the errors in Table 205 shall be returned. If the request was directed at the Connection Manager object, then one of the key-specific errors (general status 0x01 and extended status 0x0114 to 0x0116) in Table 203 shall be returned.

EXCEPTION: Device Type 0 is allowed if the recipient can emulate a device that reports the deprecated Generic Device Type Number.

NOTE IEC 61158-5-2 describes the Identity object and the rules for updating the revision fields.

4.1.9.4.3 Logical segments examples

Table 180 shows examples of logical segments.

Table 180 – Logical segments examples

First octet	Logical segment name	Padded format examples (as transmitted)	Packed format examples (as transmitted)	Notes
0x20	8-bit class	[20][04]	[20][04]	class 0x04 (Assembly object)
0x21	16-bit class	[21][00][34][12]	[21][34][12]	class 0x1234
0x24	8-bit instance	[24][04]	[24][04]	instance 0x04
0x25	16-bit instance	[25][00][34][12]	[25][34][12]	instance 0x1234
0x28	8-bit member	[28][04]	[28][04]	member 0x04
0x29	16-bit member	[29][00][34][12]	[29][34][12]	member 0x1234
0x2A	32-bit member			
0x2C	8-bit connection point	[2C][04]	[2C][04]	connection point 0x04
0x2D	16-bit connection point	[2D][00][34][12]	[2D][34][12]	connection point 0x1234
0x30	8-bit attribute	[30][04]	[30][04]	attribute 0x04
0x31	16-bit attribute	[31][00][34][12]	[31][34][12]	attribute 0x1234
0x34	electronic key	[34][04] [12][00] [EF][BE] [0E][0B] [83] [01]	[34][04] [12][00] [EF][BE] [0E][0B] [83] [01]	vendor ID = 0x0012 product type = 0xBEEF product code = 0x0B0E major revision = 0x03 minor revision = 0x01 accept compatible keys = yes

4.1.9.5 Network segment

4.1.9.5.1 Network segment structure

The segment type (first octet) of a network segment shall be in the range 0x40 through 0x5F as shown in Table 181 (the most significant bits shall be 010). The network segment shall be used to specify network parameters which could be required by a node to transmit a message across a network. The network segment shall immediately precede the port segment of the device to which it applies. In other words, the network segment shall be the first item in the path that the device receives.

Table 181 – Network segments

First octet	Network segment name
0x40	reserved
0x41	schedule segment
0x42	fixed tag segment
0x43	production inhibit time in milliseconds
0x44 to 0x4F	reserved
0x50	safety segment
0x51	production inhibit time in microseconds
0x52	user authentication session ID
0x53 to 0x5E	reserved
0x5F	extended network segment

4.1.9.5.2 Schedule Segment

This segment is reserved for the Type 2 network communication profile using the data link layer specified in IEC 61158-3-2.

The segment type of the schedule network segment shall be 0x41. The schedule network segment shall specify

- a multiplier that, when multiplied by the NUT, gives the CM_API (actual packet interval) of the scheduled transport;
- a phase that determines on which values of the `Moderator.interval_count` to transmit.

NOTE 1 The data-link layer defines the Moderator.interval_count, see IEC 61158-4-2.

This segment shall be included in the path to a device so that each intermediary node can schedule link transmit time for subsequent scheduled traffic. The multiplier shall be one of 1, 2, 4, 8, 16, 32, 64 or 128. The phase shall be in the range 0 through (multiplier – 1). The second octet of the schedule network segment shall encode both the multiple and phase by adding them together.

NOTE 2 If a transport produces every 64th NUT starting on `interval_count` = 17, then the encoded value is 17 + 64 = 81.

An encoded value of zero shall specify that the transport has not yet been given permission to use the scheduled priority. If a node receives a request for a scheduled connection in which either no schedule network segment exists, or the schedule network segment exists but the encoded value is 0, the node shall return general status = 0x01, and extended status = 0x0317.

NOTE 3 A connection originator is given permission to use the scheduled priority through the Scheduling object (IEC 61158-4-2).

The number of required schedule segments for intermediate and target nodes is defined in the Type 2 network communication profile.

4.1.9.5.3 Fixed Tag Segment

This segment is reserved for the Type 2 network communication profile using the data link layer specified in IEC 61158-3-2.

The segment type of the fixed tag network segment shall be 0x42. The fixed tag network segment shall specify the fixed tag which is to be used when sending an unconnected message. This segment subtype shall precede the port segment within the path. If the fixed tag segment is not present, then the default fixed tag shall be used.

NOTE The fixed tag segment can be used within the path of the Unconnected_Send service (see 4.1.5.6) of the Connection Manager to send requests to the Keeper object via the Management UCMM (see IEC 61158-5-2).

4.1.9.5.4 Production Inhibit Time Network Segments

4.1.9.5.4.1 General

The production inhibit time network segments shall specify the minimum time between successive transmissions of new data for the specified connection. The Production Inhibit Time Network Segments only apply to Change of State or Application triggered connections. A value of zero shall indicate no production inhibit time. When a production inhibit segment is not provided during establishment of a connection, a default value of one-fourth the RPI shall be used.

The production inhibit time shall be less than or equal to the RPI. If the production inhibit time is greater than the RPI, the Forward_Open response shall be returned with one of the following errors:

- Production Inhibit Time is greater than the RPI (status 0x01, extended status 0x11B) – recommended;
- RPI not supported (status 0x01, extended status 0x0111) – deprecated.

The production inhibit time network segment only applies to the target device.

Target devices may support neither of the Production Inhibit Time network segments. If the device supports the Production Inhibit Time in microseconds Network Segment it shall also support the Production Inhibit Time in milliseconds Network Segment.

NOTE The method for transmitting APDUs over Ethernet-TCP/IP is specified in 4.3 and Clause 11.

4.1.9.5.4.2 Production Inhibit Time in milliseconds Network Segment

The Production Inhibit Time in milliseconds Network Segment specifies a time in milliseconds.

The time specified in the Production Inhibit Time in Milliseconds Network Segment corresponds to the production inhibit definition in the Connection object production_inhibit_time attribute (17) definition.

EXAMPLE If a production inhibit time of 10 ms is specified, new data shall be sent no sooner than 10 ms after the previous new data production.

The network segment data field shall be a single USINT indicating the production inhibit time in milliseconds. The production inhibit time range is 0 ms to 255 ms.

4.1.9.5.4.3 Production Inhibit Time in microseconds Network Segment

The Production Inhibit Time in microseconds Network Segment specifies a time in microseconds.

The time specified in the Production Inhibit Time in microseconds Network Segment is used in the manner defined in the production inhibit definition in the Connection Object production_inhibit_time attribute (17) definition, except that the production inhibit time is in microseconds instead of milliseconds and is a UDINT instead of a USINT.

EXAMPLE If a production inhibit time of 250 µs is specified, new data shall be sent no sooner than 250 µs after the previous new data production.

The Network Segment Data field shall consist of:

- a USINT indicating the Number of Data Words field. The value shall be 2.
- a UDINT indicating the production inhibit time in microseconds, the production inhibit time range is 0 µs to 4 294 967 295 µs.

4.1.9.5.5 Safety Segment

See IEC 61784-3-2 for format.

4.1.9.5.6 User Authentication Session ID Network Segment

Specification of theformat for the User Authentication Session ID Network Segment is outside the scope of this document.

4.1.9.5.7 Extended Network Segment

The extended network segment allows for the definition of additional network segment subtypes. The first word of data is the extended network segment subtype. The structure of the extended network segment is shown in Figure 12.

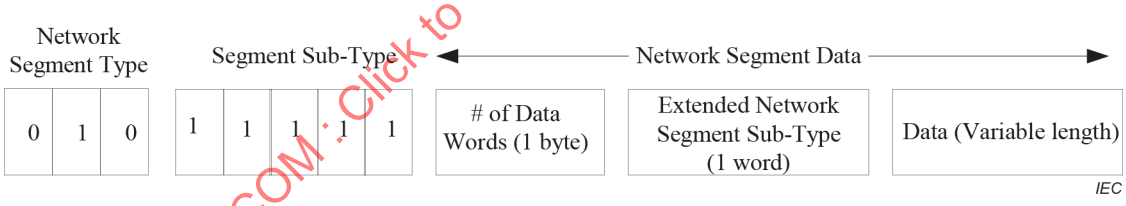


Figure 12 – Extended network segment

Each extended subtype defines the data that follows. The extended subtypes are enumerated in Table 182.

Table 182 – Extended network segment subtype definitions

Subtype Value	Subtype Definition
0x0000	Open, reserved for future use
0x0001	Participant ID for I/O aggregation [a]
0x0002 to 0x7FFF	Open, reserved for future use
0x8000 to 0xFFFF	Vendor specific
[a] I/O aggregation is outside the scope of this document	

4.1.9.6 Symbolic segment

The range of segment types reserved for symbolic segments shall be 0x60 through 0x7F.

The symbolic segment contains an International String symbol which shall be interpreted by the device. Its format is specified in Figure 13.

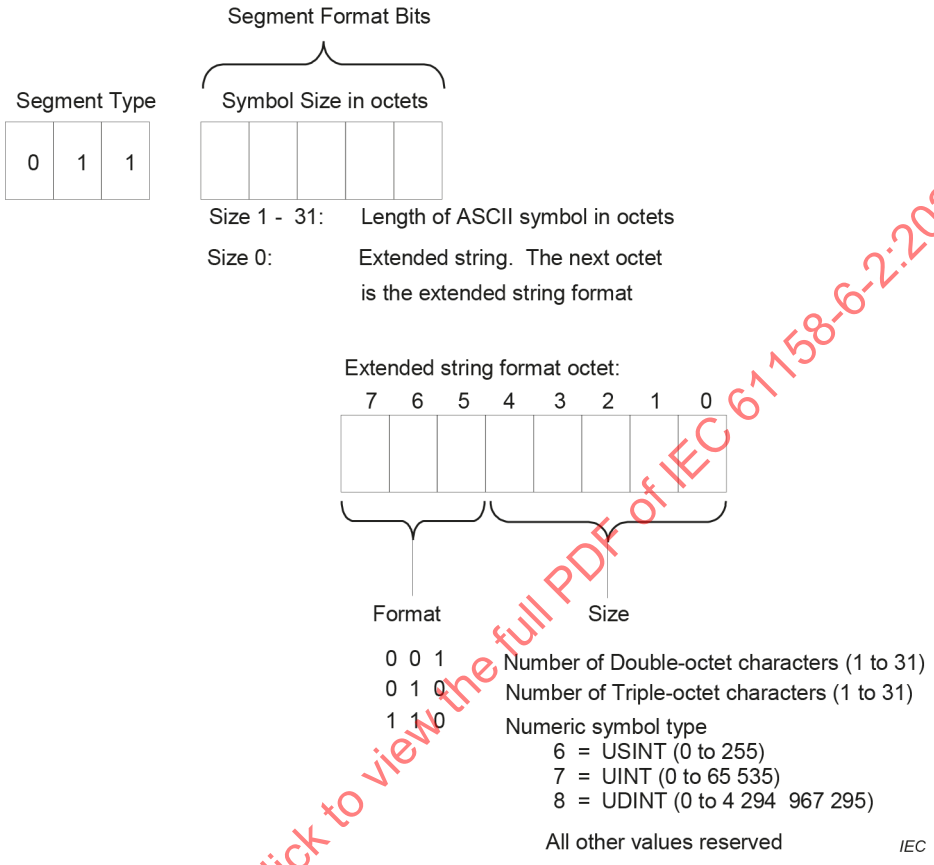


Figure 13 – Symbolic segment encoding

Character symbols can contain a maximum of 31 characters.

If the symbol is ASCII, double-octet or triple-octet, when comparing segments, the symbol portion shall be handled in a case insensitive manner. For instance "LS101" and "ls101" shall be considered equal.

Numeric symbols can be 8, 16, or 32 bits.

When a symbolic segment is used in a Padded EPATH, if the length of the segment is odd a pad octet of 0 shall be added at the end of the segment. The size shall not include the pad octet.

Table 183 shows examples of symbolic segments (values are hexadecimal).

Table 183 – Symbolic segment examples

Symbolic Segment	Notes
[65][LS101]	ASCII Symbol. This could refer to a bit in a data structure
[67][Line_23]	ASCII Symbol. This could refer to a controller in a slot
[68][Wire_off]	ASCII Symbol. This could refer to a bit in a diagnostic structure
[60][22][1234][2345]	Japanese symbol
[60][C7][1234]	16 bit Numeric Symbol
[60][C8][12345678]	32 bit Numeric Symbol

4.1.9.7 Data segment

4.1.9.7.1 Data segment purpose and structure

The data segment provides a mechanism for delivering data to an application. This may occur during connection establishment, or at any other time as defined by the application.

The segment type (first octet) of a data segment shall be in the range 0x80 through 0x9F (the three most significant bits shall be 100). This document only defines the format of the simple data segment with a segment type of 0x80; and the ANSI extended symbol segment (0x91). All other data segment types shall be reserved (0x81 through 0x90, 0x92 through 0x9F).

4.1.9.7.2 Simple Data Segment

The segment type of the simple data segment shall be 0x80. The second octet shall represent the number of 16-bit words of variable length data (up to 255). Following the second octet shall be the variable length data as shown in Table 184. A path may contain more than one simple data segment.

Table 184 – Data segment

Parameter	Format	Value
segment_type	USINT	always 0x80
segment_size	USINT	size of the data[] array in 16-bit words
data[]	UINT	

The simple data segment contains data values such as parameters for the target application. The data can be configuration information for an object, additional parameters necessary for the object, or any other set of object specific information. The data segment shall not be interpreted by any other device in the path, so only the originating and target applications need agree on its contents.

4.1.9.7.3 ANSI Extended Symbol Segment

The segment type of the ANSI extended symbol segment shall be 0x91. The second octet shall represent the number of characters (8-bit) in the symbol. Following the second octet shall be the variable length symbol as shown in Table 185.

The character portion of the ANSI extended symbol segment shall be handled in a case insensitive manner. For instance "start1" and "Start1" shall be considered equal.

Table 185 – ANSI_Extended_Symbol segment

Parameter	Format	Value
segment_type	USINT	always 0x91
symbol_size	USINT	size of the symbol[] array
symbol[]	USINT	
pad	USINT	only present if symbol_size is odd, always set to zero

The `symbol_size` shall be the size of the `symbol[]` array in octets and shall not be zero. The `symbol_size` shall not count the `pad` octet if it is included.

4.1.9.8 Segment definition hierarchy

In general, the definition of any rules related to the use of segments is defined within the Object Class and/or Device Profile. When symbolic and/or logical segments are used to construct an application path, the Backus-Naur Form definition is:

application_path::= CHOICE {*symbolic_application_path, class_application_path, assembly_class_application_path* }

symbolic_application_path::= *symbolic_segment* [Connection_Point] [*member_specification*] [*bit_specification*]

symbolic_segment::= CHOICE {Symbolic_Segment, ANSI_Extended_Symbol_Segment}

assembly_class_application_path::= *20 04 [assembly_attribute_specification]*

class_application_path::= Class_ID [*item_specification*]

NOTE The Class ID cannot specify the Assembly Object (20 04).

item_specification::= CHOICE {*attribute_specification*, *connection_point_specification*}

assembly_attribute_specification::= CHOICE {Instance ID, Connection Point} [[Attribute ID] [*member_specification*] [*bit_specification*]]

attribute_specification::= Instance ID [[Attribute ID] [*member_specification*] [*bit_specification*]]

connection_point_specification::= [Instance ID] Connection Point [*member_specification*] [*bit_specification*]

member_specification::= CHOICE {Member_ID, *extended_member_specification*}

extended_member_specification::= SEQUENCE of {Array_Index, *indirect_array_specification*, Structure_Member_Number, Structure_Member_Handle}

indirect_array_specification::= Indirect_Array_Index *application_path*

bit_specification::= CHOICE {Bit_Index, *indirect_index_bit_specification*}

indirect_bit_specification::= Indirect_Bit_Index *application_path*

A *Symbolic_application_path* shall resolve, at run time, to a *Class_application_path*.

An Indirect_Array_Index and Indirect_Bit_Index *application_path* shall evaluate to a positive integer.

The depth within the application path need only proceed to the degree required by its application.

EXAMPLE

The following are examples of valid application paths.

Class ID,

Class ID, Instance ID

Class ID, Instance ID, Attribute ID

Class ID, Instance ID, Attribute ID, Member ID

Class ID, Connection Point

Class ID, Connection Point, Member ID

Class ID, Instance ID, Connection Point (see constraint a) below)

Class ID, Instance ID, Connection Point, Member ID (see constraint a) below)

Symbolic ID

Symbolic ID, Member ID

Symbolic ID, Connection Point (see constraint b) below)

Symbolic ID, Connection Point, Member ID (see constraint b) below)

Symbolic ID, Array Index, Structure Member Number, Array Index, Bit Index

Symbolic ID, Indirect_Array_Index, [Class_ID, Instance_ID, Attribute_ID], Structure_Member_Number, Array_Index, Bit_Index

The following constraints apply:

a) Instance ID and Connection Point for Class ID 4 (Assembly Object) shall not be used together, since for the Assembly object they are defined to be the same.

b) If the Symbolic ID resolves to a Class ID of 4 (Assembly Object) and Instance ID then Symbolic ID and Connection Point shall not be used together, since for the Assembly object Instance and Connection Point are defined to be the same.

4.1.9.9 Encoded path compression rules

When multiple encoded paths are concatenated, the delineation between paths is where a segment at a higher level in the hierarchy is encountered. Multiple encoded paths may be compacted when each path shares the same values at the higher levels in the hierarchy. Extended Logical segments shall not be used in compressed paths. When a segment is encountered which is at the same or higher level but not at the top level in the hierarchy, the preceding higher levels are used for that next encoded path.

The examples below show multiple encoded paths in the full and compacted representations.

EXAMPLE 1

Full: Class A, Instance A, Attribute A, Class A, Instance A, Attribute B

Compact: Class A, Instance A, Attribute A, Attribute B

EXAMPLE 2

Full: Class A, Instance A, Attribute A, Class A, Instance B, Attribute A

Compact: Class A, Instance A, Attribute A, Instance B, Attribute A

The following special compact format is also defined, but only when the class is not the assembly object:

Full:	Class A, Instance B, Class A, Instance B, Connection Point C, Class A, Instance B, Connection Point D, Data Segment
Compact:	Class A, Instance B, Connection Point C, Connection Point D, Data Segment

When a connection path includes a configuration or I/O path consisting of an instance of the Assembly object (class code 4) without an attribute, the data attribute (attribute 3) is assumed.

EXAMPLE 3

An encoded path with the contents 20 04 24 xx 24 yy 24 zz followed by a data segment is decoded as follows:

20 04 24 xx 30 03 configuration path

20 04 24 yy 30 03 consuming I/O path

20 04 24 zz 30 03 producing I/O path

4.1.10 Class, attribute and service codes

4.1.10.1 Code ranges

4.1.10.1.1 Defined ranges

There shall be three categories for address ranges of Class IDs, Attribute IDs, Connection Points and Service Codes as specified in Table 186.

Table 186 – Addressing categories

This category	Refers to
Open/Public	A value which has the same meaning for all implementers. All object classes and services defined in IEC 61158-5-2 fall under this category.
Vendor-specific	A range of values specific to the vendor of a device. These are used by vendors to extend their devices beyond the available *Open/Public* options. A vendor internally manages the use of values within this range. Applies to object classes, attributes, and services.
Object-class specific	A range of values whose meaning is defined by an object class. This range applies to Service Code definitions.
NOTE Open values are assigned by the ODVA, Inc. organization.	

The Class ID, Attribute ID and Service code values shall be as defined in Table 187 through Table 191.

4.1.10.1.2 Class code ID ranges

The Class ID values shall be as shown in Table 187. Class Code = 0x00 is reserved and shall not be used.

Table 187 – Class code ID ranges

Range (hex)	Range (decimal)	Meaning	Quantity
0x00 to 0x63	0 to 99	Open	100
0x64 to 0xC7	100 to 199	Vendor Specific	100
0xC8 to 0xEF	200 to 239	Reserved	40
0xF0 to 0x2FF	240 to 767	Open	528
0x300 to 0x4FF	768 to 1 279	Vendor Specific	512
0x500 to 0xFFFF	1 280 to 65 535	Reserved	64 256
NOTE Reserved ranges can be further defined by the ODVA, Inc. organization.			

4.1.10.1.3 Attribute ID ranges

The Class Attribute ID values shall be as shown in Table 188.

Table 188 – Class Attribute ID ranges

Range (hex)	Range (decimal)	Meaning	Quantity
0x00	0	Open	1
0x01 to 0x07	1 to 7	Reserved Class Attributes for all object class definitions, see Table 193	7
0x08 to 0x63	8 to 99	Object Specific	92
0x64 to 0xC7	100 to 199	Vendor Specific	100
0xC8 to 0xE3	200 to 227	Reserved Class Attributes for all object class definitions, see Table 193	28
0xE4 to 0xFF	228 to 255	Reserved	28
0x100 to 0x2FF	256 to 767	Object Specific	512
0x300 to 0x4FF	768 to 1 279	Vendor Specific	512
0x500 to 0x8FF	1 280 to 2 303	Open	1 024
0x900 to 0xCFF	2 304 to 3 327	Vendor Specific	1 024
0xD00 to 0xFFFF	3 328 to 65 535	Reserved	62 208
NOTE Reserved ranges can be further defined by the ODVA, Inc. organization.			

The Instance Attribute ID values shall be as shown in Table 189.

Table 189 – Instance Attribute ID ranges

Range (hex)	Range (decimal)	Meaning	Quantity
0x00 to 0x63	00 to 99	Open	100
0x64 to 0xC7	100 to 199	Vendor Specific	100
0xC8 to 0xFF	200 to 255	Reserved	56
0x100 to 0x2FF	240 to 767	Open	512
0x300 to 0x4FF	768 to 1 279	Vendor Specific	512
0x500 to 0x8FF	1 280 to 2 303	Open	1 024
0x900 to 0xCFF	2 304 to 3 327	Vendor Specific	1 024
0xD00 to 0xFFFF	3 328 to 65 535	Reserved	62 208
NOTE Reserved ranges can be further defined by the ODVA, Inc. organization.			

4.1.10.1.4 Connection Point ranges

The Connection Point values shall be as shown in Table 190. Connection Point = 0x0000 is reserved and shall not be used.

Table 190 – Connection Point ranges

Range (hex)	Range (decimal)	Open objects	Quantity
0x0000	0	Not used	1
0x0001 to 0x0063	1 to 99	Defined by object	99
0x0064 to 0x00C7	100 to 199	Vendor Specific	100
0x00C8 to 0x00D1	200 to 209	Defined by object	10
0x00D2 to 0x00EF	210 to 239	Reserved	30
0x00F0 to 0x00FF	240 to 255	Vendor Specific	16
0x0100 to 0x02FF	256 to 767	Defined by object	512
0x0300 to 0x04FF	768 to 1 279	Vendor Specific	512
0x0500 to 0x7FFF	1 280 to 32 767	Defined by object	31 488
0x8000 to 0xFFFF	32 768 to 65 535	Vendor Specific	32 768
0x00010000 to 0x000FFFFF	65 536 to 1 048 575	Defined by object	983 040
0x00100000 to 0xFFFFFFFF	1 048 576 to 4 294 967 295	Reserved	4 293 918 720
NOTE Reserved ranges can be further defined by the ODVA, Inc. organization.			

4.1.10.1.5 Service code ranges

The **Service code** shall be a unique hexadecimal value assigned to each service. The Service Code values shall be as shown in Table 191. Service Code = 0x00 is reserved and shall not be used. The object-specific service codes shall be unique only within the class which define them.

Table 191 – Service code ranges

Range (hex)	Range (decimal)	Meaning	Quantity
0x00	00	Reserved	1
0x01 to 0x31	01 to 49	Open. These are referred to as *Common Services*. They are defined in IEC 61158-5-2	49
0x32 to 0x4A	50 to 74	Vendor Specific	25
0x4B to 0x63	75 to 99	Object Class Specific	25
0x64 to 0x7F	100 to 127	Reserved	28
0x80 to 0xFF	128 to 255	Reserved for response messages	128
NOTE Reserved range can be further defined by the ODVA, Inc. organization.			

4.1.10.2 Code definitions

4.1.10.2.1 Object classes

Table 192 defines the class codes for the object classes. All other class codes listed within the "open" range and not listed in Table 192 shall be reserved. The requirements for these objects are defined in IEC 61158-4-2 or IEC 61158-5-2.

The fourth column of Table 192 (Associated Communication object (ACO)), identifies objects that could have to be included in the Associated Communication Objects instance attribute (11) of the Port Object (0xF4). There are also cases where these objects may have instance numbering restrictions (e.g. instance 1 not allowed), in particular when there is more than one port of same underlying logical link technology (e.g. TCP/IP Interface object).

If any of these objects (ACOs) is present in a device, see the Port Object (0xF4) specifications in IEC 61158-4-2 for more information about:

- when the Port object is required;
- if the Associated Communication Objects instance attribute (11) is required;
- if the object needs to be included in the Associated Communication Objects instance attribute;
- whether there are any instance ID numbering restrictions on the object.

Table 192 – Class codes

Class code (hex)	Class code (decimal)	Object name	Associated Communication object [d]
0x01	1	Identity object	No
0x02	2	Message Router object	No
0x03	3	DeviceNet object[a]	Yes
0x04	4	Assembly object	No
0x05	5	Connection object	No
0x06	6	Connection Manager object	No
0x0F	15	Parameter object	No
0x2B	43	Acknowledge Handler object	No
0x39	57	Safety Supervisor object[b]	No
0x3A	58	Safety Validator object[b]	No
0x42	66	Motion Device Axis object[c]	No
0x43	67	Time Sync object	No
0x47	71	DLR object[a]	Yes
0x48	72	QoS object[a]	Yes
0x4C	76	SERCOS III Link object[b]	Yes
0x56	86	PRP/HSR Protocol object[a]	Yes
0x57	87	PRP/HSR Nodes Table object[a]	Yes
0xF0	240	ControlNet object[a]	Yes
0xF1	241	Keeper object[a]	Yes
0xF2	242	Scheduling object[a]	Yes
0xF3	243	Connection Configuration object[a]	No
0xF4	244	Port object[a]	No
0xF5	245	TCP/IP Interface object[a]	Yes
0xF6	246	Ethernet Link object[a]	Yes
0x109	265	LLDP Management object[a]	No
0x10A	266	LLDP Data Table object[a]	No

[a]	This object class is part of system management.
[b]	This object class is specified in IEC 61784-3-2.
[c]	This object class is specified in IEC 61800-7-202.
[d]	An Associated Communication object is defined in the Port object (instance attribute 11) and may have restrictions on the use of instance 1.

4.1.10.2.2 Predefined class attributes

Nine predefined Class Attribute IDs shall be reserved, and these predefined/reserved class attributes shall have the definitions listed in Table 193. Because these attributes are reserved, class Attribute ID numbers 1 through 7, 200 and 201 shall always be reserved. Therefore, if a class attribute is added to an object class specification, it shall start with Attribute ID #8 and be different from 200 or 201.

Table 193 – Reserved class attributes for all object class definitions

Attribute ID	Name	Data type	Semantics of values
1	Revision	UINT	The starting value assigned to this attribute is one (1). If updates that require an increase in this value are made, then the value of this attribute increases by one (1).
2	Max Instance	UINT	This short version shall be used if no instance greater than 65 535 is supported.
3	Number of Instances	UINT	This short version shall be used if no instance greater than 65 535 is supported.
4	Optional attribute list	STRUCT of	
	Number of attributes	UINT	
	Optional attributes	ARRAY of UINT	
5	Optional service list	STRUCT of	
	Number services	UINT	
	Optional services	ARRAY of UINT	
6	Maximum ID Number Class Attributes	UINT	
7	Maximum ID Number Instance Attributes	UINT	
201	Max Instance	UDINT	This long version shall be used if instances greater than 65 535 are supported.
202	Number of Instances	UDINT	This long version shall be used if instances greater than 65 535 are supported.

4.1.10.2.3 OM_Service codes

Codes of the common services for the deterministic control network objects shall be as shown in Table 194.

NOTE Table 194 lists the codes and names of the common services while IEC 61158-5-2 provides a general description of each service.

Table 194 – Common services list

Common service code	Common service name
0x00	reserved
0x01	Get_Attributes_All
0x02	Set_Attributes_All
0x03	Get_Attribute_List
0x04	Set_Attribute_List
0x05	Reset
0x06	Start
0x07	Stop
0x08	Create
0x09	Delete
0x0A	Multiple_Service_Packet
0x0B to 0x0C	reserved
0x0D	Apply_Attributes
0x0E	Get_Attribute_Single
0x0F	reserved
0x10	Set_Attribute_Single
0x11	Find_Next_Object_Instance
0x12 to 0x14	reserved
0x15	Restore
0x16	Save
0x17	NOP (No operation)
0x18	Get_Member
0x19	Set_Member
0x1A	Insert_Member
0x1B	Remove_Member
0x1C	Group_Sync
0x1D	Get_Connection_Point_Member_List
0x1E to 0x31	reserved

Codes of the object specific services for the Identity object shall be as shown in Table 195.

Table 195 – Identity object specific services list

Object specific service code	Service name
0x4B	Flash_LEDs

Codes of the object specific services for the Message Router object shall be as shown in Table 196.

Table 196 – Message Router object specific services list

Object specific service code	Service name
0x4B	Symbolic_Translation
0x4C	Send_Receive_Fragment

Codes of the object specific services for the Acknowledge Handler object shall be as shown in Table 197.

Table 197 – Acknowledge Handler object specific services list

Object specific service code	Service name
0x4B	Add_AckData_Path
0x4C	Remove_AckData_Path

Code of the object specific service for the Parameter object shall be as shown in Table 198.

Table 198 – Parameter object specific services list

Object specific service code	Service name
0x4B	Get_Enum_String

4.1.10.2.4 CM_Service codes

Codes of the services specific to the Connection Manager shall be as shown in Table 199.

NOTE Table 199 lists the codes and names of the services while IEC 61158-5-2 provides a general description of each service.

Table 199 – Services specific to Connection Manager

Service code	Service name
0x4E	Forward_Close
0x52	Unconnected_Send
0x54	Forward_Open
0x56	Get_Connection_Data
0x57	Search_Connection_Data
0x5A	Get_Connection_Owner
0x5B	Large_Forward_Open

4.1.10.2.5 CO_Service codes

Codes of the services specific to the Connection object shall be as shown in Table 200.

NOTE Table 200 lists the codes and names of the services while IEC 61158-5-2 provides a general description of each service.

Table 200 – Services specific to Connection object

Service code	Service name
0x4B	Connection_Bind
0x4C	Producing_Application_Lookup
0x4E	SafetyClose
0x54	SafetyOpen

4.1.10.3 Device types

In order to allow interoperability and interchangeability, a device type shall be used to identify similar devices which

- exhibit the same behavior;
- produce and/or consume the same basic set of data;
- contain the same basic set of configurable attributes.

The formal definition of this information is known as a Device Profile: all devices with the same device type number shall meet the requirements specified in the Device Profile for that device type.

"Device Type" is a required instance attribute of the Identity object as described in IEC 61158-5-2.

Device types shall be either publicly defined or vendor specific. Table 201 specifies the numbering scheme to be used for device type numbering.

Table 201 – Device type numbering

Range	Type	Quantity
0x00 to 0x63	Publicly Defined – Reserved	100
0x64 to 0xC7	Vendor Specific	100
0xC8 to 0xFF	Reserved	56
0x100 to 0x2FF	Publicly Defined – Reserved	512
0x300 to 0x4FF	Vendor Specific	512
0x500 to 0xFFFF	Reserved	64 256

All publicly defined device types shall have the same meaning for all implementers and are reserved.

The Generic Device type (type number = 0x00) is deprecated for new devices. It was previously used to define a device that does not fit into any of the defined device types.

NOTE The actual definition of publicly defined device types and corresponding Device Profiles is outside the scope of this document. They are defined by the ODVA, Inc. organization.

Vendor specific device types may be developed and vendors need not publish them. Each vendor shall maintain their own vendor-specific device types and corresponding number allocation.

4.1.10.4 Implementation profile numbers

Implementation Profiles describe collections of information and functionality that the device supports, independent of its Device Type. Unlike Device Profiles, Implementation Profiles group subsets of Type 2 technologies and characteristics, providing a high-level description of the capabilities of a device.

The building blocks of an Implementation Profile are its features, which represent logical groupings of functions. A function can be comprised of one or more objects, attributes and services and/or other requirements.

Each Implementation Profile is defined by a structure with two members:

- Profile number – a unique identifier (UINT);
- Features supported – a bit string (DWORD) where the meaning of the individual bits is profile specific, with the exception of bit 31 which is reserved.

This information will be used in the Implementation Profiles instance attribute of the Identity object to report supported profiles (see IEC 61158-5-2).

Table 202 specifies the numbering scheme to be used for implementation profile numbering.

Table 202 – Implementation profile numbering

Range	Type	Quantity
0x00	Reserved	1
0x01 - 0x63	Publicly Defined – Reserved	99
0x64- 0xC7	Vendor Specific	100
0xC8 - 0xFF	Reserved	56
0x100 - 0x2FF	Publicly Defined – Reserved	512
0x300 - 0x4FF	Vendor Specific	512
0x500 - 0xFFFF	Reserved	64 256

NOTE The list of public implementation profiles is managed by the ODVA, Inc. organization. Definition of the implementation profiles and their feature values is outside the scope of this document.

4.1.11 Error codes

4.1.11.1 CM errors

The error codes are returned with the response to a Connection Manager Service Request which resulted in an error. These error codes shall be used to help diagnose the problem with a Service Request. The error code shall be split into an 8 bit general status and one or more 16 bit words of extended status. Unless specified otherwise, only the first word of extended status shall be required. Additional words of extended status may be used to specify additional device specific information. All devices which originate messages shall be able to handle multiple words of extended status.

Table 203 provides a summary of the available error codes.

Only the type of node indicated in the "Detected by" column shall return the general status/extended status code. The "Detected by" column values are Originator, Router and/or Target. When detected by Router or Target devices these error codes will be contained in the response packet. When detected by Originator these error codes may be reported back to the application via an object interface (e.g. Connection Configuration object) or other internal interface.

Table 203 – Connection Manager service request error codes

General Status	Extended Status	Detected by	Explanation and description
0x00			Service completed successfully.
0x01	0x0000 to 0x00FF		Obsolete
0x01	0x0100	Router Target	CONNECTION IN USE OR DUPLICATE FORWARD OPEN This extended status code shall be returned when an originator is trying to make a connection to a target with which the originator could have already established a connection (Non-null/matching Forward_Open – see 4.1.5.3.2.2).
0x01	0x0101 to 0x0102		Reserved
0x01	0x0103	Target	TRANSPORT CLASS AND TRIGGER COMBINATION NOT SUPPORTED A transport class and trigger combination has been specified which is not supported by the target application.
0x01	0x0104		Reserved
0x01	0x0105		Reserved for IEC 61784-3-2
0x01	0x0106	Target	OWNERSHIP CONFLICT The connection cannot be established since another connection has exclusively allocated some of the resources required for this connection. An example of this would be that only one exclusive owner connection can control an output point on an I/O Module. If a second exclusive owner connection (or redundant owner connection) is attempted, this error shall be returned.
0x01	0x0107	Target	TARGET CONNECTION NOT FOUND This extended status code shall be returned in response to the Forward_Close request, when the connection that is to be closed is not found at the target node. Routers shall not generate this extended status code. If the specified connection is not found at the router, the close request shall still be forwarded using the path specified in the Forward_Close request.
0x01	0x0108	Router Target	INVALID NETWORK CONNECTION PARAMETER This extended status code shall be returned as the result of specifying a connection type, connection priority, redundant owner or fixed/variable that is not supported by the device. NOTE This extended status code is "deprecated". It is highly recommended that 0x011F, 0x0120, 0x0121, 0x0122, 0x0123, 0x0124, 0x0125 or 0x0132 be used instead.
0x01	0x0109	Router Target	INVALID CONNECTION SIZE This extended status code is returned when the target or router does not support the specified connection size. This could occur at a target because the size does not match the required size for a fixed size connection. It could occur at a router if the requested size is too large for the specified network. An additional status word may follow indicating the maximum connection size supported by the responding node. The additional status word is required when issued in response to the Large_Forward_Open. NOTE This extended status code is "deprecated". It is highly recommended that 0x0126, 0x0127, or 0x0128 be used instead. The only allowed exception is for Type 2/Type 15 translators. These translators cannot use 0x0126, 0x0127 or 0x0128 because expected sizes are unknown.
0x01	0x010A to 0x010F		Reserved
0x01	0x0110	Target	TARGET FOR CONNECTION NOT CONFIGURED This extended status code shall be returned when a connection is requested to a target application that has not been configured and the connection request does not contain a data segment for configuration (see 4.1.9.7).

<table>
<tr><th>General Status</th><th>Extended Status</th><th>Detected by</th><th colspan="3">Explanation and description</th></tr>
<tr><td>0x01</td><td>0x0111</td><td>Router
Target</td><td colspan="3">RPI NOT SUPPORTED.
This extended status code shall be returned if the device can not support the requested O⇒T or T⇒O RPI. This extended status code may also be used if the connection time-out multiplier produces a time-out value that is not supported by the device or the production inhibit time is not valid.
It is highly recommended to use Extended Status 0x0112 when the RPI values(s) are not acceptable.
Use of this extended status code when the connection time-out multiplier is not supported is deprecated. It is highly recommended that 0x0133 be used instead.
Use of this extended status code when the production inhibit time is not valid is deprecated. It is highly recommended that 0x011B be used instead.</td></tr>
<tr><td>0x01</td><td>0x0112</td><td>Router
Target</td><td colspan="3">RPI VALUE(S) NOT ACCEPTABLE
This extended status code shall be returned when the RPI value(s) in the Forward Open request are outside the range required by the application in the target device or the target is producing at a different interval. The target shall include information with acceptable RPI(s). For this error, the extended status size is 6 16-bit words and is formatted as follows.
<table>
<tr><th>Data type</th><th>Value</th><th>Explanation of field</th></tr>
<tr><td>UINT</td><td>0x0112</td><td>Extended status code</td></tr>
<tr><td>USINT</td><td>variable</td><td>Acceptable Originator to Target RPI (see below) type:
0 – the RPI specified in the Forward Open was acceptable (the Originator to Target RPI value is ignored). [a]
1 – unspecified (used to suggest an alternate RPI, e.g. default)
2 – minimum acceptable RPI (used when RPI was too fast for range)
3 – maximum acceptable RPI (used when RPI was too slow for range)
4 – required RPI to correct mismatch (used when data already being consumed at a different interval)
5 to 255 – reserved</td></tr>
<tr><td>USINT</td><td>variable</td><td>Acceptable Target to Originator RPI (see below) type:
0 – the RPI specified in the Forward Open was acceptable (the Target to Originator RPI value is ignored). [a]
1 – unspecified (used to suggest an alternate RPI, e.g.default)
2 – minimum acceptable RPI (used when RPI was too fast for range)
3 – maximum acceptable RPI (used when RPI was too slow for range)
4 – required RPI to correct mismatch (used when data already being produced at a different interval, typically multicast)
5 to 255 – reserved</td></tr>
<tr><td>UDINT</td><td>variable</td><td>Value of Originator to Target RPI that is within the acceptable range for the application. This field is defined the same as the RPI parameter in the Forward Open request.</td></tr>
<tr><td>UDINT</td><td>variable</td><td>Value of Target to Originator RPI that is within the acceptable range for the application. This field is defined the same as the RPI parameter in the Forward Open request.</td></tr>
</table></td></tr>
</table>

General Status	Extended Status	Detected by	Explanation and description
			[a] The value of the Originator to Target and Target to Originator types shall not both be 0.
0x01	0x0113	Originator Router Target	OUT OF CONNECTIONS Connection Manager cannot support any more connections. The maximum number of connections supported by the Connection Manager has already been created.
0x01	0x0114	Router Target	VENDOR ID OR PRODUCT CODE MISMATCH The Product Code or Vendor ID specified in the electronic key logical segment does not match the Product Code or Vendor ID of the device. If the compatibility bit is set this extended status code is returned when the requested Vendor ID or Product Code is 0 or the device cannot emulate the specified Vendor ID or Product Code.
0x01	0x0115	Router Target	DEVICE TYPE MISMATCH The Device Type specified in the electronic key logical segment does not match the Device Type of the device. If the compatibility bit is set this extended status code is returned when the requested Device Type is 0 or the device cannot emulate the specified Device Type. EXCEPTION: If the compatibility bit is set, Device Type 0 is allowed if the recipient can emulate a device that reports the deprecated Generic Device Type Number.
0x01	0x0116	Router Target	REVISION MISMATCH The major and minor revision specified in the electronic key logical segment does not correspond to a valid revision of the device. If the compatibility bit is set this extended status code is returned when the requested Major Revision and/or Minor Revision is 0 or the device cannot emulate the specified Major Revision.
0x01	0x0117	Target	INVALID PRODUCED OR CONSUMED APPLICATION PATH The produced or consumed application path specified in the connection path does not correspond to a valid produced or consumed application path within the target application. This error could also be returned if a produced or consumed application path was required, but not provided by a connection request. NOTE This extended status code is "deprecated". It is highly recommended that 0x012A, 0x012B, or 0x012F be used instead.
0x01	0x0118	Target	INVALID OR INCONSISTENT CONFIGURATION APPLICATION PATH An application path specified for the configuration data does not correspond to a configuration application or is inconsistent with the consumed or produced application paths. For example the connection path specifies float configuration data while the produced or consumed paths specify integer data. NOTE This extended status code is "deprecated". It is highly recommended that 0x0129 or 0x012F be used instead.
0x01	0x0119	Target	NON-LISTEN ONLY CONNECTION NOT OPENED Connection request fails since there are no non-Listen Only connections with the same T⇒O application path currently open. See IEC 61158-5-2, 6.3.1.4.5, for a description of application connection types. The extended status code shall be returned when an attempt is made to establish a Listen Only connection type to a target, which has no non-Listen Only connections with the same T⇒O application path already established.
0x01	0x011A	Target	TARGET OBJECT OUT OF CONNECTIONS The maximum number of connections supported by this instance of the target object has been exceeded. For example, the Connection Manager could support 20 connections while the target object can only support 10 connections. On the 11th Connection Request to the target object, this extended status code would be used to signify that the maximum number of connections already exist to the target object.
0x01	0x011B	Target	THE PRODUCTION INHIBIT TIME IS GREATER THAN THE RPI The Production Inhibit Time is greater than the Target to Originator RPI.

<table>
<tr><th>General Status</th><th>Extended Status</th><th>Detected by</th><th>Explanation and description</th></tr>
<tr><td>0x01</td><td>0x011C</td><td>Router
Target</td><td>TRANSPORT CLASS NOT SUPPORTED
The transport class requested in the Transport Type/Trigger parameter is not supported.</td></tr>
<tr><td>0x01</td><td>0x011D</td><td>Router
Target</td><td>T⇒O PRODUCTION TRIGGER NOT SUPPORTED
The T⇒O production trigger requested in the Transport Type/Trigger parameter is not supported.</td></tr>
<tr><td>0x01</td><td>0x011E</td><td>Target</td><td>DIRECTION NOT SUPPORTED
The direction requested in the Transport Type/Trigger parameter is not supported.</td></tr>
<tr><td>0x01</td><td>0x011F</td><td>Target</td><td>INVALID ORIGINATOR TO TARGET NETWORK CONNECTION FIXVAR
This extended status code shall be returned as the result of specifying an O⇒T fixed / variable flag that is not supported.</td></tr>
<tr><td>0x01</td><td>0x0120</td><td>Target</td><td>INVALID TARGET TO ORIGINATOR NETWORK CONNECTION FIXVAR
This extended status code shall be returned as the result of specifying a T⇒O fixed / variable flag that is not supported.</td></tr>
<tr><td>0x01</td><td>0x0121</td><td>Target</td><td>INVALID ORIGINATOR TO TARGET NETWORK CONNECTION PRIORITY
This extended status code shall be returned as the result of specifying an O⇒T priority code that is not supported.</td></tr>
<tr><td>0x01</td><td>0x0122</td><td>Target</td><td>INVALID TARGET TO ORIGINATOR NETWORK CONNECTION PRIORITY
This extended status code shall be returned as the result of specifying a T⇒O priority code that is not supported.</td></tr>
<tr><td>0x01</td><td>0x0123</td><td>Target</td><td>INVALID ORIGINATOR TO TARGET NETWORK CONNECTION TYPE
This extended status code shall be returned as the result of specifying an O⇒T connection type that is not supported.</td></tr>
<tr><td>0x01</td><td>0x0124</td><td>Router
Target</td><td>INVALID TARGET TO ORIGINATOR NETWORK CONNECTION TYPE
This extended status code shall be returned as the result of specifying a T⇒O connection type that is not supported.</td></tr>
<tr><td>0x01</td><td>0x0125</td><td>Router
Target</td><td>INVALID ORIGINATOR TO TARGET NETWORK CONNECTION REDUNDANT_OWNER
This extended status code shall be returned as the result of specifying an O⇒T Redundant Owner flag that is not supported.</td></tr>
<tr><td>0x01</td><td>0x0126</td><td>Target</td><td>INVALID CONFIGURATION SIZE
This extended status code is returned when the target device determines that the data segment provided in the Connection_Path parameter did not contain an acceptable number of 16-bit words for the configuration application path requested.
An additional status word shall follow indicating the maximum configuration size supported.
<table>
<tr><th>Data type</th><th>Value</th><th>Explanation of field</th></tr>
<tr><td>UINT</td><td>0x0126</td><td>Extended Status Code</td></tr>
<tr><td>UINT</td><td>Size</td><td>Max size in words</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>General Status</th><th>Extended Status</th><th>Detected by</th><th>Explanation and description</th></tr>
<tr><td>0x01</td><td>0x0127</td><td>Router
Target</td><td>INVALID ORIGINATOR TO TARGET NETWORK CONNECTION SIZE
This extended status code is returned by the target when the size of the consuming object declared in the Forward_Open request and available on the target does not match the size declared in the O⇒T Network Connection Parameter.
This extended status code is returned by a router when it cannot support the size requested in the O⇒T Network Connection Parameter.
An additional status word shall follow indicating the maximum originator to target size supported.
<table>
<tr><th>Data type</th><th>Value</th><th>Explanation of field</th></tr>
<tr><td>UINT</td><td>0x0127</td><td>Extended Status Code</td></tr>
<tr><td>UINT</td><td>Size</td><td>Max size in octets</td></tr>
</table></td></tr>
<tr><td>0x01</td><td>0x0128</td><td>Router
Target</td><td>INVALID TARGET TO ORIGINATOR NETWORK CONNECTION SIZE
This extended status code is returned by the target when the size of the producing object declared in the Forward Open request and available on the target does not match the size declared in the T⇒O Network Connection Parameter.
This extended status code is returned by a router when it cannot support the size requested in the T⇒O Network Connection Parameter.
An additional status word shall follow indicating the maximum target to originator size supported.
<table>
<tr><th>Data type</th><th>Value</th><th>Explanation of field</th></tr>
<tr><td>UINT</td><td>0x0128</td><td>Extended Status Code</td></tr>
<tr><td>UINT</td><td>Size</td><td>Max size in octets</td></tr>
</table></td></tr>
<tr><td>0x01</td><td>0x0129</td><td>Target</td><td>INVALID CONFIGURATION APPLICATION PATH
The configuration application path specified in the connection path does not correspond to a valid configuration application path within the target application. This error could also be returned if a configuration application path was required, but not provided by a connection request.</td></tr>
<tr><td>0x01</td><td>0x012A</td><td>Target</td><td>INVALID CONSUMING APPLICATION PATH
The consumed application path specified in the connection path does not correspond to a valid consumed application path within the target application. This error could also be returned if a consumed application path was required, but not provided by a connection request.</td></tr>
<tr><td>0x01</td><td>0x012B</td><td>Target</td><td>INVALID PRODUCING APPLICATION PATH
The produced application path specified in the connection path does not correspond to a valid produced application path within the target application. This error could also be returned if a produced application path was required, but not provided by a connection request.</td></tr>
<tr><td>0x01</td><td>0x012C</td><td>Target</td><td>CONFIGURATION SYMBOL DOES NOT EXIST
Configuration Symbol does not exist. The originator attempts to connect to a configuration tag name, but the name is not on the list of tags defined on the target.</td></tr>
<tr><td>0x01</td><td>0x012D</td><td>Target</td><td>CONSUMING SYMBOL DOES NOT EXIST
Consuming Symbol does not exist. The originator attempts to connect to a consuming tag name, but the name is not on the list of tags defined on the target.</td></tr>
<tr><td>0x01</td><td>0x012E</td><td>Target</td><td>PRODUCING SYMBOL DOES NOT EXIST
Producing Symbol does not exist. The originator attempts to connect to a producing tag name, but the name is not on the list of tags defined on the target.</td></tr>
<tr><td>0x01</td><td>0x012F</td><td>Target</td><td>INCONSISTENT APPLICATION PATH COMBINATION
The combination of configuration and/or consume and/or produce application paths specified in the connection path are inconsistent with each other.</td></tr>
</table>

General Status	Extended Status	Detected by	Explanation and description
0x01	0x0130	Target	INCONSISTENT CONSUME DATA FORMAT Information in the data segment is not consistent with the format of the consumed data. For example the configuration data specifies float configuration data while the consumed path specifies integer data.
0x01	0x0131	Target	INCONSISTENT PRODUCE DATA FORMAT Information in the data segment is not consistent with the format of the produced data. For example the configuration data specifies float configuration data while the produced path specifies integer data.
0x01	0x0132	Target	NULL FORWARD OPEN FUNCTION NOT SUPPORTED The target does not support the function requested by the Null Forward Open. The requested function may be "ping a device", "configure a device's application", or "reconfigure a target device's application".
0x01	0x0133	Target Router	CONNECTION TIMEOUT MULTIPLIER NOT ACCEPTABLE This extended status code shall be returned as the result of specifying a connection timeout multiplier value that is reserved or that produces a timeout value that is too large to support in the device.
0x01	0x0134	Target	MISMATCHED T⇒O NETWORK CONNECTION SIZE This extended status code shall be returned when an originator requests to open a Multicast connection to a T⇒O application path that is already being produced for another connection and the Size field in the T⇒O Network Connection Parameters in this request is valid but doesn't match the existing connection's Size field.
0x01	0x0135	Target	MISMATCHED T⇒O NETWORK CONNECTION FIXVAR This extended status code shall be returned when an originator requests to open a Multicast connection to a T⇒O application path that is already being produced for another connection and the Fixed/Variable bit in the T⇒O Network Connection Parameters in this request is valid but doesn't match the existing connection's Fixed/Variable bit.
0x01	0x0136	Target	MISMATCHED T⇒O NETWORK CONNECTION PRIORITY This extended status code shall be returned when an originator requests to open a Multicast connection to a T⇒O application path that is already being produced for another connection and the Priority field in the T⇒O Network Connection Parameters in this request is valid but doesn't match the existing connection's Priority field.
0x01	0x0137	Target	MISMATCHED TRANSPORT CLASS This extended status code shall be returned when an originator requests to open a Multicast connection to a T⇒O application path that is already being produced for another connection and the Transport Class in this request is valid but doesn't match the existing connection's Transport Class.
0x01	0x0138	Target	MISMATCHED T⇒O PRODUCTION TRIGGER This extended status code shall be returned when an originator requests to open a Multicast connection to a T⇒O application path that is already being produced for another connection and the T⇒O Production Trigger in this request is valid but doesn't match the existing connection's T⇒O Production Trigger.
0x01	0x0139	Target	MISMATCHED T⇒O PRODUCTION INHIBIT TIME SEGMENT This extended status code shall be returned when an originator requests to open a Multicast connection to an application path that is already being produced for another connection and the PIT in this request is valid but doesn't match the existing connection's PIT.
0x01	0x013A	Router Target	SERIAL NUMBER MISMATCH The Serial Number specified in the electronic key logical segment does not match the Serial Number of the device.
0x01	0x013B to 0x0202		Reserved
0x01	0x0203	Originator	CONNECTION TIMED OUT This extended status code shall occur when a connection has timed-out.

General Status	Extended Status	Detected by	Explanation and description
0x01	0x0204	Originator Router Target	UNCONNECTED REQUEST TIMED OUT An originator or router processing an Unconnected_Send, Forward_Open, Large_Forward_Open, or Forward_Close service shall return an Unconnected Request Timed Out error when the request cannot be delivered to the next device in the path (e.g the link specific retries fail), the allotted time is not sufficient to process the request, or no reply is received within the time specified by the Tick_time/Time-out_ticks parameters. A target processing a Forward_Open, Large_Forward_Open, or Forward_Close service may return an Unconnected Request Timed Out error when the allotted time is not sufficient to process the request. See 4.1.6.6 for more information.
0x01	0x0205	Router	PARAMETER ERROR IN UNCONNECTED REQUEST SERVICE For example, this shall be caused by a Connection Tick Time (see 4.1.6.6) and Connection time-out combination in an Unconnected_Send, Forward_Open, or Forward_Close service that is not supported by a router.
0x01	0x0206	Originator Router	MESSAGE TOO LARGE FOR UNCONNECTED_SEND SERVICE This shall be caused when the Unconnected_Send is too large to be sent out on a network.
0x01	0x0207	Originator Router	UNCONNECTED ACKNOWLEDGE WITHOUT RESPONSE The message was sent via the unconnected message service and an acknowledge was received but a data response message was not received.
0x01	0x0208	Target	THIS SERVICE REQUIRES A CONNECTION The message was sent via an unconnected message service but the message shall be sent over a connection.
0x01	0x0209 to 0x0300		Reserved
0x01	0x0301	Originator Router Target	NO BUFFER MEMORY AVAILABLE This extended status code shall occur when insufficient connection buffer memory is available in the device.
0x01	0x0302	Originator Router Target	LINK TRANSMIT TIME NOT AVAILABLE FOR DATA This extended status code shall be returned by any device in the path that is a producer and can not allocate sufficient link transmit time for the connection on its link. This can only occur for connections that are specified as scheduled priority.
0x01	0x0303	Originator Router Target	NO CONSUMED CONNECTION ID FILTER AVAILABLE Any device in the path that contains a link consumer for the connection and does not have an available consumed_connection_id filter available shall return this extended status code.
0x01	0x0304	Originator Router Target	NOT CONFIGURED TO SEND SCHEDULED PRIORITY DATA If requested to make a connection that specifies scheduled priority, any device that is unable to send packets during the scheduled portion of the network update time interval shall return this extended status code.
0x01	0x0305	Router	SCHEDULE SIGNATURE MISMATCH This extended status code shall be returned when the connection scheduling information in the originator device is not consistent with the connection scheduling information on the target network.
0x01	0x0306	Router	SCHEDULE SIGNATURE VALIDATION NOT POSSIBLE This extended status code shall be returned when the connection scheduling information in the originator device can not be validated on the target network.
0x01	0x0307	Router	STROBE OUTPUT NOT SUPPORTED Reserved for specific network communication profiles.
0x01	0x0308 to 0x0309		Reserved

General Status	Extended Status	Detected by	Explanation and description
0x01	0x0310	Router Target	PARTICIPANT CONNECTION OPEN At least one participant connection is open.
0x01	0x0311	Originator Router	PORT NOT AVAILABLE A Port specified in a Port Segment is Not Available or does not exist.
0x01	0x0312	Originator Router	LINK ADDRESS NOT VALID Link Address specified in Port Segment Not Valid This extended status code is the result of a port segment that specifies a link address that is not valid for the target network type. This extended status code shall not be used for link addresses that are valid for the target network type but do not respond.
0x01	0x0313	Router Target	DUPLICATE PARTICIPANT ID
0x01	0x0314	Router Target	PARTICIPANT ID NETWORK SEGMENT IS MISSING
0x01	0x0315	Originator Router Target	INVALID SEGMENT IN CONNECTION PATH Invalid Segment Type or Segment Value in Connection Path This extended status code is the result of a device being unable to decode the connection path. For example, this could be caused by an unrecognized path type or a segment type occurring unexpectedly. This extended status code shall only be used when no other more specific extended status code provided in this table applies.
0x01	0x0316	Router Target	FORWARD CLOSE SERVICE CONNECTION PATH MISMATCH The connection path in the Forward_Close service does not match the connection path in the connection being closed. This extended status error code has been "deprecated" because the Forward_Close service uses the connection triad for matching and doesn't use the connection path.
0x01	0x0317	Originator Router Target	SCHEDULING NOT SPECIFIED Either the Schedule Network Segment was not present or the Encoded Value in the Schedule Network Segment is invalid (i.e. 0).
0x01	0x0318	Originator Router	LINK ADDRESS TO SELF INVALID Under some conditions (depends on the device), a link address in the Port Segment which points to the same device (loopback to oneself) is invalid.
0x01	0x0319	Router Target	SECONDARY RESOURCES UNAVAILABLE In a dual chassis redundant system, a connection request that is made to the primary system shall be duplicated on the secondary system. If the secondary system is unable to duplicate the connection request, then this extended status code shall be returned.
0x01	0x031A	Target	RACK CONNECTION ALREADY ESTABLISHED A request for a module connection has been refused because part of the corresponding data is already included in a rack connection.
0x01	0x031B	Target	MODULE CONNECTION ALREADY ESTABLISHED A request for a rack connection has been refused because part of the corresponding data is already included in a module connection.
0x01	0x031C	Originator Router Target	MISCELLANEOUS This extended status is returned when no other extended status code applies for a connection related error.

General Status	Extended Status	Detected by	Explanation and description
0x01	0x031D	Target	REDUNDANT CONNECTION MISMATCH This extended status code shall be returned when the following fields do not match when attempting to establish a redundant owner connection to the same target path: O=>T_RPI; O=>T_connection_parameters; T=>O_RPI; T=>O_connection_parameters; xport_type_and_trigger.
0x01	0x031E	Target	NO MORE USER CONFIGURABLE LINK CONSUMER RESOURCES AVAILABLE IN THE PRODUCING MODULE A target shall return this extended status when the configured number of consumers for a producing application are already in use.
0x01	0x031F	Target	NO USER CONFIGURABLE LINK CONSUMER RESOURCES CONFIGURED IN THE PRODUCING MODULE A target shall return this extended status when there are no consumers configured for a producing application to use.
0x01	0x0320 to 0x07FF		Vendor specific
0x01	0x0800	Originator Router	NETWORK LINK OFFLINE Network link in path to module is offline
0x01	0x0801 to 0x080F		Reserved for IEC 61784-3-2
0x01	0x0810	Target	NO TARGET APPLICATION DATA AVAILABLE This extended status code is returned when the target application does not have valid data to produce for the requested connection.
0x01	0x0811	Originator	NO ORIGINATOR APPLICATION DATA AVAILABLE This extended status code is returned when the originator application does not have valid data to produce for the requested connection.
0x01	0x0812	Originator Router	NODE ADDRESS HAS CHANGED SINCE THE NETWORK WAS SCHEDULED A router on a scheduled network has a different node address than the value configured in the connection originator.
0x01	0x0813	Router Target	NOT CONFIGURED FOR OFF-SUBNET MULTICAST A multicast connection has been requested between a producer and a consumer that are on different subnets, and the producer is not configured for off-subnet multicast.
0x01	0x0814	Target	INVALID PRODUCE/CONSUME DATA FORMAT Information in the data segment indicates that the format of the produced and/or consumed data is not valid. NOTE This extended status code is "deprecated". It is highly recommended that 0x0130 or 0x0131 be used instead.
0x01	0x0815 to 0x0834		Reserved for IEC 61784-3-2
0x01	0x0835 to 0x08FF		Reserved
0x01	0x0900 to 0x09FF		Reserved for security related status
0x01	0x0A00	Target	UDP PORT FOR CLASS 0/1 NOT OPEN The UDP port required to open the requested Class 0 or Class 1 connection has been disabled.
0x01	0x0A01 to 0x0AFF		Reserved for specific network communication profiles.

General Status	Extended Status	Detected by	Explanation and description
0x01	0x0B00 to 0xFCFF		Reserved
0x01	0xFD00 to 0xFFFF		Reserved (not to be used)
0x02	Empty	Originator Router	RESOURCE UNAVAILABLE FOR UNCONNECTED_SEND The device lacks the resources to fully process the Unconnected Send Request.
0x04	Empty	Router	PATH SEGMENT ERROR IN UNCONNECTED SEND Indicates the Type 2 router experienced a parsing error when extracting the Explicit Messaging Request from the Unconnected Send Request Service Data.
0x09	Index to Element	Target	ERROR IN DATA SEGMENT. This general status code shall be returned when there is an error in the data segment of a forward open. The Extended Status shall be the index to where the error was encountered in the Data Segment (see 4.1.9.7).
0x0C	Optional	Target	OBJECT STATE ERROR This general status code shall be returned when the state of the target object of the connection prevents the service request from being handled. The Extended Status reports the object's present state. The extended status is optional. For example, a target (application) object of the connection can need to be in an edit mode before attributes can be set. This is different from a service being rejected due to the state of the device.
0x10	Optional	Router Target	DEVICE STATE ERROR This general status code shall be returned when the state of the device prevents the service request from being handled. The Extended Status reports the device's present state. The extended status is optional. For example, a controller may have a key switch which when set to the "hard run" state causes Service Requests to several different objects to fail (i.e. program edits). This general status code would then be returned.
0x13	None	Router Target	NOT ENOUGH DATA The service did not supply enough data to perform the specified operation.
0x15	None	Router Target	TOO MUCH DATA The service supplied more data than was expected.

4.1.11.2 OM errors

4.1.11.2.1 General status format

General status used in the service primitives is specified in Table 204.

Table 204 – General status codes

Status code	Name	Description and meaning of status code
0x00	Success	Service was successfully performed by the object specified
0x01	Communication related problem	A communications subsystem related problem was detected along the communications path. This general status code is unique, as all extended status codes are scoped at the device level instead of the object level. They are all documented in Table 203 (Connection Manager service request error codes).
0x02	Resource unavailable	Resources needed for the object to perform the requested service were unavailable
0x03	Invalid parameter value	See status code 0x20, which is the preferred value to use for this condition
0x04	Path segment error	The path segment identifier or the segment syntax was not understood by the processing node. Path processing shall stop when a path segment error is encountered
0x05	Path destination unknown	The path is referencing an object class, instance or structure element that is not known or is not contained in the processing node. Path processing shall stop when a path destination unknown error is encountered
0x06	Partial transfer	Only part of the expected data was transferred
0x07	Connection lost	The messaging connection was lost
0x08	Service not supported	The requested service was not implemented or was not defined for this class or object instance
0x09	Invalid attribute value	Invalid attribute data detected
0x0A	Attribute list error	An attribute in the Get_Attribute_List or Set_Attribute_List response has a non zero status
0x0B	Already in requested mode/state	The object is already in the mode/state being requested by the service
0x0C	Object state conflict	The object cannot perform the requested service in its current mode/state
0x0D	Object already exists	The requested instance of object to be created already exists
0x0E	Attribute not settable	A request to modify a non-modifiable attribute was received
0x0F	Privilege violation	A permission/privilege check failed
0x10	Device state conflict	The device's current mode/state prohibits the execution of the requested service
0x11	Response data too large	The data to be transmitted in the response buffer is larger than the allocated response buffer
0x12	Fragmentation of a primitive value	The service specified an operation that is going to fragment a primitive data value, i.e. half a REAL data type
0x13	Not enough data	The service did not supply enough data to perform the specified operation
0x14	Attribute not supported	The attribute specified in the request is not supported
0x15	Too much data	The service supplied more data than was expected
0x16	Object instance does not exist	The object instance specified does not exist in the device. This error code shall be used instead of 0x05 (Path Destination Unknown) when the class is supported but the specific instance does not exist.
0x17	Service fragmentation sequence not in progress	The fragmentation sequence for this service is not currently active for this data
0x18	No stored attribute data	The attribute data of this object was not saved prior to the requested service
0x19	Store operation failure	The attribute data of this object was not saved due to a failure during the attempt.

Status code	Name	Description and meaning of status code
0x1A	Routing failure, request packet too large	The service request packet was too large for transmission on a network in the path to the destination. The routing device was forced to abort the service
0x1B	Routing failure, response packet too largek	The service response packet was too large for transmission on a network in the path from the destination. The routing device was forced to abort the service
0x1C	Missing attribute list entry data	The service did not supply an attribute in a list of attributes that was needed by the service to perform the requested behavior
0x1D	Invalid attribute value list	The service is returning the list of attributes supplied with status information for those attributes that were invalid
0x1E	Embedded service error	An embedded service resulted in an error
0x1F	Vendor specific error	A vendor specific error has been encountered. The extended status code field of the error response defines the particular error encountered. Use of this general status code should only be performed when none of the status codes presented in this table or within an object class definition accurately reflect the error
0x20	Invalid parameter	A parameter associated with the request was invalid. This code is used when a parameter does not meet the requirements of this specification and/or the requirements defined in an application object specification
0x21	Write once value or medium already written	An attempt was made to write to a write once medium (e.g. WORM drive, PROM) that has already been written, or to modify a value that cannot be changed once established
0x22	Invalid Response Received	An invalid response is received (e.g. response service code does not match the request service code, or response message is shorter than the minimum expected response size). This status code can serve for other causes of invalid responses
0x23	Buffer overflow	The message received is larger than the receiving buffer can handle. The entire message was discarded.
0x24	Message format error	The format of the received message is not supported by the server.
0x25	Key Failure in path	The Key Segment which was included as the first segment in the path does not match the destination module. The extended status shall indicate which part of the key check failed (see Table 205).
0x26	Path Size Invalid	The size of the path which was sent with the Service Request is either not large enough to allow the Request to be routed to an object or too much routing data was included.
0x27	Unexpected attribute in list	An attempt was made to set an attribute that cannot be set at this time.
0x28	Invalid Member ID	The Member ID specified in the request does not exist in the specified Class/Instance/Attribute.
0x29	Member not settable	A request to modify a non-modifiable member was received.
0x2A	Group 2 only server general failure	Reserved for specific network communication profiles.
0x2B	Unknown Type 15 error	A Type 2 to Type 15 translator received an unknown Type 15 Exception Code
0x2C	Attribute not gettable	A request to read a non-readable attribute was received
0x2D	Instance not deletable	The requested object instance cannot be deleted
0x2E	Service not supported for specified path	The object supports the service, but not for the designated application path (e.g. attribute). This code shall not be used when a more specific General Status code applies, e.g. 0x0E (Attribute not settable) or 0x29 (Member not settable).
0x2F to 0xCF	Reserved	Reserved for future extensions

Status code	Name	Description and meaning of status code
0xD0 to 0xFF	Reserved for object class and service errors	This range of status codes shall be used to indicate object class specific errors. Use of this range should only be performed when none of the status codes presented in this table accurately reflect the error that was encountered

NOTE IEC 61158-5-2 contains more detail on the service response general status codes for each common service.

4.1.11.2.2 Extended status format

The MR_response_Header contains a parameter called Extended_status[] which is labeled extended status data.

Actual usage and definition of this extended status is dependant on the object class or service: each object class defines its own extended status values and value ranges (including the vendor specific ones), except for extended status "0x00FF" which shall not be used by any object due to its special meaning for some network communication profiles. For a given object class, extended status are unique to each general status code, with the exception of general status code 0x01. All extended status values are reserved unless otherwise indicated within the object definition.

Table 205 specifies the format of the extended status for a general status of "Key Failure in path" (0x25).

Table 205 – Extended status code for a general status of "Key Failure in path

General status code	Extended status code	Status name	Explanation and description
0x25	0x0114	VENDOR ID OR PRODUCT CODE MISMATCH	The Product Code or Vendor ID specified in the electronic key logical segment does not match the Product Code or Vendor ID of the target device. If the compatibility bit is set this extended status code is returned when the requested Vendor ID or Product Code is 0 or the device cannot emulate the specified Vendor ID or Product Code.
0x25	0x0115	DEVICE TYPE MISMATCH	The Device Type specified in the electronic key logical segment does not match the Device Type of the target device. If the compatibility bit is set this extended status code is returned when the requested Device Type is 0 or the device cannot emulate the specified Device Type. EXCEPTION: If the compatibility bit is set, Device Type 0 is allowed if the recipient can emulate a device that reports the deprecated Generic Device Type Number.
0x25	0x0116	REVISION MISMATCH	The major and minor revision specified in the electronic key logical segment does not correspond to a valid revision of the target device. If the compatibility bit is set this extended status code is returned when the requested Major revision and/or Minor revision is 0 or the device cannot emulate the specified revision.
0x25	0x013A	SERIAL NUMBER MISMATCH	The Serial Number specified in the electronic key logical segment does not match the Serial Number of the device.
NOTE These extended status codes are the same defined for the Connection Manager general status code 0x01.			

4.1.11.2.3 Object-specific general and extended status format

4.1.11.2.3.1 General

Subclause 4.1.11.2.3 specifies the format of object-specific general and extended status.

4.1.11.2.3.2 Identity object status format

Table 206 specifies the format of object-specific general and extended status for the Identity object.

Table 206 – Identity object status codes

General status code	8-bit associated extended status codes	Status Name	Description of Status
0x00 to 0xCF		General status codes	Defined in 4.1.11.2.1
	0x00 to 0xEE		Reserved extended status codes
	0xF0 to 0xFE	Vendor specific	Vendor specific extended status codes
	0xFF		Used with all general status codes when required and no other extended status code is assigned
0xD0		Hardware diagnostic	Device self testing and hardware diagnostic conditions
	0x00		Reserved
	0x01		Checksum (or CRC) error – Code space/ROM – Boot section
	0x02		Checksum (or CRC) error – Code space/ROM – Application section
	0x03		Checksum (or CRC) error – NV (flash/EEPROM) memory
	0x04		Invalid non-volatile (NV) memory – Configuration bad
	0x05		Invalid non-volatile (NV) memory – No configuration established
	0x06		RAM memory bad – The RAM memory in the device was determined to be experiencing inoperative cells
	0x07		ROM/Flash memory bad
	0x08		Flash/EEPROM (NV) Memory Bad
	0x09		Interconnect wiring error / signal path problem
	0x0A		Power problem – Over current
	0x0B		Power problem – Over voltage
	0x0C		Power problem – Under voltage
	0x0D		Internal sensor problem
	0x0E		System clock fault
	0x0F		Hardware configuration does not match NV configuration
	0x10		Watchdog disabled/idle
	0x11		Watchdog timer expired
	0x12		Device over temperature
	0x13		Ambient temperature outside of operating limits
	0x14 to 0xEF	(reserved)	Reserved
	0xF0 to 0xFE		Vendor specific extended status codes
	0xFF		Used with all general status codes when required and no other extended status code is assigned
0xD1		Device status/states	Device status events and conditions
	0x01		Power applied
	0x02		Device reset

General status code	8-bit associated extended status codes	Status Name	Description of Status
	0x03		Device power loss
	0x04		Activated
	0x05		Deactivated
	0x06		Enter self-test state
	0x07		Enter standby state
	0x08		Enter operational state
	0x09		Non-specific minor recoverable fault detected
	0x0A		Non-specific minor unrecoverable fault detected
	0x0B		Non-specific major recoverable fault detected
	0x0C		Non-specific major unrecoverable fault detected
	0x0D		Fault(s) corrected
	0x0E		CCV changed
	0x0F		Heartbeat interval changed
	0x10 to 0xEF	(reserved)	
	0xF0 to 0xFE	Vendor specific	Vendor specific
	0xFF		Used with all general status codes when required and no other extended status code is assigned
0xD2 to 0xEF		Object specific general status codes	Reserved – Not yet assigned
	0x00 to 0xFF	Reserved	
0xF0 to 0xFF		Vendor specific general status codes	A vendor specific error has been encountered. The extended status code field of the error response defines the particular error encountered. Use of this general status code should only be performed when none of the status codes presented in this table or within an object class definition accurately reflect the error
	0x00 to 0xFF	Vendor specific extended status codes	All extended status codes are available for association with each vendor specific general status code

4.2 Data abstract syntax specification

4.2.1 Transport format specification

The lower layers of open system architectures are concerned with the transport of user data among distributed functional units. In these layers, the user data can be regarded simply as a sequence of octets. However, application layer entities may manipulate the values of quite complex data types. To achieve independence between the application layer and lower layers, data types may be specified in an abstract syntax notation.

Supplementing the abstract syntax with one or more algorithms (called encoding rules) can determine the values of the lower layer octets which carry the application layer values. The combination of the abstract syntax with a single set of transfer rules produces a specific transfer syntax.

4.2.2 Abstract syntax notation

The data type definitions provided in this document shall be written in Abstract Syntax Notation One (ASN.1), as defined in ISO/IEC 8824-1. These type definitions shall be a part of the ASN.1 module "Network DataTypes." The beginning ASN.1 statement indicating that these definitions are in this module is:

```
control network DataTypes DEFINITIONS::= BEGIN
```

and the closing ASN.1 statement shall be the keyword "END".

The abstract definitions that follow shall comprise the set of control network data types. In addition, provision is made to extend or derive new data types based on existing defined types, and to include those in a "type dictionary."

4.2.3 Control network data specification

The notation [typeId] for directly derived, enumerated, subrange and structured bit string data shall mean that the tag shall be taken from the "type" field in the corresponding VariableDictionaryEntry.

```
Network Data::= CHOICE{ElementaryData, DerivedData}

ElementaryData::= CHOICE{
            BOOL,
            FixedLengthInteger,
            FixedLengthReal,
            AnyTime,
            AnyDate,
            AnyString,
            FixedLengthBitString,
            EPATH}

DerivedData::= CHOICE {
            DirectlyDerivedData,
            EnumeratedData,
            SubrangeData,
            StructuredBitStringData,
            ARRAY,
            STRUCT,
            FunctionBlockData}

DirectlyDerivedData::= [typeId] NetworkData

EnumeratedData::= [typeId] USINT

SubrangeData::= [typeId] FixedLengthInteger

StructuredBitStringData::= [typeId] FixedLengthBitString

FixedLengthInteger::= CHOICE {SignedInteger, UnsignedInteger}

SignedInteger::= CHOICE {SINT, INT, DINT, LINT}

UnsignedInteger::= CHOICE {USINT, UINT, UDINT, ULINT}

FixedLengthReal::= CHOICE {REAL, LREAL}

AnyTime::= CHOICE {ITIME,TIME, FTIME, LTIME, NTIME, STIME, UTIME}

AnyDate::= CHOICE {DATE, TIME_OF_DAY, DATE_AND_TIME}

AnyString::= CHOICE {STRING, STRING2}

FixedLengthBitString::= CHOICE {SWORD, WORD, DWORD, LWORD}

BOOL::= [PRIVATE 1] IMPLICIT BOOLEAN

SINT::= [PRIVATE 2] IMPLICIT OCTET STRING-- 1 octet

INT::= [PRIVATE 3] IMPLICIT OCTET STRING-- 2 octets
```

```
DINT::= [PRIVATE 4] IMPLICIT OCTET STRING-- 4 octets

LINT::= [PRIVATE 5] IMPLICIT OCTET STRING-- 8 octets

USINT::= [PRIVATE 6] IMPLICIT OCTET STRING-- 1 octet

UINT::= [PRIVATE 7] IMPLICIT OCTET STRING-- 2 octets

UDINT::= [PRIVATE 8] IMPLICIT OCTET STRING-- 4 octets

ULINT::= [PRIVATE 9] IMPLICIT OCTET STRING-- 8 octets

REAL::= [PRIVATE 10] IMPLICIT OCTET STRING-- 4 octets

LREAL::= [PRIVATE 11] IMPLICIT OCTET STRING-- 8 octets

STIME::= [PRIVATE 12] IMPLICIT ULINT

DATE::= [PRIVATE 13] IMPLICIT UINT

TIME_OF_DAY::= [PRIVATE 14] IMPLICIT UDINT

DATE_AND_TIME::= [PRIVATE 15] IMPLICIT SEQUENCE {
 time_of_day  UDINT,
 date  UINT }

STRING::= [PRIVATE 16] IMPLICIT SEQUENCE {
            charcount      UINT,
            stringcontents OCTET STRING} -- one octet per character

SWORD::= [PRIVATE 17] IMPLICIT OCTET STRING-- 1 octet

WORD::= [PRIVATE 18] IMPLICIT OCTET STRING-- 2 octets

DWORD::= [PRIVATE 19] IMPLICIT OCTET STRING-- 4 octets

LWORD::= [PRIVATE 20] IMPLICIT OCTET STRING-- 8 octets

STRING2::= [PRIVATE 21] IMPLICIT SEQUENCE {
            charcount      UINT,
            string2contents OCTET STRING} -- 2 octets/ character

FTIME::= [PRIVATE 22] IMPLICIT DINT

LTIME::= [PRIVATE 23] IMPLICIT LINT

ITIME::= [PRIVATE 24] IMPLICIT INT

STRINGN::= [PRIVATE 25] IMPLICIT SEQUENCE {
            charsize    UINT,
            charcount   UINT,
            stringNcontents OCTET STRING} -- N octets/ character

SHORT_STRING::= [PRIVATE 26] IMPLICIT SEQUENCE {
            charcount      USINT,
            stringcontents OCTET STRING} -- one octet per character

TIME        ::=   [PRIVATE 27] IMPLICIT DINT

EPATH       ::=   [PRIVATE 28] IMPLICIT OCTET STRING  -- IEC 61158-6-2

STRINGI     ::=   [PRIVATE 30] IMPLICIT SEQUENCE{
            Stringnum   USINT (number of strings)
            array of    STRUCT
            language1   USINT (first character from ISO 639-2/T)
            language2   USINT (second character from ISO 639-2/T)
            language3   USINT (third character from ISO 639-2/T)
            datatype    EPATH limited to the values 0xD0,0xD5,0xD9,and
0xDA)
            charset     UINT     from IANA MIB Printer Codes
(IETF RFC 1759))
            stringcontents    CHOICE OF (SHORT_STRING, STRING, STRING2,
                        or STRINGN) -- based on datatype field

NTIME::= [PRIVATE 31] IMPLICIT LINT
```

```
UTIME::= [PRIVATE 12] IMPLICIT ULINT

ARRAY::= SEQUENCE OF NetworkData -- All of same base type

STRUCT::= SEQUENCE OF NetworkData -- May be different types

FunctionBlockData::= SET{
            inputs  [0] IMPLICIT STRUCT OPTIONAL,
            outputs     [1] IMPLICIT STRUCT OPTIONAL,
            controlInputs  [2] IMPLICIT STRUCT OPTIONAL,
            controlOutputs [3] IMPLICIT STRUCT OPTIONAL}
```

4.2.4 Data type specification / dictionaries

The definition of an object may include text that defines attributes. Attributes shall be assigned a **Data Type** in an object specification. The Data Type may be one of those defined in this document or may be an object specific extension to this document. The following definition shall provide a **Type Specification** for data and shall provide a structure for extending or deriving new data types based on existing defined types.

```
Dictionary::= CHOICE {VariableDictionary, TypeDictionary}

VariableDictionary::= SEQUENCE OF VariableDictionaryEntry

VariableDictionaryEntry::= SEQUENCE{
            name  AnyString,
            id FixedLengthInteger,
            type  TypeID,
            ranges   SEQUENCE OF Subrange,  -- for arrays
            accessPrivilege   BOOL {READ_ONLY(0), READ_WRITE(1)}
TypeID::= OCTET STRING  -- ASN.1 encoded tag value of the

-- DataTypeSpecification module

Subrange::= SEQUENCE {
            minValue FixedLengthInteger,
            maxValue FixedLengthInteger}

TypeDictionary::= SEQUENCE OF TypeDictionaryEntry

TypeDictionaryEntry::= SEQUENCE {
            name  AnyString,
            type  TypeID,
            spec  DataTypeSpecification}
DataTypeSpecification::= CHOICE {
            alt       [PRIVATE 0] IMPLICIT AlternateTypeSpec,
            bool  [PRIVATE 1] IMPLICIT NULL, -- BOOL
            sint  [PRIVATE 2] IMPLICIT NULL, -- SINT
            int   [PRIVATE 3] IMPLICIT NULL, -- INT
            dint  [PRIVATE 4] IMPLICIT NULL, -- DINT
            lint  [PRIVATE 5] IMPLICIT NULL, --    LINT
            usint [PRIVATE 6] IMPLICIT NULL, --    USINT
            uint  [PRIVATE 7] IMPLICIT NULL, --    UINT
            udint [PRIVATE 8] IMPLICIT NULL, --    UDINT
            ulint [PRIVATE 9] IMPLICIT NULL, --    ULINT
            real  [PRIVATE 10]   IMPLICIT NULL, --    REAL
            lreal [PRIVATE 11]   IMPLICIT NULL, --    LREAL
            stime [PRIVATE 12]   IMPLICIT NULL, --    STIME
            date  [PRIVATE 13]   IMPLICIT NULL, --    DATE
            tod   [PRIVATE 14]   IMPLICIT NULL, --    TIME_OF_DAY
            dat   [PRIVATE 15]   IMPLICIT NULL, --    DATE_AND_TIME
            str1  [PRIVATE 16]   IMPLICIT NULL, --    STRING
            sword [PRIVATE 17]   IMPLICIT NULL, --    SWORD
            word  [PRIVATE 18]   IMPLICIT NULL, --    WORD
            dword [PRIVATE 19]   IMPLICIT NULL, --    DWORD
            lword [PRIVATE 20]   IMPLICIT NULL, --    LWORD
            str2  [PRIVATE 21]   IMPLICIT NULL, --    STRING2
```

```
            ftime [PRIVATE 22]   IMPLICIT NULL, --    FTIME
            ltime [PRIVATE 23]   IMPLICIT NULL, --    LTIME
            itime [PRIVATE 24]   IMPLICIT NULL, --    ITIME
            strN  [PRIVATE 25]   IMPLICIT NULL, --    STRINGN
            shstr [PRIVATE 26]   IMPLICIT NULL, --    SHORT_STRING
            time  [PRIVATE 27]   IMPLICIT NULL, --    TIME
            epath [PRIVATE 28]   IMPLICIT NULL, --    EPATH
            strI  [PRIVATE 30]   IMPLICIT NULL, -- STRINGI
            ntime [PRIVATE 31]   IMPLICIT NULL, --    NTIME
            utime [PRIVATE 32]   IMPLICIT NULL, --    UTIME
            constructedData   CHOICE {
               abbrvStruc  [0]   IMPLICIT AbbreviatedStrucTypeSpec,
               abbrvArr    [1]   IMPLICIT AbbreviatedArrayTypeSpec,
               frmlStruc   [2]   IMPLICIT FormalStrucTypeSpec,
               frmlArr     [3]   IMPLICIT FormalArrayTypeSpec,
               expBitStr   [4]   IMPLICIT ExpandedFixedLenBitStrTypeSpec,
               expStr1     [5]   IMPLICIT ExpandedStringTypeSpec,
               expStr2     [6]   IMPLICIT ExpandedString2TypeSpec
               frm1HandleStruc [7]  IMPLICIT  FormalHandleStrucTypeSpec}
}

AbbreviatedStrucTypeSpec::= UINT

AbbreviatedArrayTypeSpec::= DataTypeSpecification

FormalStrucTypeSpec::= SEQUENCE OF DataTypeSpecification

FormalHandleStrucTypeSpec::= SEQUENCE OF DataTypeHandleSpecification

DataTypeHandleSpecification::= DataTypeSpecification MemberHandle

MemberHandle::= USINT, UINT, UDINT
FormalArrayTypeSpec::= SEQUENCE { numberOfElements IMPLICIT
FixedLengthInteger, -- Array Number of Elements
            dataType    DataTypeSpecification }

ExpandedFixedLenBitStrTypeSpec::= SEQUENCE {
            bitStrType DataTypeSpecification    -- SWORD, WORD, DWORD, or
LWORD
            bitFields [7] IMPLICIT BitFieldDef}

BitFieldDef::= SEQUENCE OF {
            bitDef [2] IMPLICIT OCTET STRING}   -- Length is always 2
octets.
                                    -- First octet contains starting
                                    -- Bit Position. Trailing octet
                                    -- contains the number of bits.

ExpandedStringTypeSpec::= UINT-- String Length In Octets

ExpandedString2TypeSpec::= UINT-- String Length In Octets
AlternateTypeSpec::= CHOICE {
            directlyDerivedTypeSpec [0]   IMPLICIT    TypeID,
            subrangeTypeSpec        [1]   IMPLICIT    SubrangeTypeSpec ,

            enumeratedTypeSpec      [2]   IMPLICIT    EnumeratedTypeSpec,
            fbTypeSpec              [3]   IMPLICIT    FBTypeSpec}

SubrangeTypeSpec::= SEQUENCE{
            baseType    TypeID,     -- NOTE  minValue and maxValue
            minValue    FixedLengthInteger,  -- shall be within the range
            maxValue    FixedLengthInteger}  -- of baseType values

EnumeratedTypeSpec::= SEQUENCE OF AnyString
```

```
BitNameDefintion::= SEQUENCE {
            bitName  AnyString,
            bitNumber   USINT}
FBTypeSpec::= SET{
            inputs         [0] IMPLICIT FbtElementSpec OPTIONAL,
            outputs        [1] IMPLICIT FbtElementTypeSpec OPTIONAL,
            controlInputs  [2] IMPLICIT FbtElementTypeSpec OPTIONAL,
            controlOutputs [3] IMPLICIT FbtElementTypeSpec OPTIONAL}
FbtElementTypeSpec::= SEQUENCE OF ElementSpec
ElementSpec::= SEQUENCE {
            name     AnyString,
            typespec    ElementTypeSpec}
ElementTypeSpec::= CHOICE {
            [0] IMPLICIT TypeID,
            [1] IMPLICIT SubrangeTypeSpec,
            [2] IMPLICIT EnumeratedTypeSpec,
            [3] IMPLICIT FormalArrayTypeSpec,
            [4] IMPLICIT ExpandedStringTypeSpec,
            [5] IMPLICIT ExpandedString2TypeSpec}
```

The following END statement shall terminate the ASN.1 module opened in 4.1.

END.

4.3 Encapsulation abstract syntax

4.3.1 Encapsulation protocol

4.3.1.1 General

In order to send Type 2 TPDUs over TCP/IP and UDP, an encapsulation protocol is required. Subclause 4.3 defines the encapsulation protocol requirements. The encapsulation messages are defined such that they are independent of the underlying transport (TCP or UDP), with a few exceptions as indicated.

Clause 11 specifies how the encapsulation protocol is used to transport Type 2 TPDUs over TCP/IP or UDP for explicit and implicit communications.

4.3.1.2 TCP and UDP port numbers

The TCP port numbers defined in Table 207 are reserved with the Internet Assigned Numbers Authority (IANA) for use with the Type 2 Ethernet encapsulation protocol.

Table 207 – TCP port numbers

Port Number	Description
44818 (0xAF12)	Used for non-secure encapsulation of TPDUs
2221 (0x08AD)	Used in conjunction with TLS to provide a secure transport for encapsulation messages.[a]
[a] This usage is outside the scope of this document	

The UDP port numbers defined in Table 208 are reserved with the Internet Assigned Numbers Authority (IANA) for use with the Type 2 Ethernet encapsulation protocol.

Table 208 – UDP port numbers

Port Number	Description
44818 (0xAF12)	Used for non-secure encapsulation TPDUs and secure and non-secure UCMM and class 3 TPDUs
2221 (0x08AD)	Used in conjunction with DTLS to provide a secure transport for Forward_Open / Forward_Close, transport class 0 and class 1 TPDUs using the Common Packet Format.[a]
2222 (0x08AE)	Used Type 2 transport class 0 and class 1 TPDUs using the Common Packet Format.
[a] This usage is outside the scope of this document.	

4.3.2 Encapsulation messages

4.3.2.1 Encapsulation message structure

All encapsulation messages shall be composed of a fixed-length header of 24 octets followed by an optional data portion. The total encapsulation message length (including header) shall be limited to 65 535 octets. The encapsulation message length shall not override length restrictions imposed by the encapsulated protocol. Its structure shall be as shown in Figure 14, where the top of the diagram indicates the portion of the message sent first on the wire.

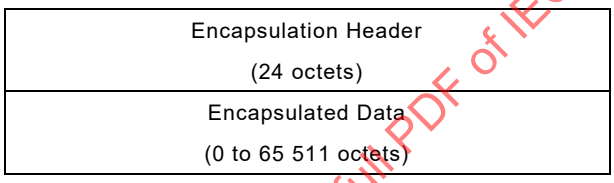


Figure 14 – Encapsulation message

The encapsulated data portion of the message is command specific and is required only for certain commands.

Multi-octet integer fields in encapsulation messages shall be transmitted as specified in 4.3.4.4 (i.e. using little endian octet ordering).

NOTE This is different from the octet ordering used in standard Internet network protocols, which is big endian.

4.3.2.2 Encapsulation header

The encapsulation header shall be as shown in Table 209.

Table 209 – Encapsulation header

Field name	Format	Description
Command	UINT	Encapsulation command
Length	UINT	Length, in octets, of the command specific data portion of the message, i.e., the number of octets following the header
Session handle	UDINT	Session identification (application dependent)
Status	UDINT	Status code
Sender context	ARRAY of 8 USHORT	Information pertinent only to the sender of an encapsulation command
Options	UDINT	Options flags

Although the header contains no explicit information to distinguish between a request and a reply, this information shall be determined in either of two ways:

- implicitly, by the command and the context in which the message is generated. (For example, in the case of the RegisterSession command, the request is generated by an originator and the target generates the reply);
- explicitly, by the contents of an encapsulated protocol packet in the data part of the message.

4.3.2.3 Command field

The allocation of command codes shall be as shown in Table 210.

Table 210 – Encapsulation command codes

Command code	Name
0x0000	NOP
0x0001 to 0x0003	Reserved for legacy usage[a]
0x0004	ListServices
0x0005	Reserved for legacy usage[a]
0x0006 to 0x0062	Reserved for future extensions[b]
0x0063	ListIdentity
0x0064	ListInterfaces
0x0065	RegisterSession
0x0066	UnRegisterSession
0x0067 to 0x006E	Reserved for legacy usage[a]
0x006F	SendRRData
0x0070	SendUnitData
0x0071 to 0x00C7	Reserved for legacy usage[a]
0x00C8	StartDTLS[c]
0x00C9 to 0xFFFF	Reserved for future extensions[b]

[a] Commands marked as "Reserved for legacy usage" indicate commands that were defined prior to the publication of this document. Their behavior is undefined in this document. Devices shall not implement these commands without prior knowledge of the legacy usage. Devices that do not support these commands shall return encapsulation status code 0x0001.

[b] Commands marked as "Reserved for future extensions" shall not be used.

[c] This command is outside the scope of this document.

If the encapsulation transport is TCP; a device shall accept commands that it does not support without breaking the session or underlying TCP connection. A status code indicating that an unsupported command was received shall be returned to the sender of the message (see 4.3.2.6).

The IP-layer transport (TCP or UDP) used for each of the encapsulation commands in Table 210 is dependent on the Type 2 Ethernet transport profile(s) the device implements.

NOTE Type 2 Ethernet transport profiles are defined in the Type 2 Ethernet Transports implementation profile, which is outside the scope of this document.

4.3.2.4 Length field

The length field in the header shall specify the size in octets of the data portion of the message. The field shall contain zero for messages that contain no data. The total length of a message shall be the sum of the number contained in the length field plus the 24-octet size of the encapsulation header.

When using TCP, the entire encapsulation message shall be read from the TCP/IP connection even if the length is invalid for a particular command or exceeds the host's internal buffers. Data that would exceed internal buffers may be discarded, however the entire encapsulation messages shall be read.

NOTE Failure to read the entire message can result in losing track of the message boundaries in the TCP octet stream.

4.3.2.5 Session handle field

The Session Handle shall be generated by the target and returned to the originator in response to a RegisterSession request. The originator shall insert it in all subsequent encapsulation command requests (sent using the commands listed in Table 210) which require sessions to that particular target. In the case where the target initiates and sends a command to the originator, the target shall include this field in the request that it sends to the originator.

NOTE Some commands (e.g. Nop) do not require a session handle, even if a session has been established. The specification of a particular command will indicate if it does not require a session.

4.3.2.6 Status field

The value in the Status field shall indicate whether or not the receiver was able to execute the requested encapsulation command. A value of zero in a reply shall indicate successful execution of the command. In all requests issued by the sender, the Status field shall contain zero. If the receiver receives a request with a non-zero Status field, the request shall be ignored and no reply shall be generated.

NOTE This field does not reflect errors that are generated by an encapsulated protocol packet contained within the data portion of the message. For example, an error encountered during an end node's processing of a Set Attributes service would be returned via the Type 2 specified error mechanism.

The status codes shall be as shown in Table 211.

Table 211 – Encapsulation status codes

Status code	Description
0x00	Success
0x01	The sender issued an invalid or unsupported encapsulation command.
0x02	Insufficient memory resources in the receiver to handle the command. This is not an application error. nstead, it only occurs if the encapsulation layer cannot obtain memory resources that it needs.
0x03	Poorly formed or incorrect data in the data portion of the encapsulation message.
0x04 to 0x63	Reserved for legacy usage[a]
0x64	An originator used an invalid session handle when sending an encapsulation message to the target.
0x65	The target received a message of invalid length (see 4.3.2.4).
0x66 to 0x68	Reserved for legacy usage[a]
0x69	Unsupported protocol version.
0x6A	Encapsulated Type 2 service not allowed on this port
0x6B to 0xFFFF	Reserved for future extensions[b]

[a] Status codes marked as "Reserved for legacy usage" indicate status codes that were defined prior to the publication of this document. Their usage is undefined in this document. Devices shall not use these status codes without prior knowledge of the legacy usage.

[b] Status codes marked as "Reserved for future extensions" shall not be used.

4.3.2.7 Sender context field

The sender of the command shall assign the value in the Sender Context field of the header. The receiver shall return this value without modification in its reply. Commands with no expected reply may ignore this field.

The sender of a command request may place any value in this field.

NOTE This field can be used to match requests with their associated replies.

4.3.2.8 Options field

The intent of this field is to provide the bits that modify the meaning of the various encapsulation commands. Options and option behavior are defined on a per-command basis.

4.3.2.9 Command specific data field

The structure of the command specific data field depends on the command code. To organize their command specific data field, most commands use either or both of the following two methods:

- use a fixed structure;
- use the common packet format (specified in 4.3.4).

The common packet format allows commands to structure their command specific data field in an extensible way.

4.3.3 Command descriptions

4.3.3.1 Nop

Either an originator or a target may send a Nop request. No reply shall be generated. The data portion of the request shall be from 0 to 65 511 octets long. The receiver shall ignore any data that is contained in the message. A Nop request does not require that a session be established.

NOTE A Nop provides a way for either an originator or target to determine if the TCP connection is still open.

The Nop request encapsulation header shall be as shown in Table 212.

Table 212 – Nop request encapsulation header

Field name	Data type	Field value
Command	UINT	Nop (0x00)
Length	UINT	Length of the command specific data
Session handle	UDINT	Any value (ignored by target)
Status	UDINT	0 [a]
Sender context	ARRAY of 8 USHORT	Chosen by sender
Options	UDINT	0

[a] For backwards compatibility, no options shall be defined for this command. The receiver shall discard packets with a non-zero option field.

4.3.3.2 RegisterSession

4.3.3.2.1 General

An originator shall send a RegisterSession request to a target to initiate a session. The RegisterSession command does not require that a session be established.

NOTE See 11.7 for detailed information on establishing and maintaining a session.

4.3.3.2.2 Request

The RegisterSession request encapsulation header shall be as shown in Table 213.

Table 213 – RegisterSession request encapsulation header

Field name	Data type	Field value
Command	UINT	RegisterSession (0x65)
Length	UINT	4
Session handle	UDINT	Any value (ignored by target)
Status	UDINT	0
Sender context	ARRAY of 8 USHORT	Any value
Options	UDINT	0 [a]

[a] For backwards compatibility, no options shall be defined for this command. The receiver shall discard packets with a non-zero option field.

The parameters in the data portion shall determine the version of the protocol and any session options as shown in Table 214. The protocol version shall be set to 1. No option flags are currently defined, so the session options flags shall be set to 0.

NOTE This options flags field is not the same as the options flags in the encapsulation header.

Table 214 – RegisterSession request data portion

Field	Data type	Description
Protocol version	UINT	Requested protocol version (1)
Options flags	UINT	Session options (0)

4.3.3.2.3 Reply

The target shall send a RegisterSession reply to indicate that it has registered the originator. The reply shall have the same format as the request as shown in Table 215.

Table 215 – RegisterSession reply encapsulation header

Field name	Data type	Field value
Command	UINT	RegisterSession (0x65)
Length	UINT	4
Session handle	UDINT	Session handle generated by target
Status	UDINT	0
Sender context	ARRAY of 8 USHORT	Value from request
Options	UDINT	0 [a]

[a] For backwards compatibility, no options shall be defined for this command. The receiver shall discard packets with a non-zero option field.

The Session Handle field of the header shall contain a target-generated identifier that the originator shall save and insert in the Session Handle field of the header for all subsequent requests to that target. This field shall be valid only if the Status field is zero (0).

The Sender Context field of the header shall contain the same values present in the original sender request.

If the originator was successfully registered with the target, the Status field shall be zero (0). If the originator was not successfully registered, the Status field shall contain the appropriate status code, as follows:

- status code 0x0001 shall be returned if the originator attempts to register more than 1 active session on the same TCP connection;
- status code 0x0002 shall be returned if the target does not have sufficient resources to register the originator;
- other status codes from Table 211 may be used as appropriate for general encapsulation related errors (e.g., poorly formed encapsulation message, invalid length);
- status code 0x0069 shall be returned for Protocol Version or Options mismatches, as described below.

The data portion of the reply shall have the same format as the request as shown in Table 216.

Table 216 – RegisterSession reply data portion (successful)

Field	Data type	Description
Protocol Version	UINT	Version from RegisterSession request if supported. If the requested version is not supported, contains the highest version supported.
Options	UINT	Options flags from RegisterSession request if supported. If any requested Options flags are not supported, contains the supported Options flags.

The Protocol Version field shall equal the requested version if the originator was successfully registered. If the target does not support the requested version of the protocol:

- the session shall not be created;
- the Status field shall be set to "unsupported encapsulation protocol" (0x0069);
- the target shall return the highest supported version in the Protocol Version field.

At present, no Options flags are defined. In order to support their future definition, targets shall check the value of the Options flags in the RegisterSession request. If all requested options are supported, the Options field in the reply shall contain the originator's requested value. If the target does not support the requested options:

- the session shall not be created;
- the Status field shall be set to "unsupported encapsulation protocol" (0x0069);
- the target shall return the options that it supports in the RegisterSession reply.

4.3.3.3 UnRegisterSession

Either an originator or a target may send this request to terminate the session. The receiver shall initiate a close of the underlying TCP/IP connection when it receives this request. The session shall also be terminated when the transport connection between the originator and target is terminated. The receiver shall perform any other associated cleanup required on its end. There shall be no reply to this command, except in the event that the command is received via UDP. If the command is received via UDP, the receiver shall reply with encapsulation status code 0x0001 (invalid or unsupported command).

The UnregisterSession request format shall be as shown in Table 217.

Table 217 – UnRegisterSession request encapsulation header

Field name	Data type	Field value
Command	UINT	UnRegisterSession (0x65)
Length	UINT	4
Session Handle	UDINT	Session handle from RegisterSession
Status	UDINT	0
Sender Context	ARRAY of 8 USHORT	Any value (ignored by target)
Options	UDINT	0 [a]

[a] For backwards compatibility, no options shall be defined for this command. The receiver shall discard packets with a non-zero option field.

The receiver shall not reject the UnRegisterSession due to unexpected values in the encapsulation header (invalid Session Handle, non-zero Status, non-zero Options, or additional command data). In all cases the TCP connection shall be closed.

NOTE See 11.7.2.3 for more details about terminating a session.

4.3.3.4 ListServices

4.3.3.4.1 General

The ListServices request shall be sent to determine which encapsulation service classes the target device supports. The ListServices command does not require that a session be established.

NOTE Each service class has a unique type code, and an optional ASCII name.

4.3.3.4.2 Request

The ListServices request encapsulation header shall be as shown in Table 218.

Table 218 – ListServices request encapsulation header

Field name	Data type	Field value
Command	UINT	ListServices (0x04)
Length	UINT	0
Session handle	UDINT	Any value (ignored by target)
Status	UDINT	0
Sender context	ARRAY of 8 USHORT	Chosen by sender
Options	UDINT	0 [a]

[a] For backwards compatibility, no options shall be defined for this command. The receiver shall discard packets with a non-zero option field.

4.3.3.4.3 Reply

The receiver shall reply with an encapsulation message consisting of the header and data, as shown in Table 219 and Table 220. The data portion of the reply shall provide the information on the services supported.

Table 219 – ListServices reply encapsulation header

Field name	Data type	Field value
Command	UINT	ListServices (0x04)
Length	UINT	Length of the command specific data
Session handle	UDINT	Any value (ignored by receiver)
Status	UDINT	0
Sender context	ARRAY of 8 USHORT	Value from request
Options	UDINT	0 [a]

[a] For backwards compatibility, no options shall be defined for this command. The receiver shall discard packets with a non-zero option field.

The data portion of the reply shall contain a 2-octet item count followed by an array of items describing the service(s) provided, as shown in Table 220.

Table 220 – ListServices reply data portion (successful)

Field name	Data type	Description
Item count	UINT	Number of items to follow
Target items	STRUCT of	Interface information
	UINT	Item ID
	UINT	Item length
	UINT	Version of encapsulated protocol (shall be set to 1)
	UINT	Capability Flags
	ARRAY of 16 USINT	Name of service

The Item ID shall identify the service class. One service class is defined, with type code 0x100 and name "Communications". This service class shall indicate that the device supports encapsulation of Type 2 PDU's. All devices that support Type 2 PDU encapsulation shall support the ListServices command and Communications service class.

NOTE See 4.3.4 for a description of items and a list of all reserved item codes.

The Version field shall indicate the version of the service supported by the target to help maintain compatibility between applications.

Each service shall have a different set of capability flags. Reserved flags shall be set to zero.

The Capability Flags, defined for the Communications service, shall be as shown in Table 221.

Table 221 – Communications capability flags

Flag value	Description
Bits 0 to 4	Reserved for legacy usage [a]
Bit 5	If the device supports Type 2 PDU encapsulation this bit shall be set (= 1); otherwise, it shall be clear (= 0)
Bits 6 to 7	Reserved for legacy usage [a]
Bit 8	Supports transport class 0 or 1 UDP-based connections
Bits 9 to 15	Reserved for future extensions

[a] Flag marked as "Reserved for legacy usage" indicate flags that were defined prior to the publication of this document. Their usage is undefined in this document. Devices shall not use these flags without prior knowledge of the legacy usage. If a device receives a reserved flag that it does not understand, the reply shall be processed and the flag ignored.

The Name field shall allow up to a 16-octet, NULL-terminated ASCII string for descriptive purposes only. The 16-octet limit shall include the NULL character.

4.3.3.5 ListIdentity

4.3.3.5.1 General

A connection originator may use the ListIdentity request to locate and identify potential targets. This request shall be sent as a unicast message using TCP or UDP, or as a broadcast message using UDP and does not require that a session be established. The reply shall always be sent as a unicast message.

When received as a broadcast message, the receiving device shall delay for a pseudo-random period of time prior to sending the reply as specified below. Delaying before sending the reply helps to spread out any resulting ARP requests and ListIdentity replies from target devices on the network.

4.3.3.5.2 Request

The ListIdentity request encapsulation header shall be as shown in Table 222.

Table 222 – ListIdentity request encapsulation header

Field name	Data type	Field value
Command	UINT	ListIdentity (0x63)
Length	UINT	0
Session handle	UDINT	Any value (ignored by target)
Status	UDINT	0
Sender context	UINT	MaxResponseDelay in ms, see below
	ARRAY of 6 USHORT	Reserved, shall be ignored by the receiver, values shall be 0
Options	UDINT	0 [a]

[a] For backwards compatibility, no options shall be defined for this command. The receiver shall discard packets with a non-zero option field.

4.3.3.5.3 Reply

Several reply items are defined for this command. The CFP 2 Identity item shall be supported (returned) by all Type 2 devices.

A receiver of the ListIdentity command shall reply with an encapsulation message consisting of the header and applicable data items, as shown in Table 223 and Table 224. The reply shall be sent to the IP address from which the request was received.

When the ListIdentity request has been received as a UDP broadcast message, the receiver shall delay before sending the reply. When received as a unicast message (either via UDP or TCP), the receiver shall not delay.

The receiver's delay shall be a random value, in milliseconds, between 0 and the MaxResponseDelay specified in the ListIdentity request. If the sender specifies a MaxResponseDelay value of 0 ms, a default value of 2 000 ms shall be used by the receiver. If the sender specifies a MaxResponseDelay value of 1 ms to 500 ms, a value of 500 ms shall be used by the receiver. A new random value shall be chosen for each request.

The purpose of the delay is to spread the ListIdentity responses (and the ARP messages that can result) over the MaxResponseDelay interval. It is therefore important that each device generate a unique random delay value. Devices shall ensure they each generate a unique value, for example by seeding their random number generators with a unique value such as their IP address or Ethernet MAC address.

It is possible that devices receive additional broadcast ListIdentity requests while delaying for the response, for example, if multiple clients issue the broadcast ListIdentity request. Devices should be able to accept and process at least 2 outstanding broadcast ListIdentity requests concurrently.

After issuing a broadcast ListIdentity request, a client should not issue further requests until the MaxResponseDelay interval for its current request has expired. Client behavior for handling ListIdentity responses received beyond MaxResponseDelay is vendor specific.

Table 223 – ListIdentity reply encapsulation header

Field name	Data type	Field value
Command	UINT	List Identity (0x63)
Length	UINT	Length of the command specific data
Session handle	UDINT	Any value (ignored by receiver)
Status	UDINT	0
Sender context	ARRAY of 8 USHORT	Value from request
Options	UDINT	0 [a]

[a] For backwards compatibility, no options shall be defined for this command. The receiver shall discard packets with a non-zero option field.

The data portion of the reply is structured as a Common Packet Format that contains a 2-octet item count followed by an array of items (see Table 224), providing the target identity as a minimum.

Table 224 – ListIdentity reply data portion (successful)

Field name	Data type	Field value
Item count	UINT	Number of target items to follow
Target items	STRUCT of	
	UINT	Item ID
	UINT	Item length
	ARRAY of octets	Item data

The CFP 2 Identity item shall be the first item returned and has the format as defined in Table 225. Part of this item definition follows the Get Attribute All service response definition of the Identity object (data returned based on instance one of this object). Unlike most fields in the Common Packet Format, the Socket Address field shall be sent in big endian order.

Clients should be aware that, while the Socket Address information supplied in the Type 2 Identity item is accurate from the perspective of the device sending the response, it could be not accurate from the perspective of the client if address translation such as NAT is used between the client and the device.

Two additional items are defined, the Type 2 Security Information item and the Type 2 Ethernet Capability item.

NOTE 1 The Type 2 Security Information item is outside the scope of this document.

Receivers of the ListIdentity reply shall ignore unexpected items.

Table 225 – Type 2 identity item

Field name	Data type	Description
Item ID	UINT	Item ID of Type 2 Identity (0x0C)
Item length	UINT	Number of octets in item which follows (length varies depending on Product Name string)
Version	UINT	Encapsulation protocol version supported (also returned with Register Session reply)
Socket Address	STRUCT of:	Socket Address describing the device's Encapsulation interface
sin_family	INT	Shall be AF_INET = 2. This field shall be sent in big endian order.
sin_port	UINT	Shall be 0xAF12 (TCP port number for the unsecured Encapsulation protocol). This field shall be sent in big endian order. Notice that this port may be closed on secure devices, but shall still be returned in this field.
sin_addr	UDINT	Shall be the IPv4 address of the IP interface in this device that is responding to the request. This field shall be sent in big endian order.
sin_zero	ARRAY of USINT	Length of 8. Should be set to zero by sender. Ignored by receiver.
Vendor ID[a]	UINT	Device manufacturers Vendor ID
Device Type[a]	UINT	Device Type of product
Product Code[a]	UINT	Product Code assigned with respect to device type
Revision[a]	USINT[2]	Device revision
Status[a]	WORD	Current status of device
Serial Number[a]	UDINT	Serial number of device
Product Name[a]	SHORT_STRING	Human readable description of device
State[b]	USINT	Current state of device

[a] These parameters are further defined by the corresponding instance attribute of the Identity object.

[b] The State attribute is an optional attribute of the Identity Object. If not implemented, the value shall be 0xFF.

The Type 2 Ethernet Capability item has the format as defined in Table 226. It may be used to define Type 2 Ethernet transport capabilities for the various message types for a device.

Table 226 – Type 2 Ethernet Capability item

Field name	Data type	Description
Item ID	UINT	Item ID of Type 2 Ethernet Capability (0x87)
Item length	UINT	Number of octets = 4
Type 2 Ethernet transport profile	DWORD	This field provides a list of transport options available on TCP and UDP (UCMM, Type 2 class 0, 1, 2 and 3 connections). It is equivalent to the Features Supported member definition of the Type 2 Ethernet Transports implementation profile.

This item is required for devices that implement some Type 2 Ethernet transport profiles.

NOTE 2 Type 2 Ethernet transport profiles are defined in the Type 2 Ethernet Transports implementation profile, which is outside the scope of this document.

4.3.3.6 ListInterfaces

4.3.3.6.1 General

The optional ListInterfaces request shall be used by a connection originator to identify non-Type 2 communication interfaces associated with the target. A session need not be established to send this command.

4.3.3.6.2 Request

The ListInterfaces request encapsulation header shall be as shown in Table 227.

Table 227 – ListInterfaces request encapsulation header

Field name	Data type	Field value
Command	UINT	List Interfaces (0x64)
Length	UINT	0
Session handle	UDINT	Any value (ignored by target)
Status	UDINT	0
Sender context	ARRAY of 8 USHORT	Chosen by sender
Options	UDINT	0 [a]

[a] For backwards compatibility, no options shall be defined for this command. The receiver shall discard packets with a non-zero option field.

4.3.3.6.3 Reply

If supported, the receiver of a ListInterfaces request command shall reply with an encapsulation message consisting of the header and data, as shown below in Table 228.

Table 228 – ListInterfaces reply encapsulation header

Field name	Data type	Field value
Command	UINT	List Interfaces (0x64)
Length	UINT	Length of the command specific data
Session handle	UDINT	Any value (ignored by receiver)
Status	UDINT	0
Sender context	ARRAY of 8 USHORT	Value from request
Options	UDINT	0 [a]

[a] For backwards compatibility, no options shall be defined for this command. The receiver shall discard packets with a non-zero option field.

The data portion of the reply contains an array of items providing interface information. It is structured as a Common Packet Format, which contains a 2-octet item count followed by an array of items.

At present no public items are defined for the ListInterfaces reply. If no items are included, the Item Count shall be set to 0.

Some legacy devices may return "Reserved for legacy usage items" (see 4.3.4). Such items shall be ignored unless the receiving device has explicit knowledge of the legacy format and usage.

4.3.3.7 SendRRData

4.3.3.7.1 General

A SendRRData request shall transfer an encapsulated request/reply packet between the originator and target, where the originator initiates the command. The actual request/reply packets shall be encapsulated in the data portion of the message and shall be the responsibility of the target and originator.

NOTE When used to encapsulate Type 2 PDU's, the SendRRData request and reply are used to send encapsulated UCMM messages (see Clause 11).

4.3.3.7.2 Request

The SendRRData request encapsulation header shall be as shown in Table 229.

Table 229 – SendRRData request encapsulation header

Field name	Data type	Field value
Command	UINT	SendRRData (0x6F)
Length	UINT	Length of the command specific data
Session handle	UDINT	TCP: Session handle UDP: 0
Status	UDINT	0
Sender context	ARRAY of 8 USHORT	Chosen by sender
Options	UDINT	0 [a]

[a] For backwards compatibility, no options shall be defined for this command. The receiver shall discard packets with a non-zero option field.

The data portion of the message shall contain request parameters and the encapsulated protocol packet as shown in Table 230.

Table 230 – SendRRData request data portion

Field name	Data type	Description
Interface handle	UDINT	Shall be 0
Timeout	UINT	Operation Timeout (0 to 65 535)
Encapsulated protocol packet	ARRAY of octets	See Common Packet Format specification in 4.3.4

The Interface handle shall identify the Communications Interface to which the request is directed. This handle shall be 0 for encapsulating Type 2 PDUs.

The target shall abort the requested operation after the timeout expires. When the "Timeout" field is in the range 1 to 65 535, the timeout shall be set to this number of seconds. When the "Timeout" field is set to 0, the encapsulation protocol shall not have its own timeout. Instead, it shall rely on the timeout mechanism of the encapsulated protocol.

When the SendRRData command is used to encapsulate Type 2 PDU's, the Timeout field shall be set to 0, and shall be ignored by the target.

The encapsulated protocol packet shall be encoded in a Common Packet Format as shown in 4.3.4.

4.3.3.7.3 Reply

The SendRRData reply, as shown in Table 231, shall contain data in response to the SendRRData request. The reply to the original encapsulated protocol request shall be contained in the data portion of the SendRRData reply.

Table 231 – SendRRData reply encapsulation header

Field name	Data type	Field value
Command	UINT	SendRRData (0x6F)
Length	UINT	Length of the command specific data
Session handle	UDINT	Value from request
Status	UDINT	0
Sender context	ARRAY of 8 USHORT	Value from request
Options	UDINT	0 [a]

[a] For backwards compatibility, no options shall be defined for this command. The receiver shall discard packets with a non-zero option field.

The format of the data portion of the reply message shall be the same as that of the SendRRData request message. Since the request and reply share a common format, the reply message contains a Timeout field; however, it is not used.

4.3.3.8 SendUnitData

The SendUnitData request shall send encapsulated connected messages. A reply need not be returned. This command may be used when the encapsulated protocol has its own underlying end-to-end transport mechanism. The SendUnitData request may be sent by either end of the TCP connection.

NOTE When used to encapsulate Type 2 PDU's, the SendUnitData command is used to send Type 2 connected data in both the O⇒T and T⇒O directions.

The format of the SendUnitData request shall be as shown in Table 232.

Table 232 – SendUnitData request encapsulation header

Field name	Data type	Field value
Command	UINT	SendUnitData (0x70)
Length	UINT	Length of data portion
Session handle	UDINT	TCP: Session handle UDP: 0
Status	UDINT	0
Sender context	ARRAY of 8 USHORT	Any value (ignored by target)
Options	UDINT	0 [a]

[a] For backwards compatibility, no options shall be defined for this command. The receiver shall discard packets with a non-zero option field.

The data portion of the message shall contain request parameters as well as the encapsulated protocol packet as shown in Table 233.

Table 233 – SendUnitData request data portion

Field name	Data type	Description
Interface handle	UDINT	Shall be 0
Timeout	UINT	Operation timeout (shall be 0)
Encapsulated protocol packet	ARRAY of octets	See Common Packet Format specification in 4.3.4

Interface handle and Timeout shall be set to zero. The timeout field is not used since no reply is generated upon receipt of a SendUnitData command.

4.3.4 Common packet format

4.3.4.1 General

The common packet format (CPF) defines a standard format for protocol packets that are transported with the encapsulation protocol. The common packet format is a general-purpose mechanism designed to accommodate future packet or address types.

The common packet format shall consist of an item count, followed by a number of items (see Table 234). Some items are classified as "address items" (carries addressing information) or "data items" (carries encapsulated data). The number of items to be included depends on the encapsulation command and usage of the command. Subclause 4.3.4.4 specifies the valid Common Packet Format items for the various commands and usages.

Table 234 – Common packet format

Field name	Data type	Description
Item count	UINT	Number of items to follow
Item #1	Item Struct (see below)	First CPF item
Item #2	Item Struct (see below)	Second CPF item
…	…	…
Item #n	Item Struct (see below)	n^{th} CPF item

The address and data item structure shall be as shown in Table 235.

Table 235 – CPF item format

Field name	Data type	Description
Type ID	UINT	Type of item encapsulated
Length	UINT	Length in octets of data to follow
Data	Variable	The data (if length >0)

The item type ID numbers shall be as shown in Table 236.

Table 236 – Item Type ID numbers

Item ID number	Item type	Description
0x0000	address	Null (used for UCMM messages). Indicates that encapsulation routing is NOT needed. Target is either local (Ethernet) or routing info is in a data item.
0x0001 to 0x000B		Reserved for legacy usage[a]
0x000C		Type 2 Identity (see 4.3.3.5.3 for item definition)
0x000D to 0x0085		Reserved for legacy usage[a]
0x0086		Type 2 Security Information[c]
0x0087		Type 2 Ethernet Capability (see 4.3.3.5.3 for item definition)
0x0088 to 0x0090		Reserved for future extensions[b]
0x0091		Reserved for legacy usage[a]
0x0092 to 0x00A0		Reserved for future extensions[b]
0x00A1	address	Connection-based (used for connected messages)
0x00A2 to 0x00A4		Reserved for legacy usage[a]
0x00A5 to 0x00B0		Reserved for future extensions[b]
0x00B1	data	Connected Transport packet
0x00B2	data	Unconnected message
0x00B3 to 0x00FF		Reserved for future extensions[b]
0x0100		ListServices response (see 4.3.3.4.3 for item definition)
0x0101 to 0x010F		Reserved for legacy usage[a]
0x0110 to 0x7FFF		Reserved for future extensions[b]
0x8000	data	Sockaddr Info, originator-to-target
0x8001	data	Sockaddr Info, target-to-originator
0x8002		Sequenced Address item
0x8003 to 0xFFFF		Reserved for future extensions[b]

[a] Items marked as "Reserved for legacy usage" indicate Item IDs that were defined prior to the publication of this document. Their behavior is undefined in this document. Devices shall not use these Item IDs without prior knowledge of the legacy usage.

[b] Products compliant with this specification shall not use command codes in this range

[c] This is outside the scope of this document.

4.3.4.2 Address items

4.3.4.2.1 Null

The null address item shall contain only the type id and the length as shown in Table 237. The length shall be zero. No data shall follow the length. Since the null address item contains no routing information, it shall be used when the protocol packet itself contains any necessary routing information. The null address item shall be used for Unconnected Messages.

Table 237 – Null address item

Field name	Data type	Field value
Type ID	UINT	0
Length	UINT	0

4.3.4.2.2 Connected

This address item shall be used when the encapsulated protocol is connection-oriented. The data shall contain a connection identifier, as shown in Table 238.

NOTE Connection identifiers are exchanged in the Forward_Open service of the Connection Manager.

Table 238 – Connected address item

Field name	Data type	Field value
Type ID	UINT	0xA1
Length	UINT	4
Data	UDINT	Connection Identifier

4.3.4.2.3 Sequenced address item

This address item shall be used for class 0 and class 1 connected data. The data shall contain a connection identifier and an Encapsulation Sequence Number, as shown in Table 239. Usage is further described in 11.3.3.

Table 239 – Sequenced address item

Field name	Data type	Field value
Type ID	UINT	0x8002
Length	UINT	8
Data	UDINT	Connection Identifier
	UDINT	Encapsulation Sequence Number

4.3.4.3 Data items

4.3.4.3.1 Unconnected

The data item that encapsulates an unconnected message shall be as shown in Table 240.

Table 240 – Unconnected data item

Field name	Data type	Field value
Type ID	UINT	0xB2
Length	UINT	Length, in octets, of the unconnected message
Data	Variable	The unconnected message

The format of the "data" field is dependent on the encapsulated protocol. When used to encapsulate Type 2 PDU's, the format of the "data" field shall be the same as PDU destined for the Message Router. The UCMM header, defined in 4.1.3, shall not be present. The context field in the encapsulation header shall be used for unconnected request/reply matching.

4.3.4.3.2 Connected

The data item that encapsulates a connected transport PDU shall be as shown in Table 241.

Table 241 – Connected data item

Field name	Data type	Field value
Type ID	UINT	0xB1
Length	UINT	Length, in octets, of the transport PDU
Data	Variable	The transport PDU

The format of the "data" field is dependent on the encapsulated protocol. When used to encapsulate Type 2 PDU's, the format of the "data" field shall be the same as the connected transport PDU.

4.3.4.3.3 Sockaddr info

The Sockaddr Info items shall be used to communicate IP address or port information necessary to create Class 0 or Class 1 connections. There are separate items for originator-to-target and target-to-originator socket information. The items are present as additional data in Forward_Open / Large_Forward_Open request and reply services encapsulated in a SendRRData message. Subclause 11.2.4 specifies the usage of these items in the context of creating Type 2 connections.

The Sockaddr Info items shall have the structure shown in Table 242.

Table 242 – Sockaddr info items

Field name	Data type	Field value
Type ID	UINT	0x8000 for O⇒T, 0x8001 for T⇒O
Length	UINT	16 (octets)
sin_family	INT	Shall be AF_INET = 2. This field shall be sent in big endian order
sin_port	UINT	For point-point connections, sin_port shall be set to the UDP port to which packets for this Type 2 connection will be sent. For point-point connections, it is recommended that the registered UDP port (0x8AE) be used. When used with a multicast connection, the sin_port field shall be set to the registered UDP port number (0x08AE) and treated by the receiver as "don't care". This field shall be sent in big endian order
sin_addr	UDINT	For multicast connections, sin_addr shall be set to the IP multicast address to which packets for this Type 2 connection will be sent. When used with a point-point connection, the sin_addr field shall be treated by the receiver as "don't care". It is recommended that the sender set sin_addr to 0 for point-point connections. This field shall be sent in big endian order.
sin_zero	ARRAY of 8 USINT	Recommended value of zero; not enforced

Theformat of the Sockaddr Info item has been patterned after the sockaddr_in structure as defined in the Winsock specification, version 1.1.

4.3.4.4 Valid Common Packet Format item usage summary

The Common Packet Format is used with the following encapsulation commands:

- ListIdentity reply
- ListInterfaces reply
- ListServices reply
- SendRRData request and reply
- SendUnitData
- Transport class 0 and class 1 packets (no encapsulation header)

Table 243 shows the valid usage of CPF items for the various encapsulation commands.

NOTE Clause 11 contains the detailed formats and usage for Type 2 connected and unconnected messages.

Table 243 – Usage of CPF items

Command	Required CPF items	Optional CPF items	Action if unexpected or undefined CPF items are present
ListIdentity reply	Type 2 Identity item	Type 2 Security Information Type 2 Ethernet Capability	Ignore items
ListInterfaces reply	None	Legacy devices may return "Reserved for legacy usage" items	Ignore items
ListServices reply	ListServices item for the "Communications" service	Legacy devices may return "Reserved for legacy usage" items	Ignore items
SendRRData request	Address item followed by Data item	When used to encapsulate the Forward_Open service, additional Sockaddr_info items can be present, as specified in Clause 11	Return error (0x0003)
SendRRData reply	Address item followed by Data item	When used to encapsulate the Forward_Open response, additional Sockaddr_info items can be present, as specified in Clause 11	Signal error to the calling application. For Forward_Open response, connection shall not be established at the originator
SendUnitData	Address item followed by Data item	None	Discard message
Class 0/1 packet	Address item followed by Data item	None	Discard message

5 Transfer syntax

5.1 Compact encoding

5.1.1 Encoding rules

Subclause 5.1 describes the means by which the data types defined in this document shall be encoded/transferred across the control network. The abstract syntax definition along with a particular set of encoding rules shall result in the transfer syntax. For application user data, a single set of encoding rules shall be defined (Compact Encoding), resulting in the Compact transfer syntax.

Compact Encoding rules shall start with the encoding rules defined in ISO/IEC 8825-1. Compact Encoding then applies optimization rules, starting with the outer most Service Data Unit (SDU) and progressing to each successive encapsulated SDU. Compact Encoding shall define a more efficient encoding mechanism by reducing the amount of information (overhead) transferred between devices.

The difference between a Compact encoded value and an ASN.1 encoded value shall be the removal of the fields describing the type and length of the information. The TAG and LENGTH components of an ASN.1-encoded value shall not be transmitted on the control network. In addition, the Compact Encoding rules shall indicate that octet ordering rules are the reverse of those seen in ASN.1.

Given the conditions listed in 5.1.2, general rules shall be applied to an ASN.1 encoded value to generate a Compact encoded value. The general rules shall be as follows:

- remove the Identifier Octets;
- remove the "TAG" octets specified by ASN.1;
- remove the Length Octets;
- remove the "LENGTH" octets specified by ASN.1;
- reverse the octet ordering for multiple content octets.

5.1.2 Encoding constraints

The representation of a variable value using Compact Encoding shall be possible with the following restrictions:

- the variable type shall be fixed length and shall have no conditional or optional fields;
- the encoding of a given variable shall be represented with a constant number of octets derived from the type specification of this variable.

5.1.3 Examples

5.1.3.1 BOOL encoding

The BOOLEAN encoding shall be performed on a single OCTET as described in Table 244.

Table 244 – BOOLEAN encoding

If the value is:	Then:
FALSE	The octet shall be 0x00
TRUE	The octet shall be 0x01

A FALSE BOOL shall be represented as shown in Table 245.

Table 245 – Example compact encoding of a BOOL value

Octet number	1st
BOOL	00

5.1.3.2 SignedInteger encoding

The SignedInteger encoding shall be performed as described in Table 246.

Table 246 – Encoding of SignedInteger values

Octet number	1st	2nd	3rd	4th	5th	6th	7th	8th
SINT	0LSB							
INT	0LSB	1LSB						
DINT	0LSB	1LSB	2LSB	3LSB				
LINT	0LSB	1LSB	2LSB	3LSB	4LSB	5LSB	6LSB	7LSB
NOTE The example in Table 247 illustrates the encoding of a variable of type DINT whose value is 0x12345678.								

Table 247 – Example compact encoding of a SignedInteger value

Octet number	1st	2nd	3rd	4th
DINT	78	56	34	12

5.1.3.3 UnsignedInteger encoding

The UnsignedInteger encoding shall be performed as described in Table 248.

Table 248 – UnsignedInteger values

Octet number	1st	2nd	3rd	4th	5th	6th	7th	8th
USINT	0LSB							
UINT	0LSB	1LSB						
UDINT	0LSB	1LSB	2LSB	3LSB				
ULINT	0LSB	1LSB	2LSB	3LSB	4LSB	5LSB	6LSB	7LSB
NOTE Table 249 illustrates the encoding of a variable of type UDINT whose value is 0xAABBCCDD.								

Table 249 – Example compact encoding of an UnsignedInteger

Octet number	1st	2nd	3rd	4th
UDINT	DD	CC	BB	AA

5.1.3.4 FixedLengthReal encoding

The FixedLengthReal encoding shall be performed as described in Table 250.

Table 250 – FixedLengthReal values

Octet number	1st	2nd	3rd	4th	5th	6th	7th	8th
REAL	0LSB	1LSB	2LSB	3LSB				
LREAL	0LSB	1LSB	2LSB	3LSB	4LSB	5LSB	6LSB	7LSB

Table 251 illustrates the encoding of a variable (Float1) whose type is REAL and whose value is Float1: = 10,0.

NOTE 1 The assignment of the value is using the IEC 61131-3 notation. The value is 0x41200000 in IEEE format: $+1 \times 1{,}25 \times 2^3$, sign bit is 0 (+1), exponent is 130 (bias 127), fraction is 0,25.

Table 251 – Example compact encoding of a REAL value

Octet contents	0LSB	1LSB	2LSB	3LSB
REAL	00	00	20	41

Table 252 illustrates the encoding of a variable (Float2) whose type is LREAL and whose value is Float2: = –100,0.

NOTE 2 The value is 0xC059000000000000 in IEEE format:-1 × 1,562 5 × 2^6, sign bit is 1 (-1), exponent is 1 029 (bias 1 023), fraction is 0,562 5.

Table 252 – Example compact encoding of a LREAL value

Octet contents	0LSB	1LSB	2LSB	3LSB	4LSB	5LSB	6LSB	7LSB
LREAL	00	00	00	00	00	00	59	C0

5.1.3.5 Time encodings

Subclause 5.1.3.5 gives examples of the Compact Encoding of TIME, DATE, TIME_OF_DAY, DATE_AND_TIME, FTIME, LTIME, ITIME, NTIME, STIME, UTIME data values. Table 253 provides a generic illustration of the encoding of Time values.

Table 253 – FixedLengthReal values

Octet number	1st	2nd	3rd	4th	5th	6th	7th	8th
TIME	0LSB	1LSB	2LSB	3LSB				
DATE	0LSB	1LSB						
TIME_OF_DAY	0LSB	1LSB	2LSB	3LSB				
DATE_AND_TIME	0LSB-Time	1LSB-Time	2LSB-Time	3LSB-Time	0LSB-Date	1LSB-Date		
FTIME	0LSB	1LSB	2LSB	3LSB				
LTIME	0LSB	1LSB	2LSB	3LSB	4LSB	5LSB	6LSB	7LSB
ITIME	0LSB	1LSB						
NTIME	0LSB	1LSB	2LSB	3LSB	4LSB	5LSB	6LSB	7LSB
STIME	0LSB	1LSB	2LSB	3LSB	4LSB	5LSB	6LSB	7LSB
UTIME	0LSB	1LSB	2LSB	3LSB	4LSB	5LSB	6LSB	7LSB

5.1.3.6 String encodings

Subclause 5.1.3.6 gives examples of the Compact Encoding of STRING, STRING2, STRINGN, and SHORT_STRING data values.

NOTE The preferred string type for user supplied string data is STRING2 due to international character string requirements.

Table 254 provides a generic illustration of the encoding of a STRING value.

Table 254 – STRING value

	Contents (charcount)		Contents (string contents)
STRING	0LSB	1LSB	0LSB
			1 octet characters

Table 255 provides a generic illustration of the encoding of a STRING2 value.

Table 255 – STRING2 value

	Contents (charcount)		Contents (string2contents)	
STRING2	0LSB	1LSB	0LSB	1LSB
				2 octet characters

Table 256 provides a generic illustration of the encoding of a STRINGN value.

Table 256 – STRINGN value

	Contents (charsize)		Contents (charcount)		Contents (stringNcontents)	
STRINGN	0LSB	1LSB	0LSB	1LSB	0LSB	NLSB
					N octet characters	

Table 257 provides a generic illustration of the encoding of a SHORT_STRING value.

Table 257 – SHORT_STRING value

	Contents (charcount)	Contents (short_string)
SHORT_STRING	0LSB	0LSB
		1 octet characters

Table 258 illustrates the encoding of a string variable whose contents equal "Mill". Encoding examples of all string types are presented. Character coding is specified in ISO/IEC 10646. The hexadecimal equivalent is: 0x4D696C6C for 8-bit encoding.

Table 258 encodes "Mill" as a STRING type.

Table 258 – Example compact encoding of a STRING value

	Contents (charcount)		Contents (string contents)			
STRING	04	00	4D	69	6C	6C

Table 259 encodes "Mill" as a STRING2 type.

Table 259 – Example compact encoding of STRING2 value

	Contents (charcount)		Contents (string2 contents)							
STRING2	04	00	4D	00	69	00	6C	00	6C	00

Table 260 encodes "Mill" as a SHORT_STRING type.

Table 260 – SHORT_STRING type

	Contents (charcount)	Contents (short_string contents)			
SHORT_STRING	04	4D	69	6C	6C

5.1.3.7 FixedLengthBitString encoding

Subclause 5.1.3.7 provides examples of the Compact Encoding of SWORD, WORD, DWORD, LWORD data values. Figure 15 illustrates the bit placement rules associated with the Compact Encoding of a FixedLengthBitString.

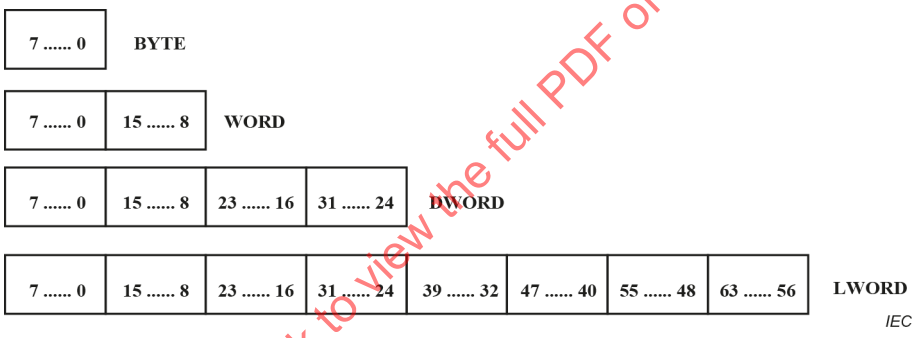


Figure 15 – FixedLengthBitString compact encoding bit placement rules

Figure 16 through Figure 19 illustrate the encoding of SWORD, WORD, DWORD, and LWORD.

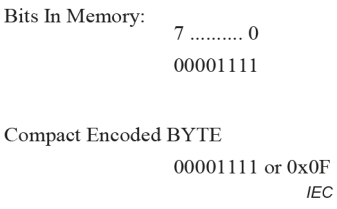


Figure 16 – Example compact encoding of a SWORD FixedLengthBitString

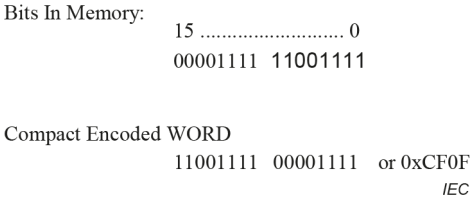


Figure 17 – Example compact encoding of a WORD FixedLengthBitString

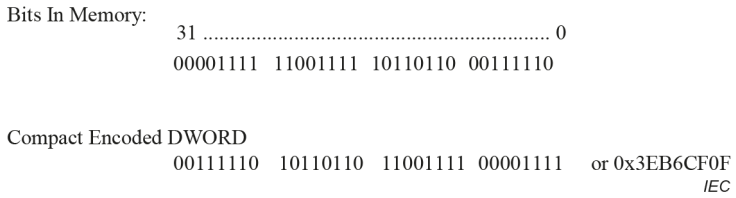


Figure 18 – Example compact encoding of a DWORD FixedLengthBitString

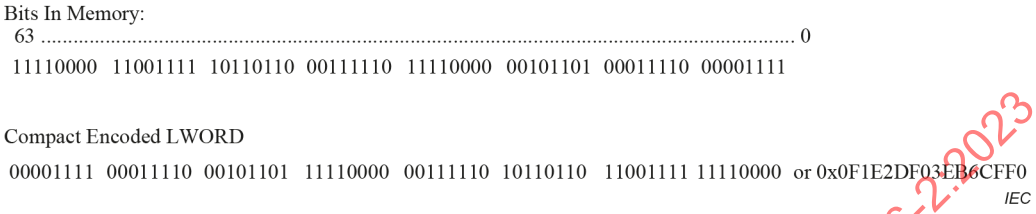


Figure 19 – Example compact encoding of a LWORD FixedLengthBitString

5.1.3.8 Array encoding

5.1.3.8.1 One-dimensional array encoding

The Array encoding shall use the encoding rules for the data types for each element and concatenates the elements which compose the array. The encoded values of the array elements shall be encoded in the same order as they are declared in the corresponding type or variable specification. These elements may be of any data type.

The definition of a single–dimensional array in the control network shall be:

```
ARRAY::= SEQUENCE OF { array_elements, NetworkData }

Assume the following array definition::
ARRAY1::= SEQUENCE OF {array_elements:=2, UINT}
```

Plugging the UINT values {1,2} into this array definition yields the encoding specified in Table 261.

Table 261 – Example compact encoding of a single dimensional ARRAY

Octet number	1st	2nd	3rd	4th
ARRAY	01	00	02	00

5.1.3.8.2 Two-dimensional array encoding

```
ARRAY::= SEQUENCE OF { array_elements
            SEQUENCE OF { array_elements, NetworkData } }
```

5.1.3.8.3 Three-dimensional array encoding

```
ARRAY::= SEQUENCE OF { array_elements,
            SEQUENCE OF { array_elements,
            SEQUENCE OF { array_elements,
NetworkData } } }
```

Since control network data may comprise either ElementaryData or DerivedData, a new type or variable specification can be required before transmitting the values for the ARRAY.

A multi–dimensional array shall be seen on the wire as a single–dimensional array. The order of the array elements shall be maintained via the packing/unpacking sequence followed by the end nodes. The sequence followed shall be to access the Nth dimension of the array for all values of the other dimensions.

This shall be achieved by first accessing the array with all dimensions set to their initial index values. After this the Nth dimension is incremented through all of its index values. When the end of the index range for the Nth dimension is reached, the (N-1)th dimension is incremented, and the Nth dimension is set to its initial index value. This process is repeated until all of the array's dimensions have reached the ends of their index ranges, and results in the array being packed into the message buffer as a single–dimensional array. The same procedure is followed to unpack the single–dimensional array into a multi–dimensional array.

The two–dimensional array

```
ARRAY1 [2,3] of UINT:= { { 1, 2, 3 },{ 4, 5, 6 } }
```

results in the data stream shown in Table 262 when it is packed into a single–dimensional array following the compact encoding rules:

Table 262 – Example compact encoding of a multi-dimensional ARRAY

Octet number	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
ARRAY	01	00	02	00	03	00	04	00	05	00	06	00

5.1.3.9 Structure encoding

The structure encoding shall use the encoding rules for the data types for each element and concatenates the elements which compose the structure.

The encoded values of the structure elements shall be encoded in the same order as they are declared in the corresponding ASN.1 type or variable specification. These elements may be of any Data type.

```
STRUCT::= SEQUENCE OF NetworkData –- May be different types
```

Since NetworkData may be comprised of either ElementaryData or DerivedData, a new type or variable specification can be required before transmitting the values for the STRUCT.

Assume the following structure definition:

```
newStruct::= SEQUENCE { BOOL,UINT,DINT}
```

Plugging the values {TRUE,0x1234,0x56789ABC} into the structure results in the encoding as specified in Table 263.

Table 263 – Example compact encoding of a STRUCTURE

Octet number	1st	2nd	3rd	4th	5th	6th	7th
newStruct	01	34	12	BC	9A	78	56

5.1.3.10 Complex encoded data format examples

5.1.3.10.1 General

The examples in 5.1.3.10.2 and 5.1.3.10.3 show how more complex data formats shall be packed. Example 5.1.3.10.2 shows the packing of an array of structures. Example in 5.1.3.10.3 shows how a structure with an array element is packed.

5.1.3.10.2 Example 1: encoding an array of structures:

```
STRUCT1::= SEQUENCE OF {
             UINT     ele1;
             USINT    ele2;
             USINT    ele3;
             USINT    ele4;
             UINT     ele5;
}
  ARRAY1 [ 2,3 ] of STRUCT1:= {
             { { 1, 2, 3, 4, 5 }, { 6, 7, 8, 9, 10 },
              { 11, 12, 13, 14, 15 } },
             { { 15, 14, 13, 12, 11 }, { 10, 9, 8, 7, 6 },
              { 5, 4, 3, 2, 1 } } }
```

results in the following data stream:

```
[01][00][02][03][04][05][00] [06][00][07][08][09][0A][00]
[0B][00][0C][0D][0E][0F][00] [0F][00][0E][0D][0C][0B][00]
[0A][00][09][08][07][06][00] [05][00][04][03][02][01][00]
```

5.1.3.10.3 Example 2: encoding a structure with an array element

```
STRUCT2::= SEQUENCE OF {
             UINT     ele1;
             ARRAY [ 3 ] of USINT array2;
             UINT     ele5;
}
STRUCT2:= { 1, { 2, 3, 4 }, 5 }
```

results in the following data stream:

```
[01][00] [02][03][04] [05][00]
```

5.2 Data type reporting

5.2.1 Object data representation

Objects may choose to implement a mechanism for reporting Data Type of a particular Attribute or transmitting type information along with the actual data. Subclause 5.2 defines the means by which Data Typing information is conveyed.

The specification of Data Type information utilizes the ASN.1 methodology specified in ISO/IEC 8824-1 and ISO/IEC 8825-1 with the control network defined optimizations to encode the **DataTypeSpecification** production defined in 4.2.4.

The control network defined optimization is that the Length Octet of a NULL type is not encoded.

NOTE For example, the encoding of 'abc [PRIVATE 1] IMPLICIT NULL' would be: 0xC1 (a tag with no length octet).

5.2.2 Elementary data type reporting

Elementary data types shall be identified using the identification codes defined in Table 264. These codes shall define the encoding of the primitive members of the DataTypeSpecification production. The control network specifies that ASN.1 NULL types shall not report the Length Octet of zero (0).

Table 264 – Identification codes and descriptions of elementary data types

Data type name	Data type code (in hex)	Data type description
UTIME	C0	System time information
BOOL	C1	Logical Boolean with values TRUE and FALSE
SINT	C2	Signed 8-bit integer value
INT	C3	Signed 16-bit integer value
DINT	C4	Signed 32-bit integer value
LINT	C5	Signed 64-bit integer value
USINT	C6	Unsigned 8-bit integer value
UINT	C7	Unsigned 16-bit integer value
UDINT	C8	Unsigned 32-bit integer value
ULINT	C9	Unsigned 64-bit integer value
REAL	CA	32-bit floating point value
LREAL	CB	64-bit floating point value
STIME	CC	System time information
DATE	CD	Date information
TIME_OF_DAY	CE	Time of day
DATE_AND_TIME	CF	Date and time of day
STRING	D0	character string (1 octet per character)
SWORD	D1	bit string - 8-bits
WORD	D2	bit string - 16-bits
DWORD	D3	bit string - 32-bits
LWORD	D4	bit string - 64-bits
STRING2	D5	character string (2 octets per character)
FTIME	D6	Duration (high resolution)
LTIME	D7	Duration (long)
ITIME	D8	Duration (short)
STRINGN	D9	character string (N octets per character)
SHORT_STRING	DA	character sting (1 octet per character, 1 octet length indicator)
TIME	DB	Duration (milliseconds)
EPATH	DC	Path segments
STRINGI	DE	International Character String
NTIME	DF	Duration (nanoseconds)
	E0 – E3	Reserved for future use

5.2.3 Constructed data type reporting

5.2.3.1 General

Subclause 5.2.3 details the means by which the structure and array information presented within the DataTypeSpecification production is represented.

Table 265 specifies the identification codes used for the various constructed data types.

Table 265 – Identification codes and descriptions of constructed data types

Data type name	Data type code (in hex)	Data type description
Abbreviated Structure	A0	Structure identified by 16-bit CRC value
Abbreviated Array	A1	Array identified by 16-bit CRC value
Formal Structure	A2	Structure defined by member type list
Formal Array	A3	Array defined by type and size
	A4-A7	Reserved – do not use
Formal Handle Structure	A8	Structure defined by member type and member handle list
	A9-BF	Reserved

5.2.3.2 Structure type definition

5.2.3.2.1 General

The control network defines three different methods for reporting Structure type definitions:

- Formal Encoding (FormalStrucTypeSpec);
- Formal Handle Encoding (FormalHandleStrucTypeSpec);
- Abbreviated Encoding (AbbreviatedStrucTypeSpec).

Formal encoding shall be used to provide a detailed report of the complete structure definition, including the complete definition of all component data types(the structure member number can be obtained based on the component position). Formal Handle encoding is used to provide a detailed report of the complete structure definition, including the complete definition of all component data types and component handles. Abbreviated encoding shall be used to specify a shorter form of the structure definition. This shorter form shall not include the data types associated with the structure's components.

5.2.3.2.2 Formal encoding for structure type information

Table 266 defines the formal encoding format for non-nested structures.

Table 266 – Formal structure encoding definition

Octet	Definition
0	Formal Structure (A2)
1	Length of structure definition in octets (n)
2 to (n+1)	Data type code (C0 to DF)

The examples in 5.2.3.2.3 and 5.2.3.2.4 illustrate formal encoding for structure type specifications. This is actually an example of the encoding of the FormalStrucTypeSpec production defined in 4.2.4.

5.2.3.2.3 Example 1

Figure 20 illustrates the encoding of the following structure definition.

```
STRUCT::= SEQUENCE OF { BOOL, UINT, DINT }
```

STRUCT type	Type length	Data type (BOOL)	Data type (UINT)	Data type (DINT)
A2	03	C1	C7	C4
NOTE The IMPLICIT NULL types from the DataTypeSpecification production are not followed by a Length Octet of zero (0).				

Figure 20 – Example 1 of formal encoding of a structure type specification

5.2.3.2.4 Example 2

Figure 21 illustrates the encoding of the following structure definition.

```
STRUCT_MAIN::= SEQUENCE OF { UINT, STRUCT_SUB, INT }

with subelement STRUCT_SUB defined as:

STRUCT_SUB::= SEQUENCE OF { UINT, SINT, INT }
```

Struct type	Type length	Component						
		Data type (UINT)	Struct type	Type length	Nested Component			Data type (INT)
					Data type (UINT)	Data type (SINT)	Data type (INT)	
A2	07	C7	A2	03	C7	C2	C3	C3

Figure 21 – Example 2 of formal encoding of a structure type specification

5.2.3.2.5 Formal Encoding for Handle Structure Type Information

Table 267 defines the formal encoding format for structures with handles.

Table 267 – Formal structure with handles encoding definition

Octet	Definition
0	Formal Handle Structure (A8)
1	Length of structure definition in octets (n)
2	Handle length (1, 2 or 4 octets)
3	Data type code (C0 to DF) 1
4 to 4 + (Handle length – 1)	Handle (1, 2 or 4 octet value assigned by application) [a]
[a] Additional members are represented by pairs of data type codes and handles.	

The two examples in 5.2.3.2.6 and 5.2.3.2.7 illustrate formal encoding for handle structure type specifications. This is actually an example of the encoding of the FormalHandleStrucTypeSpec production defined in 4.2.4.

5.2.3.2.6 Example 3

Figure 22 shows the encoding of the following structure definition.

```
STRUCT::= SEQUENCE OF { BOOL, UINT, DINT }
```

Struc type	Type length	Handle length	Data type (BOOL)	Member handle	Data type (UINT)	Member handle	Data type (DINT)	Member handle
A8	10	04	C1	D9 B9 74 3E	C7	F4 15 59 93	C4	0B 7B 24 A6

Figure 22 – Example 3 of formal encoding of a handle structure type specification

5.2.3.2.7 Example 4

Figure 23 shows the encoding of the following structure definition

```
STRUCT_MAIN::= SEQUENCE OF { UINT, STRUCT_SUB, INT }
```

with sub element STRUCT_SUB defined as:

```
STRUCT_SUB::= SEQUENCE OF { SINT, INT }
```

Struct type	Type length	Handle length	Component										
			Data type (UINT)	Member handle	Struct type	Type length	Handle length	Nested component				Data Type (INT)	Handle
								Data Type (SINT)	Member Handle	Data Type (INT)	Member Handle		
A8	0E	02	C7	90 1D	A8	05	01	C2	F8	C3	B2	C3	36 ED

Figure 23 – Example 4 of formal encoding of a handle structure type specification

5.2.3.2.8 Abbreviated encoding for structure type information

Table 268 defines the abbreviated encoding format for structures.

Table 268 – Abbreviated structure encoding definition

Octet	Definition
0	Abbreviated Structure (A0)
1	Length of abbreviated structure (02)
2 to 3	UINT containing CRC

The example in 5.2.3.2.9 illustrates the abbreviated encoding for structure type specifications. This is actually an example of the encoding of the AbbreviatedStrucTypeSpec production defined in 4.2.4.

The UINT defined within the AbbreviatedStrucTypeSpec production shall be initialized with a 16 bit Cyclic Redundancy Check (CRC) value (see IEC 61158-4-2). This can be used by application logic to determine whether or not the format of the structure has changed. The octet stream used to produce the CRC is the actual formally encoded (FormalStrucTypeSpec) structure type specification.

5.2.3.2.9 Example 5

Figure 24 shows the abbreviated encoding of the structure definition presented in 5.2.3.2.8:

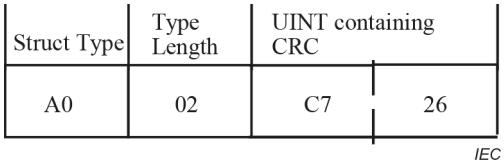


Figure 24 – Example 5 of abbreviated encoding of a structure type specification

NOTE The algorithms presented in this document are used to generate the CRC value of 0x26C7 from the Formally Encoded type specification: [A2][07][C7][A2][03] [C7][C2][C3][C3].

5.2.3.3 Array type definition

5.2.3.3.1 General

Two different methods for reporting array type definitions shall be:

- Formal Encoding (FormalArrayTypeSpec);
- Abbreviated Encoding (AbbreviatedArrayTypeSpec).

Formal encoding shall be used to provide a detailed report of the complete array definition, including the data content and the array's dimensions. Abbreviated encoding shall be used to specify a shorter form of the array definition. This shorter form shall not include information specifying the array's dimensions.

5.2.3.3.2 Formal encoding for array type information

Table 269 defines the formal encoding format for arrays.

Table 269 – Formal array encoding definition

Octet	Definition
0	Formal Array (A3)
1 to 4	Number of elements in the dimension (UDINT)
5 to end	One of: 1 Array element data type code (C0 to DF) 2 Formal array encoding [a] 3 Formal structure encoding 4 Formal handle structure encoding
[a] Each dimension of the array shall be represented by a formal array	

The examples in 5.2.3.3.3 and 5.2.3.3.4 illustrate formal encoding for structure type specifications. This is actually an example of the encoding of the FormalArrayTypeSpec production defined in 4.2.4.

5.2.3.3.3 Example 1

Figure 25 shows the formal encoding of the following array definition (one dimensional array of 10 UINT elements).

```
ARRAY1::= SEQUENCE OF { array_elements:= 10, UINT }
```

Array	Array elements (octet 0)	Array elements (octet 1)	Array elements (octet 2)	Array elements (octet 3)	Data type (UINT)
A3	0A	800	000	000	C7

Figure 25 – Example 1 of formal encoding of an array type specification

NOTE The IMPLICIT NULL types from the DataTypeSpecification production are not followed by a Length Octet of zero (0).

5.2.3.3.4 Example 2

Figure 26 shows the encoding of the following array definition (two dimensional array of 20 elements by 256 elements of a structure consisting of a UINT, SINT and INT).

```
ARRAY1::= SEQUENCE OF { array_elements:= 20,
                SEQUENCE OF { array_elements:= 256, STRUCT_ELE } }
```

in which `STRUCT_ELE` is defined as:

```
STRUCT_ELE::= SEQUENCE OF { UINT, SINT, INT }
```

Formal Encoding: [A3][14][00][00][00][A3][00][01][00][00][A2][03][C7][C2][C3]

Array type	Array elements (octet 0)	Array elements (octet 1)	Array elements (octet 2)	Array elements (octet 3)
A3	14	00	00	00

	Array contents				
	Array Type	Array elements (octet 0)	Array elements (octet 1)	Array elements (octet 2)	Array elements (octet 3)
…	A3	00	01	00	00

	Nested array contents				
	Struct type	Type length	UINT	SINT	INT
…	A2	03	C7	C2	C3

Figure 26 – Example 2 of formal encoding of an array type specification

NOTE The IMPLICIT NULL types from the DataTypeSpecification production are not followed by a Length Octet of zero (0).

5.2.3.3.5 Abbreviated tag encoding for array type information

Table 270 defines the abbreviated encoding format for arrays.

Table 270 – Abbreviated array encoding definition

Octet	Definition
0	Abbreviated Array (A1)
1	Length of abbreviated array (n)
2 to (2+n-1)	One of: 1 Array element data type code (C0 to DF) 2 Abbreviated array encoding [a] 3 Abbreviated structure encoding
[a] Each dimension of the array shall be represented by an abbreviated array.	

The abbreviated encoding of an Array type shall not include the information specifying the Array's dimensions. This is actually an example of the encoding of the AbbreviatedArrayTypeSpec production defined in 4.2.4.

5.2.3.3.6 Example 1

Figure 27 shows the abbreviated encoding of the following array definition (one dimensional array of 10 UINT elements):

```
ARRAY2::= SEQUENCE OF { array_elements:= 10, UINT }
```

Array type	Type length	Data type (UINT)
A1	01	C7

Figure 27 – Example 1 of abbreviated encoding of an array type specification

NOTE The IMPLICIT NULL types from the DataTypeSpecification production are not followed by a Length Octet of zero (0).

5.2.3.3.7 Example 2

Figure 28 shows the abbreviated encoding of the following array definition (two dimensional array of 20 elements by 900 elements of a structure consisting of a UINT, SINT and INT):

```
ARRAY::= SEQUENCE OF { array_elements:= 20,
                SEQUENCE OF { array_elements:= 900, STRUCT_ELE } }
```

in which `STRUCT_ELE` is defined as:

```
STRUCT_ELE::= SEQUENCE OF { UINT, SINT, INT }
```

Array type	Type length	Array type	Type length	Structure (STRUCT_ELE)			
				Struct type	Type length	UINT containing CRC	
A1	06	A1	04	A0	02	59	51

Figure 28 – Example 2 of abbreviated encoding of an array type specification

NOTE The algorithms presented in this document are used to generate the CRC value of 0x5159 from the Formally Encoded type specification: [A2][03][C7][C2][C3].

6 Structure of FAL protocol state machines

Interface to FAL services and protocol machines are specified in Clause 6. Conventions used for the descriptions are given in IEC 61158-1.

This fieldbus follows the structure outlined for Type 1 fieldbus with the following specific features:

- There is no formal definition of AP-Context Machine
- There is a formally-defined FSPM Machine serving as an interface between FAL User and ARPM.
- There are ARPM Machines of two different types:
  1) one ARPM machine for connection-less application relationships
  2) seven ARPM machines for connection-oriented application relationships
- DMPM Machines are defined at the interface to the supported Data-link layer (Type 2 or others).

7 AP-Context state machine

7.1 Overview

Type 2 supports the AP-Context State Machine specified in 7.2, when the Connection object is also supported.

These state machines refer to the following additional internal services.

- Send_Message – Used internally to trigger the transmission of a message. This results in the invocation of the associated Link Producer's Send service. If the message needs to be transmitted in a fragmented fashion, this service breaks up the message into multiple fragments and invokes the associated Link Producer's Send service multiple times.
- Receive_Data – Used internally to deliver a received frame to the Connection object. This service is invoked internally by a Link Consumer. The Connection object is responsible for determining whether or not it shall reassemble a series of data fragments into a complete message before processing the message.

7.2 Connection object state machine

7.2.1 I/O Connection instance behavior

Figure 29 provides a general overview of the behavior associated with an **I/O Connection object** (**instance_type** attribute = I/O).

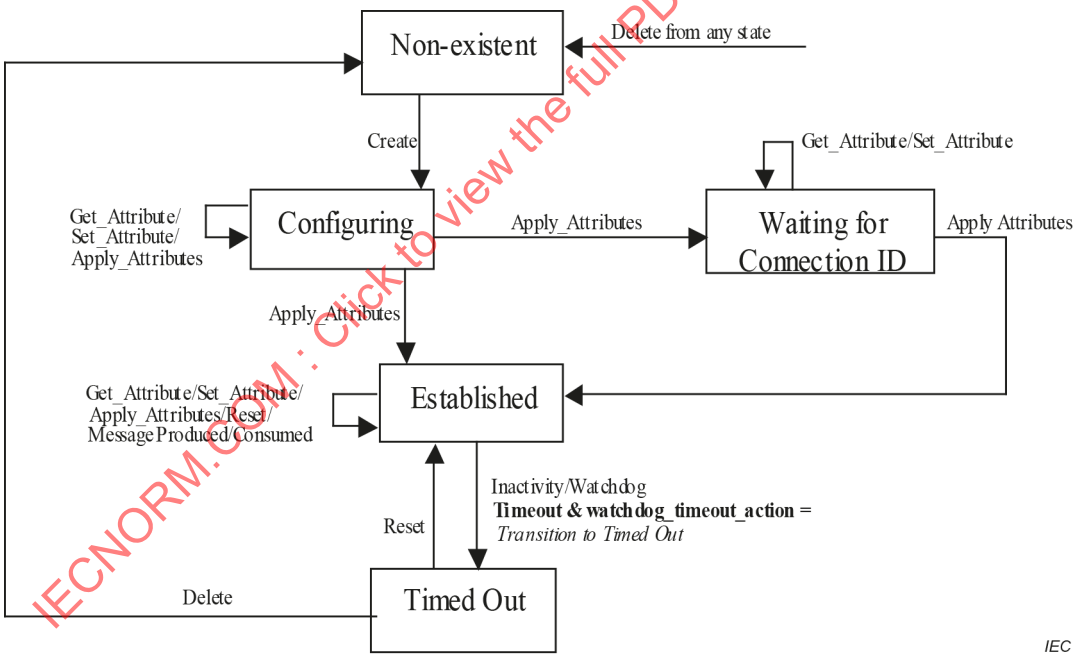


Figure 29 – I/O Connection object state transition diagram

Important: Table 271 provides a detailed State Event Matrix for an I/O Connection object and implementations should be based on this information. This State Event Matrix does not dictate rules with regards to product specific, internal logic. Any attempt to access the Connection Class or a Connection object Instance can need to pass through product specific verification. This can result in an error scenario that is not indicated by the SEM in Table 271. This can also result in additional, product specific indications delivered from a Connection object to the application and/or a specific application object. The point to remember is that the Connection object shall exhibit the externally visible behavior specified by the SEM and the attribute definitions.

Table 271 – I/O Connection state event matrix

Event	I/O Connection object state				
	Non-Existent	**Configuring**	**Waiting for Connection ID**	**Established**	**Timed Out**
Connection Class receives a Create Request	Class instantiates a Connection object. Set instance_type to I/O. Set all other attributes to default values. Transition to Configuring	Not applicable	Not applicable	Not applicable	Not applicable
Connection Class receives a Delete Request	Error: Object does not exist (General Error Code 0x16)	Release all associated resources. Transition to Non-existent	Release all associated resources. Transition to Non-existent.	Release all associated resources. Transition to Non-existent.	Release all associated resources. Transition to Non-existent.
Set_Attribute_Single	Error: Object does not exist (General Error Code 0x16)	Validate/service the request based on internal logic and per the Access Return response.	If request to modify produced or consumed_connection_id then validate the value and service the request. Return appropriate response. If this is a request to access an attribute other than the produced or consumed_connection_id, then return an Error Response whose General Error Code is set to 0x0C (The object can not perform the requested service in its current mode/state)	Validate/service the request based on internal logic and per the Access Rules Return appropriate response.	Validate/service the request based on internal logic and per the Access Rules Return appropriate response.
Get_Attribute_Single	Error: Object does not exist (General Error Code 0x16)	Validate/service the request based on internal logic and per the Access Rules Return response.	Validate/service the request based on internal logic and per the Access Rules Return response.	Validate/service the request based on internal logic and per the Access Rules Return response.	Validate/service the request based on internal logic and per the Access Rules Return response.

Event	I/O Connection object state				
	Non-Existent	**Configuring**	**Waiting for Connection ID**	**Established**	**Timed Out**
Reset	Error: Object does not exist (General Error Code 0x16)	Error: The object cannot perform the requested service in its current mode/state. (General Error Code value = 0x0C)	Error: The object cannot perform the requested service in its current mode/state. (General Error Code value = 0x0C)	Cancel the current Inactivity/Watchdog Timer. Using the value in the expected_packet_rate attribute, re-start the Inactivity/Watchdog Timer. A success response is returned even if an Inactivity/Watchdog Timer is not utilized by the Connection object (Client Transport Class 0, expected_packet_rate = 0x0C).	Using the value in the expected_packet_rate attribute, start the Inactivity/Watchdog timer and transition back to the Established state. If the expected_packet_rate attribute has been set to zero (0) while the Connection was in the Timed Out state, then just transition back to Established without activating an Inactivity/Watchdog Timer.

Event	I/O Connection object state				
	Non-Existent	**Configuring**	**Waiting for Connection ID**	**Established**	**Timed Out**
Apply_ Attributes	Error: Object does not exist (General Error Code 0x16)	Deliver Connection object to the application which validates the attribute information. If either of the connection_id attributes (produced or consumed) needs to be configured and cannot be generated by this module, then perform all the other steps necessary to configure the connection, return a Successful Response and transition to the Waiting For Connection ID state. The inability to generate a produced or consumed connection ID value IS NOT reported as an error. If all attributes are validly configured, then perform all the steps necessary to satisfy this connection, start all required timers, and transition to the Established state. If an error is detected, then an Error Response is returned and the Connection remains in the Configuring state[a] and, if a Client Connection with a production trigger value of 0 or 1 (Cyclic or Change of State), produce initial data.	If either of the connection_id attributes (produced or consumed) still needs to be configured and cannot be generated by this module, then return a Successful Response and remain in the Waiting For Connection ID state. The inability to generate a produced or consumed connection ID value IS NOT reported as an error. If the produced and/or consumed_connection_id attributes are now validly configured, then transition to the Established state and return a Successful Response[a] and, if a Client Connection with a production trigger value of 0 or 1 (Cyclic or Change of State), produce initial data.	All modifications take place immediately once the Connection has transitioned to the Established state. Return Error: The object cannot perform the requested service in its current mode/state. (General Error Code value = 0x0C)	Error: The object cannot perform the requested service in its current mode/state. (General Error Code value = 0x0C)

Event	I/O Connection object state				
	Non-Existent	**Configuring**	**Waiting for Connection ID**	**Established**	**Timed Out**
Receive_Data	Not applicable	Discard the message	Discard the message	If a complete, valid[b] message has been received, reset the Inactivity/Watchdog Timer[c] and deliver the I/O Message to the Application. A Connection object shall exhibit the externally visible behavior associated with the current state of its attributes (see Access Rules). If this is a fragmented portion of an I/O Message, process as specified by subnet.	Discard the message
Send_Message	Not applicable	Return internal error - do not send the message	Return internal error - do not send the message	Transmit the complete I/O Message or fragment as required by the subnet. If this is a Client Connection and the expected_packet_rate attribute is non-zero, restart the Transmission Trigger Timer.	Return internal error - do not send the message
Inactivity/ Watchdog Timer expires	Not applicable	Not applicable	Not applicable	Examine the watchdog_timeout_action attribute of the Connection and perform the indicated action. If the watchdog_timeout_action attribute indicates that the Connection is to remain in the Established state (*Auto Reset*), then immediately re-start the Inactivity/Watchdog Timer.	Not applicable

NOTE Attribute Access Rules are specified in IEC 61158-5-2, 6.2.3.2.1.4.
[a] If the configuration indicates that a Message ID needs to be allocated and an available Message ID does not exist in the specified Message Group, then an Error Response whose General Error Code indicates *Resource Unavailable* (0x02) is returned. If a Connection object attribute value passed the range check when it was initially configured but the attribute value conflicts with another piece of information in the node when the Apply request is processed, then an Error Response is returned whose General Error Code is set to *Invalid Attribute Value* (0x09) and whose Extended Code is set to the Attribute ID of the *offending* Connection object Attribute ID.
[b] The Connection object verifies that the length of the received I/O Message is less than or equal to the consumed_connection_size attribute prior to processing the message. If the length of the received message is less than or equal to the consumed_connection_size attribute, then the I/O Connection object resets the Inactivity/Watchdog Timer, exhibits the externally visible behavior indicated by its attribute settings, and delivers the message to the Application. If the length of the received message is greater than the consumed_connection_size attribute, then the I/O Connection object immediately discards the message and discontinues any subsequent processing. This is the only message content validation performed by an I/O Connection object. Subsequent validation shall be performed by the Application.
[c] If a fragmented message is being received, then the Inactivity/Watchdog Timer is not reset until the entire message has been validly received.

Important: The Receive_Data event is only delivered to an I/O Connection when a message whose Connection Identifier Field matches the consumed_connection_id attribute is received. If a message is received whose Connection Identifier Field does not match any Established Connection object's consumed_connection_id attribute, then the message is discarded. Connection Identifiers are subnet-type specific.

If an implementation detects that it does not support an Explicit Messaging Service indicated in Table 271, then an Error Response specifying a General Error Code 0x08 (Service Not Supported) is returned.

7.2.2 Bridged Connection instance behavior

Figure 30 provides a general overview of the behavior associated with a **Bridged** Connection object (**instance_type** attribute = Bridged). Bridged connections are used to make connections offlink. Both I/O and Explicit Messaging can be accomplished using this connection type. The Connection Manager object definition provides more details these types of connections.

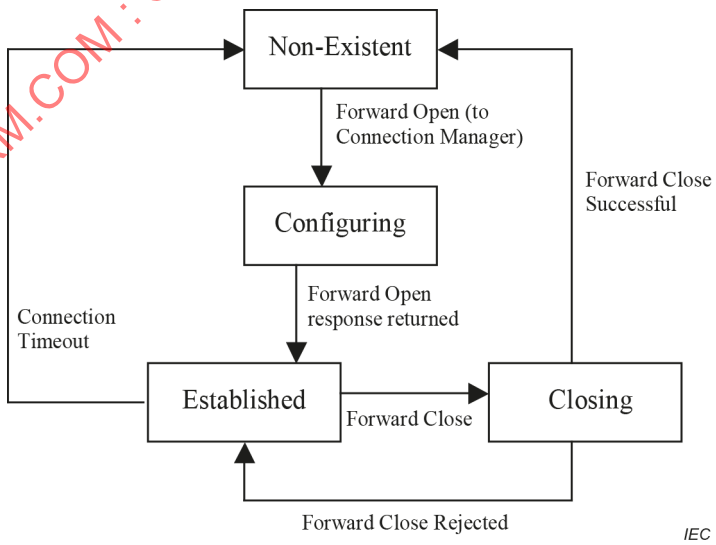


Figure 30 – Bridged Connection object state transition diagram

Table 272 provides a detailed State Event Matrix for a Bridged Connection object.

Table 272 – Bridged Connection state event matrix

Event	Bridged Connection object state			
	Non-Existent	**Configuring**	**Established**	**Closing**
Connection Manager receives a Forward Open Request	Connection Class instantiates a Connection object. Set **instance_type** to **Bridged**. Set attributes to value delivered by Forward Open service or default for Bridged connections. Transition to **Configuring.**	Not applicable	Not applicable	Not applicable
Connection Manager receives notification that connection establishment is complete to target	Not applicable	Transition to **Established**	Not applicable	Not applicable
Connection Manager receives a Forward Close Request	Not applicable	Ignore event	Transition to **Closing**	Ignore event
Connection Manager receives a Forward Close Response	Not applicable	Release all resources and transition to **Non-Existent**	Release all resources and transition to **Non-Existent**	Release all resources and transition to **Non-Existent**
Delete	Error: Object does not exist (General Error Code 0x16)	Release all resources and transition to **Non-Existent**	Release all resources and transition to **Non-Existent**	Release all resources and transition to **Non-Existent**
Get_Attribute_Single	Error: Object does not exist (General Error Code 0x16)	Validate/service the request based on internal logic and per the Access Rules. Return appropriate response.	Validate/service the request based on internal logic and per the Access Rules. Return appropriate response.	Validate/service the request based on internal logic and per the Access Rules. Return appropriate response.
Set_Attribute_Single	Error: Object does not exist (General Error Code 0x16)			
Reset	Error: Object does not exist (General Error Code 0x16)	Error: Service Not Supported (General Error Code 0x08)	Error: Service Not Supported (General Error Code 0x08)	Error: Service Not Supported (General Error Code 0x08)
Apply_Attributes	Error: Object does not exist (General Error Code 0x16)	Error: Service Not Supported (General Error Code 0x08)	Error: Service Not Supported (General Error Code 0x08)	Error: Service Not Supported (General Error Code 0x08)
Receive_Data	Not applicable	Ignore event	Invoke send service of Connection object on destination port, passing the received data.	Ignore event
Send_Message	Not applicable	Ignore event	Send data on subnet.	Ignore event
Inactivity/Watchdog Timer expires	Not applicable	Not applicable	Release all resources and transition to **Non-Existent**	Release all resources and transition to **Non-Existent**
NOTE Attribute Access Rules are specified in IEC 61158-5-2, 6.2.3.2.1.4.				

7.2.3 Explicit Messaging Connection instance behavior

Figure 31 provides a general overview of the behavior associated with an **Explicit Messaging Connection object** (**instance_type** attribute = Explicit Messaging).

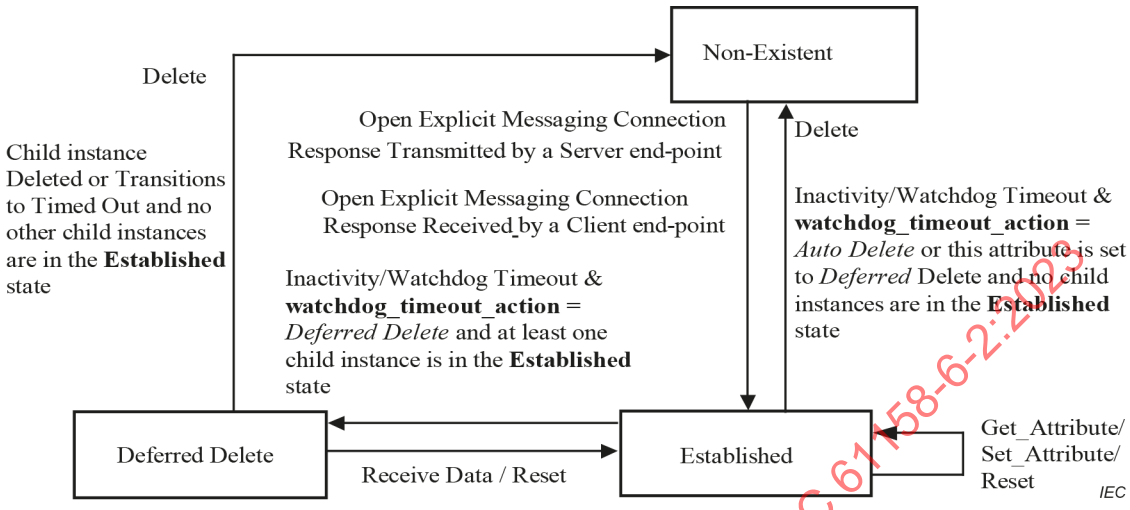


Figure 31 – Explicit Messaging Connection object state transition diagram

Table 273 provides a detailed State Event Matrix for an Explicit Messaging Connection object. Implementations should be based on the information in Table 273.

Table 273 – Explicit Messaging Connection state event matrix

Event	Explicit Messaging Connection object state		
	Non-Existent	**Established**	**Deferred Delete**
UCMM receives an Open Explicit Messaging Connection Request/Response and invokes the Create service of the Connection Class	If possible, Class instantiates Connection object. Set **instance_type** attribute to *Explicit Messaging*[a]. Other attributes are automatically configured using the information in the Open Explicit Messaging Connection Request/Response. Transition to **Established**. If request received, Transmit Open Explicit Messaging Connection Response.	Not applicable	Not applicable
UCMM receives a Close Request and invokes the Delete service of the Connection Class	Error: Object does not exist (General Error Code 0x16)	Release all associated resources. Transition to **Non-existent**.	Release all associated resources. Transition to **Non-existent**.
Connection Class receives a Delete Request	Error: Object does not exist (General Error Code 0x16)	Release all associated resources. Transition to **Non-existent**.	Release all associated resources. Transition to **Non-existent**.
Set_Attribute_Single	Error: Object does not exist (General Error Code 0x16)	Validate/service the request based on internal logic and per the Access Rules. Return appropriate response.	Validate/service the request based on internal logic and per the Access Rules. Return appropriate response.

Event	Explicit Messaging Connection object state		
	Non-Existent	**Established**	**Deferred Delete**
Get_Attribute_Single	Error: Object does not exist (General Error Code 0x16)	Validate/service the request based on internal logic and per the Access Rules. Return appropriate response.	Validate/service the request based on internal logic and per the Access Rules. Return appropriate response.
Reset	Error: Object does not exist (General Error Code 0x16)	Cancel the current Inactivity/Watchdog Timer. Using the value in the **expected_packet_rate** attribute, re-start the Inactivity/Watchdog Timer.	Using the value in the **expected_packet_rate** attribute, re-start the Inactivity/Watchdog Timer and transition back to the Established state.
Apply_Attributes	Error: Object does not exist (General Error Code 0x16)	Error: The object cannot perform the requested service in its current mode/state. (General Error Code value = 0x0C)	Error: The object cannot perform the requested service in its current mode/state. (General Error Code value = 0x0C)
Receive_Data	Not applicable	If a valid message or message fragment has been received, then reset the Inactivity/Watchdog Timer. Either process/store the fragment or handle the Explicit Message.	If a valid message or message fragment has been received, then restart the Inactivity/Watchdog Timer and transition back to the **Established** state. Either process/store the fragment or handle the Explicit Message.
Send_Message	Not applicable	Examine the length of the message to transmit and, if necessary, perform a fragmented series of transmissions. Otherwise, transmit the complete Explicit Message.	Examine the length of the message to transmit and, if necessary, perform a fragmented series of transmissions. Otherwise, transmit the complete Explicit Message.
Inactivity/Watchdog Timer expires	Not applicable	If the **watchdog_timeout_action** attribute is set to *Auto Delete* or is set to *Deferred Delete* and no child connection instances are in the **Established** state release all associated resources and Transition to **Non-existent**. If the **watchdog_timeout_action** attribute is set to *Deferred Delete* and at least one child connection instance is in the **Established** state transition to **Deferred Delete**.	Not applicable.
Child connection instance Deleted or Transitions to Timed Out	Not applicable	Ignore event	If no other child connection instances are in the **Established** state release all associated resources and transition to **Non-existent**.
NOTE Attribute Access Rules are specified in IEC 61158-5-2, 6.2.3.2.1.4.			
[a] If the configuration indicates that a connection resource needs to be allocated and an available resource does not exist, then an Error Response whose General Error Code indicates Resource Unavailable (0x02) is returned.			

Important: The Receive_Data event is only delivered to an Explicit Messaging Connection when a message who's Connection ID matches the consumed_connection_id attribute is received. If a message is received whose connection id does not match any Established Connection object's consumed_connection_id attribute, then the message is discarded.

If an implementation detects that it does not support an Explicit Messaging Service indicated in Table 273, then an Error Response specifying a General Status Code 0x08 (Service Not Supported) is returned.

8 FAL service protocol machine (FSPM)

8.1 General

This fieldbus FAL Service Protocol State Machine maps FAL User services onto services of communication objects internal to FAL.

8.2 Primitive definitions

The Objects within FSPM shall provide the following services:

Get_Attributes_All	Reads values of all attributes of the specified object class or instance
Set_Attributes_All	Writes specified values to all attributes of the specified object class or instance
Get_Attribute_List	Reads values of the specified list of attributes of the specified object class or instance
Set_Attribute_List	Writes specified values to the specified list of attributes of the specified object class or instance
Get_Attribute_Single	Reads value of the specified attribute of the specified object class or instance
Set_Attribute_Single	Writes specified value to the specified attribute of the specified object class or instance
Reset	Resets the specified object class or instance
Create	Creates an instance of the specified object class
Delete	Deletes an instance of the specified object class
Start	Starts execution of the specified object
Stop	Stops execution of the specified object
Find_Next_Object_Instance	Finds the identifier of the next unused instance of the specified object class
NOP	Triggers corresponding NOP response from the specified object
Apply_Attributes	Causes pending attribute values to become active in the specified object
Save	Saves attributes contents of the specified object
Restore	Restores attributes contents of the specified object
Get_Member	Reads member(s) information from within an attribute
Set_Member	Writes member(s) information in an attribute
Insert_Member	Inserts member(s) into an attribute

Remove_Member	Removes member(s) from an attribute
Group_Sync	Verifies that each member of a group is synchronized to System Time
Multiple_Service_Packet	Performs a set of services as an autonomous sequence
Get_Connection_Point_Member_List	Returns EPATHs and associated sizes of the value for member attributes defining the structure of a Connection Point

Refer to IEC 61158-5-2 for detailed definition of these services.

Primitives of Common Services exchanged between UCMM and FAL User are shown in Table 275 and Table 276.

All services have the following common parameters, as shown in Table 274.

Table 274 – Primitives issued by FAL user to FSPM

Common parameters	Req	Ind	Rsp	Cnf
Argument	M			
AREP	M			
Local	S			
UCMM Record identifier	S			
Transport identifier	S			
Receiver/Server Local ID		M		
Path	M	C		
Routing Path	M			
Add. Path	U	U(=)		
Port ID		M		
Result (+)			S	S(=)
AREP				M=
Receiver/Server Local ID			M=	
Service status			M	M(=)
Result (-)			S	S(=)
AREP				M=
Receiver/Server Local ID			M=	
Service status			M	M(=)

Only those argument parameters additional to the common ones are shown in Table 275 and Table 276.

Additional parameters of indication service primitives are the same as those of the corresponding request primitive.

Additional parameters of confirmation service primitives are the same as those of the corresponding response primitive.

Table 275 – Primitives issued by FAL user to FSPM

Primitive name	Source	Additional parameters	Functions
Get_attributes_All.req	FAL User	None	Conveys a request from FAL User to a target object to supply values of all attributes of the specified object class or instance
Set_attributes_All.req	FAL User	Attribute Data	Conveys a request from FAL User to a target object to write specified values of all attributes of the specified object class or instance
Get_attribute_list.req	FAL User	Attribute Count Attribute List	Conveys a request from FAL User to a target object to supply values of specified list of attributes of the specified object class or instance
Set_attribute_list.req	FAL User	Attribute Count Attribute Data	Conveys a request from FAL User to a target object to write specified values of specified list of attributes of the specified object class or instance
Reset.req	FAL User	Object Specific Data (optional)	Conveys a request from FAL User to reset specified target object class or instance
Start.req	FAL User	Object Specific Data (optional)	Conveys a request from FAL User to a target object to start an instance of the specified object class
Stop.req	FAL User	Object Specific Data (optional)	Conveys a request from FAL User to a target object to stop an instance of the specified object class
Create.req	FAL User	Object Specific Data (optional)	Conveys a request from FAL User to a target object to create an instance of the specified object class
Delete.req	FAL User	Object Specific Data (optional)	Conveys a request from FAL User to a target object to delete an instance of the specified object class
Multiple_Service_Packet.req	FAL User	Number of Services Service Offsets Service List	Conveys a request from FAL User to a target object to perform a set of services as an autonomous sequence
Apply_Attributes.req	FAL User	Object Specific Data (optional)	Conveys a request from FAL User to a target object to activate pending attribute values
Get_attribute_single.req	FAL User	None	Conveys a request from FAL User to a target object to supply values of the specified attribute of the specified object class or instance
Set_attribute_single.req	FAL User	Attribute Data	Conveys a request from FAL User to a target object to write the specified values into specified attribute of the specified object class or instance
Find_next_object_instance.req	FAL User	Maximum Returned Values	Conveys a request from FAL User to a target device to find the identifier of the next unused instance of the specified object class
Restore.req	FAL User	Object Specific Data (optional)	Conveys a request from FAL User to a target object to restore its attributes contents
Save.req	FAL User	Object Specific Data (optional)	Conveys a request from FAL User to a target object to save its attributes contents
NOP.req	FAL User	None	Conveys a request from FAL User to a target object to send back a corresponding NOP response
Get_Member.req	FAL User	None	Conveys a request from FAL User to a target object to supply member(s) information from within the specified attribute
Set_Member.req	FAL User	Member Data	Conveys a request from FAL User to a target object to write member(s) information in the specified attribute
Insert_Member.req	FAL User	Member Data (optional)	Conveys a request from FAL User to a target object to inserts member(s) into the specified attribute
Remove_Member.req	FAL User	None	Conveys a request from FAL User to a target object to removes member(s) from the specified attribute

Primitive name	Source	Additional parameters	Functions
Group_Sync.req	FAL User	Object Specific Data (optional)	Conveys a request from FAL User to a target object to verify that each member of a group is synchronized to System Time
Get_Connection_Point_ Member_List.req	FAL User	None	Conveys a request from FAL User to a target object to return EPATHs and associated sizes of the value for member attributes defining the structure of a Connection Point
Get_attributes_All.rsp	FAL User	(+) Attribute Data (−) Specific Status Code	Returns a response from FAL User to a target object to supply values of all attributes of the specified object class or instance
Set_attributes_All.rsp	FAL User	(+) None (−) Specific Status Code	Returns a response from FAL User to a target object to write specified values of all attributes of the specified object class or instance
Get_attribute_list.rsp	FAL User	(+) Attribute Count Attribute Data (−) Specific Status Code	Returns a response from FAL User to a target object to supply values of specified list of attributes of the specified object class or instance
Set_attribute_list.rsp	FAL User	(+) Attribute_count Attribute Status List (−) Specific Status Code	Returns a response from FAL User to a target object to write specified values of specified list of attributes of the specified object class or instance
Reset.rsp	FAL User	(+) Object Specific Data (optional) (−) Specific Status Code	Returns a response from FAL User to a target object to confirm that the instance of the specified object class has been reset
Start.rsp	FAL User	(+) Object Specific Data (optional) (-) Specific Status Code	Returns a response from FAL User to a target object to confirm that the instance of the specified object class has started
Stop.rsp	FAL User	(+) Object Specific Data (optional) (−) Specific Status Code	Returns a response from FAL User to a target object to confirm that the instance of the specified object class has stopped
Create.rsp	FAL User	(+) Object Specific Data (optional) (−) Specific Status Code	Returns a response from FAL User to a target object to confirm that the instance of the specified object class has been created
Delete.rsp	FAL User	(+) Object Specific Data (optional) (−) Specific Status Code	Returns a response from FAL User to a target object to confirm that the instance of the specified object class has been deleted
Multiple_Service_Packet. rsp	FAL User	(+) Number of Responses Response Offsets Response List (−) Specific Status Code	Returns a response from FAL User to a target object containing responses to the set of services performed as an autonomous sequence
Apply_Attributes.rsp	FAL User	(+) Object Specific Data (optional) (−) Specific Status Code	Returns a response from FAL User to a target object to confirm that pending attribute values have been activated
Get_attribute_single.rsp	FAL User	(+) Attribute Data (−) Specific Status Code	Returns a response from FAL User to a target object to supply values of the specified attribute of the specified object class or instance
Set_attribute_single.rsp	FAL User	(+) Object Specific Data (optional) (−) Specific Status Code	Returns a response from FAL User to a target object to write the specified values into specified attribute of the specified object class or instance
Find_next_object_ instance.rsp	FAL User	(+) Number Of List Members Instance ID List (−) Specific Status Code	Returns a response from FAL User to a target device to find the identifier of the next unused instance of the specified object class

Primitive name	Source	Additional parameters	Functions
Restore.rsp	FAL User	(+) Object Specific Data (optional) (−) Specific Status Code	Returns a response from FAL User to a target object to confirm that its attributes contents have been restored
Save.rsp	FAL User	(+) Object Specific Data (optional) (−) Specific Status Code	Returns a response from FAL User to a target object to confirm that its attributes contents have been saved
NOP.rsp	FAL User	None	Returns a response from FAL User to a target object to confirm that the NOP has been received
Get_Member.rsp	FAL User	(+) Member ID Member Data (−) Specific Status Code	Returns a response from FAL User to a target object to supply member(s) information from within the specified attribute
Set_Member.rsp	FAL User	(+) Member ID (conditional) Member Data (optional) (−) Specific Status Code	Returns a response from FAL User to a target object to write member(s) information in the specified attribute
Insert_Member.rsp	FAL User	(+) Member ID Member Data (optional) (−) Specific Status Code	Returns a response from FAL User to a target object to inserts member(s) into the specified attribute
Remove_Member.rsp	FAL User	(+) Member ID Member Data (−) Specific Status Code	Returns a response from FAL User to a target object to removes member(s) from the specified attribute
Group_Sync.rsp	FAL User	(+) IsSynchronized Object Specific Data (optional) (−) Specific Status Code	Returns a response from FAL User to a target object to verify that each member of a group is synchronized to System Time
Get_Connection_Point_Member_List_rsp	FAL User	(+) Item Count Members (−) Specific Status Code	Returns a response from FAL User to a target object to provide EPATHs and associated sizes of the value for member attributes defining the structure of a Connection Point

Table 276 – Primitives issued by FSPM to FAL user

Primitive name	Source	Additional parameters	Functions
Get_attributes_All.ind	FSPM	same as in .req primitive	Indicates reception of Get_attributes_All.req
Set_attributes_All.ind	FSPM	same as in .req primitive	Indicates reception of Set_attributes_All.req
Get_attribute_list.ind	FSPM	same as in .req primitive	Indicates reception of Get_attribute_list.req
Set_attribute_list.ind	FSPM	same as in .req primitive	Indicates reception of Set_attribute_list.req
Reset.ind	FSPM	same as in .req primitive	Indicates reception of Reset.req
Start.ind	FSPM	same as in .req primitive	Indicates reception of Start.req
Stop.ind	FSPM	same as in .req primitive	Indicates reception of Stop.req
Create.ind	FSPM	same as in .req primitive	Indicates reception of Create.req
Delete.ind	FSPM	same as in .req primitive	Indicates reception of Delete.req
Multiple_Service_Packet.ind	FSPM	same as in .req primitive	Indicates reception of Multiple_Service_Packet.req
Apply_Attributes.ind	FSPM	same as in .req primitive	Indicates reception of Apply_Attributes.req
Get_attribute_single.ind	FSPM	same as in .req primitive	Indicates reception of Get_attribute_single.req
Set_attribute_single.ind	FSPM	same as in .req primitive	Indicates reception of Set_attribute_single.req

Primitive name	Source	Additional parameters	Functions
Find_next_object_ instance.ind	FSPM	same as in .req primitive	Indicates reception of Find_next_object_instance.req
Restore.ind	FSPM	same as in .req primitive	Indicates reception of Restore.req
Save.ind	FSPM	same as in .req primitive	Indicates reception of Save.req
NOP.ind	FSPM	same as in .req primitive	Indicates reception of NOP.req
Get_Member.ind	FSPM	same as in .req primitive	Indicates reception of Get_Member.req
Set_Member.ind	FSPM	same as in .req primitive	Indicates reception of Set_Member.req
Insert_Member.ind	FSPM	same as in .req primitive	Indicates reception of Insert_Member.req
Remove_Member.ind	FSPM	same as in .req primitive	Indicates reception of Remove_Member.req
Group_Sync.ind	FSPM	same as in .req primitive	Indicates reception of Group_Sync.req
Get_Connection_Point_ Member_List.ind	FSPM	same as in .req primitive	Indicates reception of Get_Connection_Point_Member_List.req
Get_attributes_All.cnf	FSPM	same as in .rsp primitive	Indicates reception of Get_attributes_All.rsp
Set_attributes_All.cnf	FSPM	same as in .rsp primitive	Indicates reception of Set_attributes_All.rsp
Get_attribute_list.cnf	FSPM	same as in .rsp primitive	Indicates reception of Get_attribute_list.rsp
Set_attribute_list.cnf	FSPM	same as in .rsp primitive	Indicates reception of Set_attribute_list.rsp
Reset.cnf	FSPM	same as in .rsp primitive	Indicates reception of Reset.rsp
Start.cnf	FSPM	same as in .rsp primitive	Indicates reception of Start.rsp
Stop.cnf	FSPM	same as in .rsp primitive	Indicates reception of Stop.rsp
Create.cnf	FSPM	same as in .rsp primitive	Indicates reception of Create.rsp
Delete.cnf	FSPM	same as in .rsp primitive	Indicates reception of Delete.rsp
Multiple_Service_Packet. cnf	FSPM	same as in .rsp primitive	Indicates reception of Multiple_Service_Packet.rsp
Apply_Attributes.cnf	FSPM	same as in .rsp primitive	Indicates reception of Apply_Attributes.rsp
Get_attribute_single.cnf	FSPM	same as in .rsp primitive	Indicates reception of Get_attribute_single.rsp
Set_attribute_single.cnf	FSPM	same as in .rsp primitive	Indicates reception of Set_attribute_single.rsp
Find_next_object_ instance.cnf	FSPM	same as in .rsp primitive	Indicates reception of Find_next_object_instance.rsp
Restore.cnf	FSPM	same as in .rsp primitive	Indicates reception of Restore.rsp
Save.cnf	FSPM	same as in .rsp primitive	Indicates reception of Save.rsp
NOP.cnf	FSPM	same as in .rsp primitive	Indicates reception of NOP.rsp
Get_Member.cnf	FSPM	same as in .rsp primitive	Indicates reception of Get_Member.rsp
Set_Member.cnf	FSPM	same as in .rsp primitive	Indicates reception of Set_Member.rsp
Insert_Member.cnf	FSPM	same as in .rsp primitive	Indicates reception of Insert_Member.rsp
Remove_Member.cnf	FSPM	same as in .rsp primitive	Indicates reception of Remove_Member.rsp
Group_Sync.cnf	FSPM	same as in .rsp primitive	Indicates reception of Group_Sync.rsp
Get_Connection_Point_ Member_List.cnf	FSPM	same as in .rsp primitive	Indicates reception of Get_Connection_Point_Member_List.rsp

8.3 Parameters of primitives

The parameters used with the primitives exchanged between the FSPM and the ARPM are described in Table 277.

Table 277 – Parameters used with primitives exchanged between FAL user and FSPM

Parameter name	Description
AREP: Local identifier UCMM Record identifier Transport identifier	Identifies the entity to be used to convey the service. This parameter may use a dedicated identifier associated with a local entity, the identifier of a UCMM transaction record previously created, or the transport identifier returned by the connection establishment process and associated with the selected AR.
Receiver/Server Local ID	Generated by the Message Router ASE of the responding node. Identifies locally this invocation of the service. It is used to associate service responses with indications.
Path: Routing Path Additional path	In the request, it specifies the FAL APO or FAL APO element that is the destination of the service request. In the indication, it contains only those segments beyond the logical class segment from the service request, i.e. the optional additional information for the target APO (Add.Path).
Port ID	Indicates on which port of the device the service indication arrived.
Service status: Status Code (mandatory) Extended Status (conditional)	Provides information on the result of service execution. It is returned in all confirmed service response primitives (+ and -). Status code indicates the type of error (see IEC 61158-5-2 for details). Extended status code gives details of the status (see IEC 61158-5-2 for details).
Attribute Data	1) A stream of information containing the values of each attribute that the Class/Object defines for the request/response format. Classes/Objects which support this service shall define the format of this parameter. 2) An array of structures, predefined by the system for the given service
Attribute Count	Number of attribute numbers in the attribute list
Attribute list []	List (array) of the attribute numbers of the attributes to get from the class or object
Attribute Number	Number representing the attribute value
Attribute Status	Status information of attribute
Attribute Value	Sequence of data specific to the attribute of the object or class
Object Specific Data	Class/Instance specific parameters. Class/Instance specification shall specify the format.
Instance ID	Value assigned to identify the newly created object
Maximum Returned Values	Maximum number of Instance ID values to be returned in the response message
Number Of List Members	Number of Instance IDs specified in response message
Instance ID List	Returned Instance ID List. The Instance IDs are returned in 16 bit integer fields.
IsSynchronized	Indicates if object is synchronized to the PTP Time Master
Item Count	Number of STRUCTs returned
Members	List of EPATHs of each member of the Connection Point structure, or the EPATH to the full Parameter Object Instance that refers to the member

8.4 FSPM state machines

FSPM State Machine has got only one possible state: Running.

9 Application relationship protocol machines (ARPMs)

9.1 General

This fieldbus has Application Relationship Protocol Machines for:

- connection-less application relationships,
- connection-oriented application relationships.

Connection-less relationship is of one type only.

Connection-oriented relationships fit into one of 4 transport classes:

0 Null (or Base)
1 Duplicate Detection
2 Acknowledged
3 Verified

Although similar, each of these transport classes has its own ARPM.

9.2 Connection-less ARPM (UCMM)

9.2.1 General

Functions of the connection-less ARPM are provided by the Unconnected Message Manager (UCMM) object. UCMM shall provide an unconnected request/response message services, limited to a single link that supports multiple outstanding messages. The required number of outstanding messages shall be implementation specific. The UCMM shall be present in all nodes, and shall support at least one outstanding message.

The UCMM detailed specification varies depending on the different data link layer associated which can be associated with the Type 2 application layer. The underlying data link layer defines how the UCMM is accessed and may limit the messaging which can occur across the UCMM.

9.2.2 Primitive definitions

The UCMM object shall provide the following services:

UCMM_Create	Creates an instance of transaction record. Puts UCMM into Running state. This service is local, it does not result in a PDU being sent.
UCMM_Delete	Deletes existing transaction record. Puts UCMM into Inactive state. This service is local, it does not result in a PDU being sent. This service is local, it does not result in a PDU being sent.
UCMM_Write	Writes an item of application data into Transport PDU buffer; this results in sending the data to a specified target.
UCMM_Abort	Aborts existing transaction.

Refer to IEC 61158-5-2 for detailed definition of these services.

Primitives exchanged between UCMM and FSPM are shown in the following Table 278 and Table 279.

Table 278 – Primitives issued by FSPM to ARPM

Primitive name	Source	Associated parameters	Functions
UCMM_Create_req	FSPM	fixed tag max retries,	Conveys a request from the FSPM to the ARPM to create a transaction record.
UCMM_Delete_req	FSPM	record	Conveys a request from the FSPM to the ARPM to delete previously established transaction record.
UCMM_Write_req	FSPM	record destination ID UCMM service response timeout transaction priority application data	Conveys a request from the FSPM to the ARPM to send an item of application data using a previously created transaction record.
UCMM_Write_rsp	FSPM	record application data	Conveys a response from the FSPM, via Message Router to the ARPM to send a response to UCMM_Send_req using a previously created transaction record.
UCMM_Abort_req	FSPM	record	Aborts the transaction corresponding to the specified transaction record; removes the packet from the local DLL if it has not yet been transmitted.

Table 279 – Primitives issued by ARPM to FSPM

Primitive name	Source	Associated parameters	Functions
UCMM_Create_cnf	ARPM	record service_status	Conveys a confirmation from the ARPM to the FSPM that transaction record has been created.
UCMM_Write_ind	ARPM	record source ID application data	Conveys an indication from the ARPM to the Message Router that data has arrived on the previously created transaction record. The Message Router then passes the indication to the appropriate application object.
UCMM_Write_cnf	ARPM	record service status application data	Conveys a confirmation from the ARPM to the Message Router of the execution of FSPM UCMM_Send_req on a previously created transaction record.

9.2.3 Parameters of primitives

The parameters used with the primitives exchanged between the FSPM and the ARPM are described in Table 280.

Table 280 – Parameters used with primitives exchanged between FSPM and ARPM

Parameter name	Description
record	Identifies unambiguously the instance of the temporary connection along which the FSPM has issued a UCMM_Send request primitive. A means for such identification is not specified in this document.
application data	Conveys FAL-User data.
fixed tag	Set to value of 0x83 for UCMM and 0x88 for Management UCMM
destination ID	Unambiguous identifier (MAC ID) of the source node of UCMM_write_req.
source ID	Unambiguous identifier (MAC ID) of the destination node of UCMM_write_req.
service	The service parameter shall specify the delivery mechanism to use for this message and shall be one of: Request_With_Acknowledge = 2 (retries until acknowledged) Request_With_No_Response = 4 (no acknowledgement) Request_With_No_ACK = 7 (retries until response) Request_With_No_Retry = 8 (with response) NOTE These values correspond to command codes contained in the UCMM header
timeout	Duration of the transaction in microseconds. If no UCMM_Send_cnf is received before the time-out expires, the transaction is aborted and the send_status parameter shall be TIMEOUT.
retries	Conveys the maximum allowable number of retries.
create_status	Status returned with UCMM_Create_conf = – success – cannot create
send_status	Status returned with UCMM_Send_conf = – success – record_not_created – packet_too_big – no_acknowledge – aborted – timeout

9.2.4 UCMM state machines

9.2.4.1 UCMM client

9.2.4.1.1 States

The defined states and their descriptions of the UCMM Client are listed in Table 281.

Table 281 – UCMM client states

State	Description
Inactive	The record for UCMM transfer does not exist.
Running	The record for UCMM transfer has been created.
Waiting for response	Client sent an item of application data and is waiting for a response.

9.2.4.1.2 State transition diagram

Figure 32 shows the state transition diagram of UCMM client.

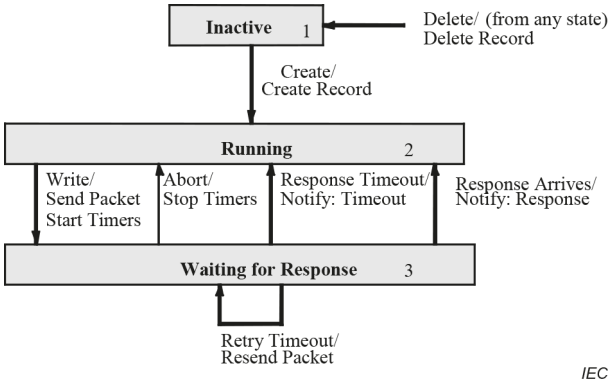


Figure 32 – State transition diagram of UCMM client9

9.2.4.1.3 State event matrix

The state transitions for the UCMM Client shall be as specified in Table 282.

Table 282 – State event matrix of UCMM client

Event	State		
	Inactive	Running	Waiting for response
Create.req	1) create record 2) transition to Running		
Delete.req	no action	1) delete record 2) increment SEQUENCE 3) transition to Inactive	1) Delete record 2) increment SEQUENCE 3) transition to Inactive
Write.req	confirm status = INVALID_RECORD	1) send packet 2) start Response Timer 3) initialize Retry Count 4) start Retry Timer 5) transition to Waiting	confirm status = BUSY
Abort.req	confirm status = INVALID_RECORD	no action	1) stop timers 2) increment SEQUENCE 3) transition to Running
Retry Timeout Request packet available			1) Decrement Retry Count IF Retry Count expired 2) Notify: Timeout-No ACK 3) Free request buffer 4) Increment Sequence # 5) Stop Response Timer 6) Transition to Running ELSE. 1) Resend packet 2) Restart Retry Timer
Response Timeout			1) confirm with status = TIMEOUT-No Response 2) increment SEQUENCE 3) transition to Running
Response Arrives		no action	1) confirm with status = SUCCESS 2) Send ACK_RESP, unless response indicates no ACK_RESP desired 3) increment SEQUENCE 4) transition to Running
ACK_REQ Arrives, sequence number matches stored value		No Action	1) Free request buffer 2) stop retry timer

Event	State		
	Inactive	Running	Waiting for response
ACK_REQ Arrives, sequence number not equal to stored value		No Action	No Action

The sequence number shall be set to zero at initialization. The sequence number value shall be maintained in the inactive state, to be used when the record transitions to running. The retry timeout value shall be fixed for the link at a value which guarantees that both the client and server nodes have an opportunity to transmit an unscheduled packet.

The response time-out is the response time provided when the record is created.

9.2.4.2 High-end UCMM server

9.2.4.2.1 Functions

When a packet arrives at the server an instance of a transaction shall be created if resources are available. If resources are not available the packet shall be dropped. When the instance is created, a transaction record shall be created for that instance. This record shall be active for the life of this transaction. The transaction shall end:

- when an ACK_RESP is received after a response was sent;
- when the response time timer expires; or
- when a new packet is received after a response was sent.

9.2.4.2.2 States

The defined states and their descriptions of the UCMM High-end Server are listed in Table 283.

Table 283 – High-end UCMM server states

State	Description
Inactive	The record for UCMM transfer does not exist.
Waiting for Response	Data packet arrived with new Transaction ID. New record is created. The Server is waiting for response to be sent by the Server application.
Response sent	Server application sent a response.

9.2.4.2.3 State transitions

Figure 33 shows the high-end UCMM Server state transition diagram.

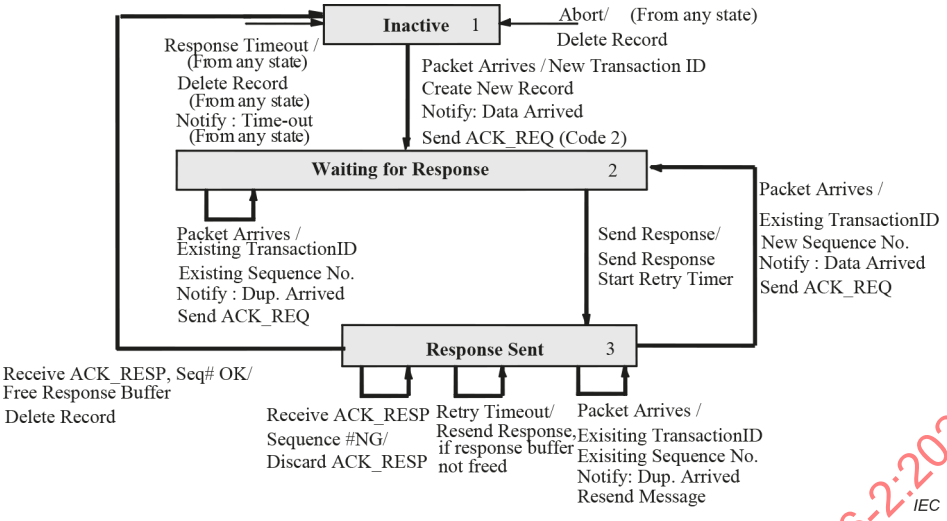


Figure 33 – State transition diagram of high–end UCMM server

9.2.4.2.4 State event matrix

The state transitions for the high-end UCMM server shall be as specified in Table 284.

The sequence number shall be set to zero at initialization. The sequence number value shall be maintained in the Inactive state, to be used when the record transitions to Running. The retry time-out value shall be fixed for the local link.

The response time-out shall be the response time provided when the record is created.

Table 284 – State event matrix of high-end UCMM server

Event	State		
	Inactive	Waiting for response	Response sent
Packet arrives request (code 2) New Transaction ID and source address	1) Create new record 2) Notify: Data Arrived 3) Send ACK_REQ 4) Start Response Timer 5) Transition to Waiting for App Response	Not Applicable	Not Applicable
Packet arrives request (code 7) New Transaction ID and source address	1) Create new record 2) Notify: Data Arrived 3) Start Response Timer 4) Transition to Waiting for App Response	Not Applicable	Not Applicable
Packet arrives Existing Transaction ID and source address New Sequence #	Not Applicable	No Action	1) Update Record 2) Notify: Data Arrived 3) Send ACK_REQ 4) Transition to Waiting for App Response

Event	State		
	Inactive	Waiting for response	Response sent
Packet arrives Existing Transaction ID Existing Sequence #	Not Applicable	1) Notify: Dup. Arrived (Optional) 2) Send ACK_REQ	1) Notify: Dup. Arrived (Optional) 2) Resend Response Message
Response Timer Expires	Not Applicable	1) Notify: Timeout 2) Delete record 3) Transition to Inactive	1) Notify: Timeout 2) Delete record 3) Transition to Inactive
Abort	Error	1) Delete record 2) Transition to Inactive	1) Delete record 2) Transition to Inactive
Send Response	Error	1) Send Response 2) Start Retry Timer 3) Transition to Response Sent	Error
Retry Timeout	Not Applicable	Not Applicable	1) Decrement Retry Count IF Retry Count expired 2) Free Response buffer 3) Stop Response Timer 4) Transition to Inactive ELSE 1) Resend Response message 2) Start Retry Timer
ACK_RESP arrives, sequence number matches stored value	No action	No action	1) Delete record 2) Transition to Inactive
ACK_RESP arrives, sequence number not equal to stored value	No action	No action	No action

The response time is the response time received in the message header.

9.2.4.3 Low-end UCMM server

9.2.4.3.1 Functions

The low-end server cannot support the following features:

- perform response message retries,
- detect duplicate messages.

9.2.4.3.2 States

The defined states and their descriptions of the UCMM Low-end Server are listed in Table 285.

Table 285 – Low-end UCMM server states

State	Description
Inactive	The record for UCMM transfer does not exist.
Waiting for Response	Data packet arrived with new Transaction ID. New record is created. The Server is waiting for response to be sent by the Server application.

9.2.4.3.3 State transitions

Figure 34 shows the low-end UCMM server state transition diagram.

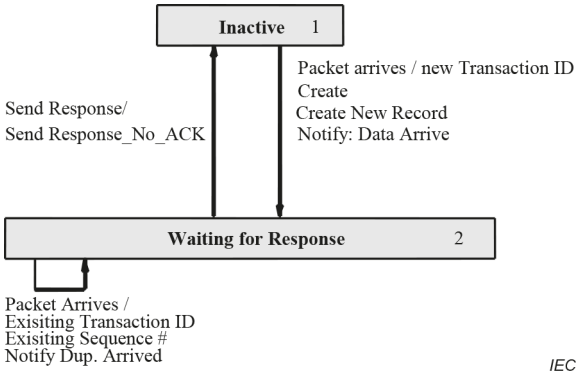


Figure 34 – State transition diagram of low–end UCMM server

9.2.4.3.4 State event matrix

The state transitions for the Low-end UCMM server shall be as specified in Table 286.

Table 286 – State event matrix of low–end UCMM server

Event	State	
	Inactive	Waiting for response
Packet arrives New Transaction ID and source address	1) Create new record 2) Notify: Data Arrived 3) IF Response not immediately available, Send ACK_REQ 4) Transition to Waiting for App Response	Not Applicable
Packet arrives Existing Transaction ID and source address New Sequence #	No action	No action
Packet arrives Existing Transaction ID Existing Sequence #	No action	1) Notify: Dup. Arrived (Optional)
Send Response	Error	1) Send Response_No_ACK 2) Transition to Inactive
ACK_RESP arrives	No action	No Action

9.2.5 Examples of UCMM sequences

Figure 35 shows a sequence diagram for a UCMM with one outstanding message and Figure 36 shows a sequence diagram for a UCMM with multiple outstanding messages.