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Intelligent transport systems — Lower layer protocols for usage in the European digital tachograph

Systèmes de transport intelligents - Protocoles de couche basse pour utilisation dans le cadre du chrono tachygraphe numérique européen

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems.*

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document is designed to encompass communication requirements in support of the Smart Digital Tachograph (SDT) as identified by Regulation 2016/799 of the European Union[23].

This document specifies SDT Communications (SDTC). SDTC is the application of CEN Dedicated Short Range Communication (DSRC) for SDT. See the following:

— EN 12253, *Road transport and traffic telematics — Dedicated short-range communication — Physical layer using microwave at 5,8 GHz*[1]

— EN 12795, *Road transport and traffic telematics — Dedicated Short Range Communication (DSRC) — DSRC data link layer: medium access and logical link control*[2]

— EN 12834, *Road transport and traffic telematics — Dedicated Short Range Communication (DSRC) — DSRC application layer*[3]

— EN 13372, *Road transport and traffic telematics — Dedicated short-range communication — Profiles for RTTT applications*[4]

Complementing the standardized specifications and descriptions, several private documents describe this dedicated short range semi-passive communication technology in an informative manner, providing additional detailed explanations and implementation hints. See for example:

— DSRC tutorial published by ESF GmbH in July 2003 (publicly available)[24];

— GSS industry specification published in August 2003[25] (no longer available from the authors; essential content is now available in ISO 15509).

It is to be noted that the abovementioned private documents provide information that can be essential to easily achieving interoperability with existing DSRC equipment and optimum performance.

EN 12253[1] deals with the physical layer of the DSRC protocol stack presented in Figure 1; i.e. it comprises requirements for Open Systems Interconnection (OSI) Layer 1 at 5,8 GHz for DSRC.

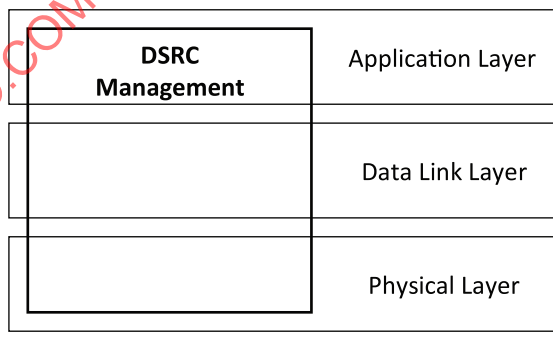


Figure 1 — DSRC protocol stack

EN 12253[1] does not include associated measurement procedures for verification of the requirements. Test methods for conformity are provided in ETSI EN 300674-1[12], ETSI EN 300674-2-1[13] and ETSI EN 300674-2-2[14].

EN 12253[1] caters for on-board units based on transponder technologies. Furthermore, it allows for mixed time, frequency and space division multiple access approaches.

EN 12253[1] is conceived for the 10 MHz part (i.e. 5,795 GHz to 5,805 GHz) of the ISM band at 5,8 GHz which is recommended by ECC/DEC(01)01[10]. An additional sub-band (5,805 GHz - 5,815 GHz) may be

allocated on a national basis. National restrictions on the usage of these frequency bands can apply according to CEPT/ERC REC 70-03[11].

EN 12795[2] gives the architecture and services offered by the DSRC data link layer.

EN 12834[3] and the almost identical ISO 15628 give the architecture and services offered by the DSRC application layer.

EN 13372[4] deals with the interlayer management of the DSRC protocol stack.

Figure 2 illustrates the global data flow between the elements of the SDTC stack, (physical layer, data link layer and application layer) and the SDT application.

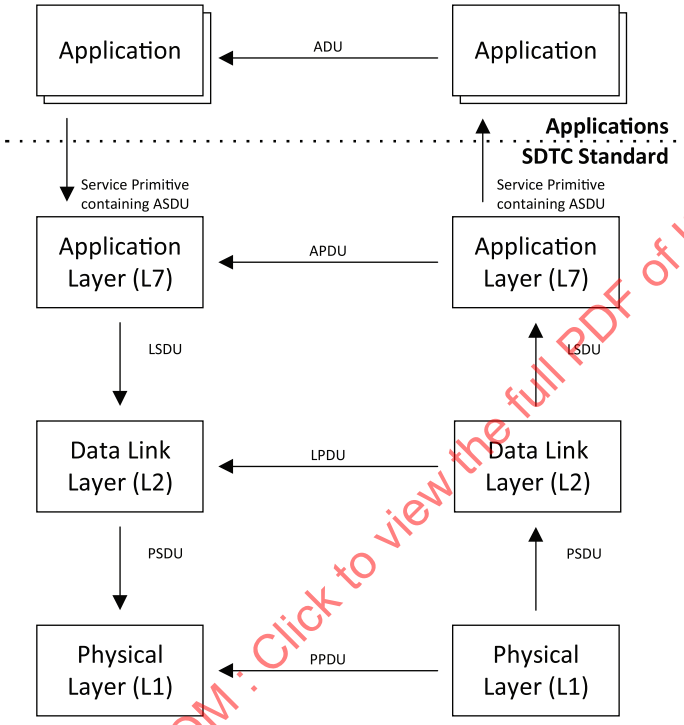


Figure 2 — Architecture and data flow of the SDTC stack

Intelligent transport systems — Lower layer protocols for usage in the European digital tachograph

1 Scope

This document specifies communication requirements in support of the Smart Digital Tachograph (SDT) as identified by Regulation 2016/799 of the European Union[23].

The specification covers:

— the physical layer at 5,8 GHz for SDT communications (SDTC);

— the data link layer (DLL) of SDTC;

— the application layer of SDTC;

— SDTC profiles which provide coherent sets of communication tools for applications based on SDTC.

This document provides further information beneficial for the design and development of SDTC equipment.

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.

ISO 15628, *Intelligent transport systems — Dedicated short range communication (DSRC) — DSRC application layer*

ISO/IEC 13239, *Information technology — Telecommunications and information exchange between systems — High-level data link control (HDLC) procedures*

3 Terms and definitions

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
adjacent channel
neighbouring SDTC channel for use by two or more emissions

Note 1 to entry: It is possible that a SDTC channel has either one of two adjacent channels.

3.2
antenna bore sight direction
direction of maximum antenna gain

3.3
application
set of processes including related functions and structured data that uses the services offered by the SDTC communication stack

3.4
beacon service table
BST
data structure transmitted by the fixed equipment indicating available services

3.5
bit error ratio
averaged number of erroneous bits relative to the total number of transmitted bits

3.6
co-channel
refers to the use of the same SDTC channel by two or more emissions

3.7
communication initialization
procedure used to establish communication between an RSU and a newly arrived OBU

Note 1 to entry: Terms prefixed with D present downlink parameters; downlink parameters apply to transmission of data from RSU to OBU.

3.8
D1 — carrier frequencies
number and values of the downlink carrier frequencies, which are equal to the frequencies of the CW, transmitted by the RSU and used by transponder OBUs for uplink communication

Note 1 to entry: Each carrier frequency is the centre frequency of a downlink channel.

3.9
D1a — tolerance of carrier frequencies
maximum deviation of the carrier frequency resulting from any cause

Note 1 to entry: It is expressed in parts per million (ppm)

EXAMPLE ±1 ppm of a 5,8 GHz carrier allows for the carrier frequency to be in the range of 5,8 GHz ± 5,8 kHz.

3.10
D2 — RSU transmitter spectrum mask
maximum allowed power within a defined frequency band emitted by the RSU transmitter

3.11
D3 — OBU minimum frequency range
minimum range of frequencies that has to be received by the OBU receiver

3.12
D4 — maximum E.I.R.P.
maximum allowed value of E.I.R.P.

3.13
D4a — angular E.I.R.P. mask
E.I.R.P. as a function of the angle Θ, where Θ indicates the angle relative to a vector perpendicular to the road surface, pointing downwards

3.14
D5 — polarization
locus of the tip of the vector of the electrical field strength in a plane perpendicular to the transmission vector

EXAMPLE Horizontal and vertical linear polarization and left- and right-hand circular polarization.

3.15
D5a — cross-polarization
ellipticity of polarization
antenna designed to transmit left-hand circular waves, which can transmit some right-hand circular waves in addition

Note 1 to entry: Cross-polar discrimination (XPD) is defined as the ratio between left- and right-hand circular power, P_{LHC}/P_{RHC}, when the total power transmitted is $P_{LHC} + P_{RHC}$. XPD is related to the ellipticity of polarization.

3.16
D6 — modulation
keying of the carrier wave by coded data

EXAMPLE Amplitude shift keying (ASK), phase shift keying (PSK), frequency shift keying (FSK) and linear amplitude modulation (AM).

3.17
D6a — modulation index
ratio of the variation of the modulation parameter (frequency, amplitude, phase) caused by the modulation signal (data signal)

EXAMPLE Given the minimum and maximum values V_{max} and V_{min} of the envelope amplitude V of the modulated signal, the amplitude modulation index m is defined as:

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}.$$

3.18
D7 — data coding
downlink base band signal presentation, i.e. a mapping of logical bits to physical signals

EXAMPLE Bi-phase schemes (Manchester, FM0, FM1, differential Manchester), NRZ and NRZI. NRZI: No transition at beginning of "1" bit, transition at beginning of "0" bit, no transition within bit.

3.19
D8 — bit rate
number of bits per second, independent of the data coding

3.20
D8a — tolerance of bit clock
maximum downlink deviation of the bit clock resulting from any cause, expressed in ppm

EXAMPLE 100 ppm of 500 kbit/s allows for the bit clock to be in the range of 500 kHz ± 50 Hz.

3.21
D9 — bit error ratio for communication
maximum allowed bit error ratio valid within the dynamic range of the receiver as defined by D11a and D11b

3.22
D10 — wake-up trigger for OBU
signal which:

a) indicates to the OBU that it is within a communication zone, i.e. that it can now communicate with an RSU;

b) switches the OBU main circuitry from sleep mode to the active mode

Note 1 to entry: This is a feature to allow the OBU to save battery power. It is not mandatory for an OBU to use a wake-up process.

3.23
D10a — maximum start time
maximum time between the reception of the wake-up trigger and the time when the OBU has switched to the active mode

3.24
D11 — communication zone
spatial region within which the incident power of the OBU has a dynamic range as defined by D11a and D11b

3.25
D11a — power limit for communication (upper)
upper level of incident power referred to a lossless isotropic antenna (0 dB) in front of the OBU

Note 1 to entry: This is the level below which, subject to D11b, communication is guaranteed with a specified bit error ratio. Communication can take place above this limit, but is not guaranteed. Together with D11b it also specifies the minimum dynamic range of the OBU receiver. Power values are measured without any additional losses due to rain or misalignment.

3.26
D11b — power limit for communication (lower)
lower level of incident power referred to a lossless isotropic antenna (0 dB) in front of the OBU

Note 1 to entry: This is the level above which, subject to D11a, communication is guaranteed with a specified bit error ratio. Communication can take place below this limit, but is not guaranteed. Together with D11a it also specifies the minimum dynamic range of the OBU receiver. Power values are measured without any additional losses due to rain or misalignment

3.27
D12 — cut-off power level of OBU
incident power that is lower than the specified cut-off power level that does not result in communication

3.28
D13 — preamble
specific downlink layer 1-bit pattern

Note 1 to entry: Preamble is the bit pattern transmitted immediately before a frame.

3.29
D13a — preamble length
length of the downlink preamble measured in number of bits

3.30
D13b — preamble wave form
signal shape of the preamble

3.31
D13c — trailing bits
sequence of bits transmitted after the end flag of the data link layer

3.32
downlink
communication channel on which the fixed equipment transmits its information

3.33
downlink communication
communication from the RSU to the OBU

3.34
equivalent isotropically radiated power
E.I.R.P.
signal power fed into an ideal lossless antenna radiating equally in all directions that generates the same power flux at a reference distance as the one generated by a signal fed into the antenna under consideration in a predefined direction within its far field region

3.35
fixed equipment
fixed communication facility with one or more downlink channels and, optionally, one or more uplink channels

Note 1 to entry: Normally the fixed equipment is installed at a fixed location, but it may be installed on a mobile platform.

3.36
interlayer management
assembly of communication parameters of all protocol layers such that a consistent communication protocol is provided

3.37
link identifier
LID
unique address used for addressing the mobile equipment

3.38
mobile equipment
mobile communication facility capable of receiving information from the fixed equipment on the downlink and, optionally, also capable of transmitting information to the fixed equipment on the uplink

Note 1 to entry: The mobile equipment normally corresponds to the vehicle's communication unit.

3.39
on-board unit
OBU
physical assembly that is located and operated in or on the vehicle to transmit and/or receive SDTC signals

Note 1 to entry: An OBU may be in a form that is removable from the vehicle, or mountable in or on any part of the vehicle structure, or bonded to a part of the vehicle, or an integral part of a vehicle component, such as a windscreen, bumper or licence plate. In this document, parameters that refer to an OBU relate to the form that the OBU takes as it is supplied to the vehicle manufacturer or constructor.

Note 2 to entry: An OBU is an alternative descriptor to Mobile Equipment.

3.40
roadside unit
RSU
SDTC equipment usually residing by the side of the road or overhead the road

Note 1 to entry: An RSU is an alternative descriptor to Fixed Equipment.

3.41
SDTC channel
frequency band for SDTC indicated by reference to the downlink centre frequency of one of up to four frequency bands with 5 MHz width each

3.42
SDTC profile
consistent and standardized set of cross layer parameters controlling the behaviour of the SDTC

3.43
service access point
SAP
interface point between data link layer and application layer, that has a unique link identifier and that allows layers to communicate

3.44
smart digital tachograph communication
SDTC
CEN DSRC applied for the Smart Digital Tachograph (SDT)

Note 1 to entry: This is as identified by Regulation 2016/799 of the European Union[23].

3.45
termination
procedure used to terminate communication between an RSU and an OBU

3.46
U1 — sub-carrier frequencies
number and values of the uplink sub-carrier frequencies, i.e. the frequency separation from the centre of the uplink side band to the centre of the corresponding downlink band

3.47
U1a — tolerance of sub-carrier frequencies
maximum deviation of the sub-carrier frequency resulting from any cause

EXAMPLE 1 % of 1,5 MHz sub-carrier allows for the sub-carrier frequency to be in the range of 1,5 MHz ± 15 kHz.

Note 1 to entry: Normally this is expressed in percentage (%) or in parts per million (ppm) of the sub-carrier frequency.

Note 2 to entry: Terms prefixed with U present uplink parameters; uplink parameters apply to transmission of data from OBU to RSU.

3.48
U1b — use of side bands
specification of the use of the uplink side bands

Note 1 to entry: Data can be modulated on the upper side band only, or the lower side band only, or on both side bands. In principle, different data can be modulated on the two side bands.

3.49
U2 — OBU transmitter spectrum mask
maximum allowed power emitted by the OBU transmitter within a defined frequency band

3.50
U4 — maximum single side band E.I.R.P. (bore sight)
maximum E.I.R.P. transmitted by the OBU within a single side band, measured at the maximum incident power defined by D11a

Note 1 to entry: For a non-isotropic OBU antenna the single side band E.I.R.P varies with the direction of the incident power and the direction in which the emitted power is measured.

3.51
U4a — maximum single side band E.I.R.P. (bore sight)
measurement when the incident power is in bore sight and the emitted power is measured in bore sight

3.52
U4b — maximum single side band E.I.R.P. (35°)
measurement when the incident power is in bore sight and the emitted power is measured at any angle not less than 35° away from bore sight

3.53
U5
uplink parameter indicating the uplink polarization

3.54
U5 — cross-polarization
uplink parameter indicating the cross-polarization

3.55
U6 — sub-carrier modulation
keying of the sub-carrier wave by coded data

EXAMPLE Amplitude shift keying (ASK), phase shift keying (PSK), and frequency shift keying (FSK).

Note 1 to entry: U6b is not used.

3.56
U6b — duty cycle
ratio of the length of high or low pulses to the duration of a complete cycle

Note 1 to entry: In NRZI a sequence of zero bits results in a pulse of alternating high- and low-level sections. A low-level section and the adjacent high-level section constitute a cycle of the pulse. The nominal duration of such a single section is equal to the bit duration. The cycle duration is twice the bit duration. The duty cycle is the ratio of the duration of the high-level section to the cycle duration.

3.57
U6c — modulation on carrier
keying of the carrier wave by the modulated sub-carrier

3.58
U7 — data coding
uplink base band signal presentation, i.e. a mapping of logical bits to physical signals

3.59
U8 — bit rate
number of bits per second, independent of the data coding

3.60
U8a — tolerance of symbol clock
maximum uplink deviation of the bit clock resulting from any cause, expressed in ppm

3.61
U9 — bit error ratio for communication
maximum allowed bit error ratio valid within the dynamic range of the receiver

3.62
U11 — communication zone
spatial region within which the OBU is situated such that its transmissions are received by the RSU with a bit error ratio of less than a specified value

3.63
U12 — conversion gain
difference between OBU E.I.R.P. within one side band and the carrier incident power on OBU

3.64
U13 — preamble
specific uplink layer 1-bit pattern

3.65
U13a — preamble length
length of the uplink preamble

Note 1 to entry: Preamble length is measured either in multiples of symbols or in seconds.

3.66
U13b — trailing bits
sequence of bits transmitted after the end flag of the data link layer

3.67
uplink
communication channel on which mobile equipment transmits its information

3.68
uplink communication
communication from the OBU to the RSU

3.69
vehicle service table
VST
data structure transmitted by the OBU to indicate available services

3.70
window
period of time during which the physical medium is allocated either to the fixed equipment or to the mobile equipment

4 Abbreviated terms and symbols

2-PSK	binary phase shift keying
ACK	acknowledge
ACn	acknowledged command with sequence bit n
ADU	application data unit
AM	amplitude modulation
APDU	application protocol data unit
ASDU	application service data unit
ASK	amplitude shift keying
C/R	command/response
CEN	European Committee for Standardization
CEPT	European Conference of Postal and Telecommunications Administrations
CW	continuous wave
DLL	data link layer
DSRC	dedicated short-range communication
EC	European Commission

EDTC	European digital tachograph communication
EFC	electronic fee collection
EN	European Standard
ERC	European Radiocommunications Committee
ERM	electromagnetic compatibility and radio spectrum matters
ETSI	European Telecommunications Standards Institute
F	final
FCS	frame check sequence
FE	fixed equipment
FM0 / FM1	bi-phase coding scheme, bit inverse to FM1 / FM0
FSK	frequency shift keying
HDLC	high-level data link control
ISM	industrial, scientific, medical
L1	layer 1 of SDTC (physical layer)
L2	layer 2 of SDTC (data link layer)
L7	layer 7 of SDTC (application layer)
LLC	logic link control
LPDU	link layer protocol data unit
LSB	least significant bit
LSDU	link layer service data unit
M	modifier function bit
MAC	medium access control
ME	mobile equipment
MSB	most significant bit
NRZ	non-return to zero
NRZI	non-return to zero inverted
OSI	open systems interconnection
P	poll
P/F	poll/final
PICS	protocol implementation conformance statement
PDU	protocol data unit

PPDU	physical layer protocol data unit
PSDU	physical layer service data unit
ppm	parts per million
PSK	phase shift keying
R	response
R&TTE	radio and telecommunications terminal equipment
RR	response request
RTTT	road transport and traffic telematics
TDMA	time division multiple access
TSS&TP	test suite structure and test purposes
UI	unnumbered information
V_{rx}	receive state variable (LLC)
V_{tx}	transmit state variable (LLC)
XPD	cross-polar discrimination

5 Digital tachograph interrogation

5.1 General

A regulatory device such as a smart tachograph needs to offer an interface for interrogation by authorized officers. Such an interface may be carried through a physical connector, or via a wireless communication interface. When the second option is chosen, stringent requirements of confidentiality and, in general, security, arise.

A DSRC helps in satisfying these security requirements because of its localized nature and because of the experience already gained in securing this type of links. This is one of the reasons the specification of the application for digital tachograph interrogation in ISO 15638-9 is based on this type of communication mechanism.

Some legislations require that a radio link shall be available in smart tachograph devices, such as in Europe, where Regulation 165/2014[21] requires that "*In order to facilitate targeted roadside checks by the competent control authorities, tachographs installed in vehicles ... shall be able to communicate to those authorities while the vehicle is in motion*".

The right to allocate frequencies for DSRC and to determine suitable protocols for interrogation applications is left to regional legislation.

In Europe the frequency band of 5,8 GHz has been in use for EFC applications for example for many years. The communication and application layers defined for EFC are also suitable for other types of short range radio interrogations, such as that for the digital tachograph, and that which is required in Annex 14 of the Smart Tachograph Implementing Regulation of the EU [22]. The requirements on lower layers for the European digital tachograph are thus expressed in 5.2 and 5.3.

5.2 SDTC protocol stack

5.2.1 Simplified OSI layered

SDTC is based on a simplified OSI layered model presented in Figures 1 and 2. The OSI Layers 3 (Network) and 4 (Transport) do not exist, as SDTC concerns localized communications, i.e. not providing routing of packets through a network.

NOTE The definition of "localized communications" can be found in ISO 21217. However, ISO 21217 is not needed for the understanding of this document, or for an interoperable implementation of SDTC.

Functionality of OSI Layers 5 (Session), 6 (Presentation) and 7 (Application) is provided in the SDTC Layer, application layer (L7).

The OSI Layer 1 maps to the SDTC Layer, physical layer (L1), and the OSI Layer 2 maps to the SDTC Layer, data link layer (L2).

Details of the digital tachograph application, which resides on top of L7, are out of the scope of this document. For details of the SDTC Layers, see 5.2.2, 5.2.3, 5.2.4 and 5.3.

5.2.2 SDTC L1

The SDTC physical layer specifications for the required 5,8 GHz DSRC shall be as specified in Annex A of this document.

5.2.3 SDTC L2

The SDTC data link layer procedures shall be as specified in Annex B of this document.

5.2.4 SDTC L7

The SDTC application layer to be used as a support for the digital tachograph interrogation shall be as specified in Annex C of this document.

5.3 SDTC profiles

The specification of SDTC L1, L2 and L7 allows for different implementations. To avoid ambiguity and non-interoperable implementations, a choice of options referred to as "SDTC profiles" shall be as specified in Annex D of this document.

6 Test methods

The exact specification of conformance testing procedures is left to national regulations. However, it is worthwhile noting here that the following conformance testing standards are available for all requirement standards listed in Clause 5, and in Annex A, Annex B, Annex C, and Annex D, and can be used in national certification procedures:

a) For the physical layer, including testing Layer 1 requirements specified in the profiles in Annex D:

   1) ETSI EN 300 674-1[12] for the general test procedures and test environment setup;

   2) ETSI EN 300 674-2-1[13] for the roadside unit;

   3) ETSI EN 300 674-2-2[14] for the roadside unit.

b) For the data link layer, including testing Layer 2 requirements specified in the profiles in Annex D:

   1) ETSI TS 102 486-1-1[15] for the protocol implementation conformance statement (PICS);

   2) ETSI TS 102 486-1-2[16] for the test suite structure and test purposes (TSS&TP);

3) ETSI TS 102 486-1-3[17] for the abstract test suite and partial PIXIT proforma.

c) For the application layer, including testing Layer 7 requirements specified in the profiles in Annex D:

1) ETSI TS 102 486-2-1[18] for the protocol implementation conformance statement (PICS);

2) ETSI TS 102 486-2-2[19] for the test suite structure and test purposes (TSS&TP);

3) ETSI TS 102 486-2-3[20] for the abstract test suite and partial PIXIT proforma.

Annex A
(normative)

SDTC physical layer

A.1 Overview and relation to CEN EN 12253

This annex:

— specifies the physical layer at 5,8 GHz for SDT Communications (SDTC); and

— provides requirements for the communication medium to be used for exchange of information between roadside units (RSUs) and on-board units (OBU);

It provides specifications equivalent to those published in CEN EN 12253[1] and as used in the specification for the Digital Tachograph; see ISO 15638-9, Reference [21] and Reference [22].

The terms "SDTC" and "DSRC" used in this annex are synonymous in terms of their applicability for the SDT.

A.2 SDTC link parameters

A.2.1 General

This clause defines relevant downlink and uplink parameters of the SDTC OSI Layer 1 (physical layer). The values to be used shall be set in accordance with SDTC profiles defined in Annex D.

OSI Layer 1 parameters are measured for free space propagation. Attention is drawn to the definition of an OBU in 3.38, which means that measurements are taken in the absence of a windscreen or other obscuring material unless it forms part of the manufactured OBU assembly.

A.2.2 Downlink parameters

Table A.1 shows downlink parameters.

Table A.1 — Downlink parameters

Item No.	Parameter	Value(s)	Remark
D1	Carrier frequencies	Two downlink channels at: Downlink channel 1: 5,797 5 GHz Downlink channel 2: 5,802 5 GHz	Other 10 MHz bands within the same ISM band allocated for RTTT on a national basis: Downlink channel 3: 5,807 5 GHz Downlink channel 4: 5,812 5 GHz These channels are defined in accordance with ECC/DEC(02)01[10]. The selection of carrier frequencies is outside the scope of this document.

Table A.1 *(continued)*

Item No.	Parameter	Value(s)	Remark
D1a	Tolerance of carrier frequencies	Within ±5 ppm	
D2	RSU transmitter spectrum mask	1) Out band power: see ETSI EN 300 674-1[12] 2) In band power: ≤ +33 dBm 3) Unwanted emission for unmodulated carrier wave shall be less than: Co-channel uplink at 1,5 MHz: ≤ -27 dBm in 500 kHz. Co-channel uplink at 2,0 MHz: ≤ -27 dBm in 500 kHz. Adjacent channel uplinks: ≤ -47 dBm in 500 kHz.	
		4) For in-band unwanted emission with modulated carrier wave, three different requirement classes are defined:	Equipment conforming with the different classes results in different re-use distances. See ETSI EN 300 674-1[12] for more details
		Class A: Co-channel uplink at 1,5 MHz: ≤ -7 dBm in 500 kHz. Co-channel uplink at 2,0 MHz: ≤ -27 dBm in 500 kHz. Adjacent channel uplinks: ≤ -30 dBm in 500 kHz.	*Class A* is originally specified in the respective CEN European Norm, indicating that this *Class A* should not be used in new installations. Further on, it is not considered for the European Digital Tachograph.
		Class B: Co-channel uplink at 1,5 MHz: ≤ -17 dBm in 500 kHz. Co-channel uplink at 2,0 MHz: ≤ -27 dBm in 500 kHz. Adjacent channel uplinks: ≤ -37 dBm in 500 kHz.	
		Class C: Co-channel uplink at 1,5 MHz: ≤ -27 dBm in 500 kHz. Co-channel uplink at 2,0 MHz: ≤ -27 dBm in 500 kHz. Adjacent channel uplinks: ≤ -47 dBm in 500 kHz.	
D3	OBU Minimum Frequency Range	5,795 GHz – 5,815 GHz	
D4	Maximum E.I.R.P.	+33 dBm	
D4a	Angular E.I.R.P. mask	$\Theta \leq 70°$: ≤ +33 dBm $\Theta > 70°$: ≤ +18 dBm	
D5	Polarization	Left-hand circular	

Table A.1 *(continued)*

Item No.	Parameter	Value(s)	Remark
D5a	Cross-polarization	XPD: In bore sight: $RSU_t \geq 15$ dB, $OBU_r \geq 10$ dB At -3 dB area: $RSU_t \geq 10$ dB, $OBU_r \geq 6$ dB	
D6	Modulation	Two level amplitude modulation.	
D6a	Modulation index	0,5 - 0,9	
D7	Data coding	FM0 "1" bit has transitions only at the beginning and end of the bit interval. "0" bit has an additional transition in the middle of the bit interval compared to the "1" bit.	
D8	Bit rate	500 kbit/s	
D8a	Tolerance of bit clock	Better than ±100 ppm	
D9	Bit error ratio for communication	≤ 10^{-6} when incident power at OBU is in the range given by [D11a to D11b].	
D10	Wake-up trigger for OBU	OBU shall wake up on receiving any frame with 11 or more octets (including preamble).	No special wake-up pattern is necessary. OBU may wake up on receiving a frame with less than 11 octets.
D10a	Maximum start time	≤ 5 ms	
D11	Communication zone	Spatial region within which a bit error ratio according to D9 is achieved.	
D11a	Power limit for communication (upper)	Incident power: D11a-0: -24 dBm D11a-1: -17 dBm	Implemented values are subject to profiles and sets defined in Annex D.
D11b	Power limit for communication (lower)	Incident power: -43 dBm	
D12	Cut-off power level of OBU	-60 dBm	Applicability of this parameter is subject to profiles and sets defined in Annex D.
D13	Preamble	Preamble is mandatory.	
D13a	Preamble length	16 bits ± 1 bit	
D13b	Preamble wave form	An alternating sequence of low level and high level with pulse duration of 2 µs. The tolerance is given by D8a.	
D13c	Trailing bits	The RSU is permitted to transmit a maximum of 8 bits after the end flag. An OBU is not required to take these additional bits into account.	

A.2.3 Uplink parameters

Table A.2 shows uplink parameters.

Table A.2 — Uplink parameters

Item No.	Parameter	Value(s)	Remark
U1	Sub-carrier frequencies	An OBU shall support 1,5 MHz and 2,0 MHz. An RSU shall support 1,5 MHz or 2,0 MHz or both. U1-0: 1,5 MHz U1-1: 2,0 MHz	Selection of sub-carrier frequency (1,5 MHz or 2,0 MHz) depends on profile indicated by the RSU. For interoperability with existing installations it is recommended that a 1,5 MHz sub-carrier frequency is used wherever possible.
U1a	Tolerance of sub-carrier frequencies	Within ±0,1 %	
U1b	Use of side bands	Same data on both sides.	
U2	OBU transmitter spectrum mask	1) Out band power: see ETSI EN 300674-1[12] 2) In band power: ≤ [U4a] dBm in 500 kHz 3) Emission in any other uplink channel: U2(3)-0 = -39 dBm in 500 kHz U2(3)-1 = -35 dBm in 500 kHz	Information on the choice of values can be found, for example, in Annex D.
U4a	Maximum single side band E.I.R.P. (bore sight)	U4a-0: -14 dBm U4a-1: -21 dBm	Information on the choice of values can be found, for example, in Annex D.
U4b	Maximum single side band E.I.R.P. (35°)	-17 dBm	Applicability of this parameter is subject to profiles and sets defined in Annex D.
U5	Polarization	Left-hand circular transmitted when left-hand circular received.	
U5a	Cross-polarization	XPD: In bore sight: $RSU_r \geq 15$ dB, $OBU_t \geq 10$ dB At -3 dB: $RSU_r \geq 10$ dB, $OBU_t \geq 6$ dB	
U6	Sub-carrier modulation	2-PSK Encoded data synchronized with sub-carrier: Transitions of encoded data coincide with transitions of sub-carrier.	
U6b	Duty cycle	50 % ± α, $\alpha \leq 5$ %	
U6c	Modulation on carrier	Multiplication of modulated sub-carrier with carrier.	
U7	Data coding	NRZI	
U8	Bit rate	250 kbit/s	
U8a	Tolerance of bit clock	Within ±1 000 ppm	
U9	Bit error ratio for communication	$\leq 10^{-6}$	
U11	Communication zone	The spatial region within which the OBU is situated such that its transmissions are received by the RSU with a bit error ratio of less than that given by U9.	

Table A.2 *(continued)*

Item No.	Parameter	Value(s)	Remark
U12a	Conversion gain (lower limit)	1 dB for each side band Range of angle: Circularly symmetric between bore sight and ±35°.	Greater or equal to the specified value for each side band within a circular cone around bore sight of ±35° opening angle.
U12b	Conversion gain (upper limit)	10 dB for each side band	Less than the specified value for each side band within a circular cone around bore sight of ±35° opening angle. Applicability of this parameter is subject to sets and profiles defined in Annex D.
U13	Preamble	Preamble is mandatory.	
U13a	Preamble length and pattern	32 µs to 36 µs modulated with sub-carrier only, then 8 bits of NRZI coded "0" bits.	
U13b	Trailing bits	The OBU is permitted to transmit a maximum of 8 bits after the end flag. An RSU is not required to take these additional bits into account.	

Annex B
(normative)

SDTC data link layer

B.1 Overview and relation to CEN EN 12795

This annex specifies the data link layer (DLL) of SDTC. The DLL of SDTC:

— is positioned with respect to other related standards by the layers defined in the OSI basic reference model specified in ISO/IEC 7498-1, as adopted for SDTC;

— supports broadcast and half-duplex transmission modes;

— supports a variety of fixed equipment configurations;

— supports configurations where one instance of a fixed equipment communicates with one instance of a mobile equipment, as well as configurations where one instance of a fixed equipment can communicate with several instances of a mobile equipment;

— takes into account that the mobile equipment communicates with the fixed equipment while passing through a communication zone with limited size;

— defines parameters to be used in negotiation procedures taking place between fixed equipment and mobile equipment.

By defining two distinct sublayers of the DLL, namely the "Medium Access Control" (MAC) sublayer and the "Logical Link Control" (LLC) sublayer, this annex defines:

a) MAC procedures for the shared physical medium;

b) addressing rules and conventions;

c) data flow control procedures;

d) acknowledgement procedures;

e) error control procedures;

f) services provided to the application layer.

The MAC sublayer is specific to SDTC. The LLC services offered are unacknowledged and acknowledged connectionless services based on ISO/IEC 8802-2.

This annex provides specifications equivalent to those published in CEN EN 12795[2] and as used in the specification for the Digital Tachograph; see ISO 15638-9, Reference [21] and Reference [22].

The terms "SDTC" and "DSRC" used in this annex are synonymous in terms of their applicability for the SDT.

B.2 Frame format

B.2.1 Frame structures and bit streams

All SDTC transmissions are in frames, and each frame conforms to the structure shown in Figure B.1.

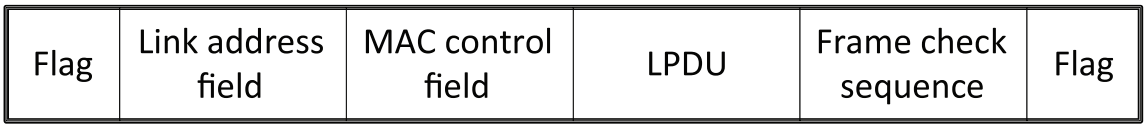


Figure B.1 — Frame structure

Frames containing no LPDU form a special case; see Figure B.2.

Figure B.2 — Frame structure, no LPDU

The physical bit stream can also comprise a preamble and/or trailing bits; see Figure B.3.

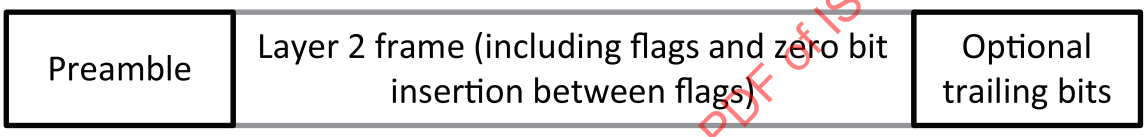


Figure B.3 — Physical layer bit stream

B.2.2 Flags

All frames shall start and end with a flag. A flag is a *0*-bit followed by six *1*-bits followed by a *0*-bit (*0111 1110*). When in receiving state, all stations shall continuously check on a bit-by-bit basis for this sequence. A transmitter shall send only complete flags with eight bits.

The flag which ends a frame shall not be used as the start flag for the next frame.

In order to achieve transparency, the flag is prevented from accidentally occurring in the link address field, MAC control field, LPDU and frame check sequence via a *0*-bit insertion procedure described in B.2.8.

B.2.3 Link address field

B.2.3.1 General

The link address field carries the "Link Identifier" (LID). The link address field shall contain either a private LID (contained in 4 octets), a multicast LID (contained in one octet) or a broadcast LID (contained in one octet). The LSB of each octet in the link address field is an extension bit.

B.2.3.2 Private LID

The private LID is a number in the range of 0 to 268435455. Thus, the private LID consists of 28 bits. The private LID is encoded into the link address field as shown in Figure B.4.

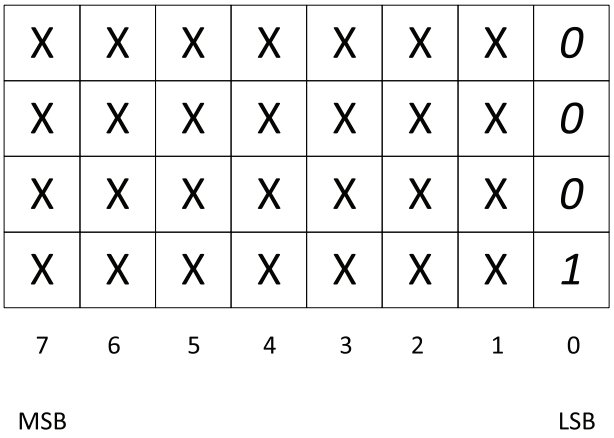


Figure B.4 — Private link address field format

The LSB of the first three octets are set to *0* indicating that a further octet of the link address field follows. The LSB of the fourth octet is set to *1* indicating that this is the last octet of the link address field.

B.2.3.3 Broadcast LID

The broadcast LID equals 127. Thus, the broadcast LID consists of 7 bits. The broadcast LID is encoded into the link address field as in Figure B.5.

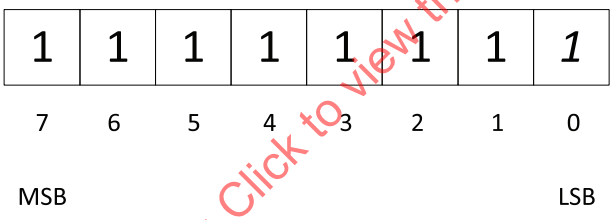
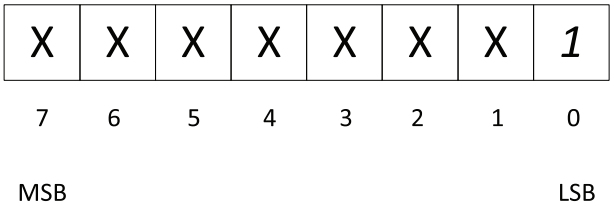


Figure B.5 — Broadcast link address field format

The LSB of the link address field in Figure B.5 is set to *1* indicating that it consists of one octet only.

B.2.3.4 Multicast LID

The multicast LID is a number in the range of 0 to 126. Thus, the multicast LID consists of 7 bits. The multicast LID 0 is reserved for test purposes and multicast LID in the range 120 to 126 are reserved for private use. The multicast LID is encoded into the link address field as in Figure B.6.



NOTE X = other than all *1*s.

Figure B.6 — Multicast link address field format

The LSB of the link address field in Figure B.6 is set to *1* indicating that it consists of one octet only.

B.2.4 MAC control field

The MAC control field shall have the encoding as described in B.4.3.2.

B.2.5 LPDU format

The LPDU shall have the encoding as described in B.5.3.

B.2.6 Frame check sequence

All frames shall include a 16-bit FCS just prior to the end flag for error detection purposes. The contents of the link address field, MAC control field and LPDU shall be included in the calculation of the FCS.

The FCS shall be conformant with a 16-bit frame checking sequence as defined in ISO/IEC 13239. The generator polynomial shall be $X^{16} + X^{12} + X^5 + 1$, and the initial value used shall be $FFFF_{16}$. The *1*s complement of the resulting remainder shall be transmitted as the 16-bit FCS.

B.2.7 Bit order

Flag, link address, MAC control field and LPDU shall be transmitted with the LSB first in each octet.

The FCS shall be transmitted with the coefficient of the highest term first.

B.2.8 Transparency

The occurrence of the flag within a frame other than the start and end flags shall be prevented by a *0*-bit insertion procedure as follows:

The transmitter shall insert a *0*-bit following five contiguous *1*-bits anywhere between the start flag and the end flag of the frame. The insertion of the *0*-bit thus applies to the contents of the LID field, the MAC control field, the LPDU and the FCS.

The receiver shall continuously monitor the received bit stream; after receiving five contiguous *1*-bits, the receiver shall inspect the following bit. If it is a *0*, the five *1*-bits are passed as data and the *0* is deleted. If the sixth bit is a *1*, the receiver shall inspect the seventh bit. If this bit is a *0*, a valid flag has been received; if it is a *1*, an abort has been received, and the receiving station shall ignore that frame.

B.3 Address establishment

B.3.1 General

Each fixed equipment shall contain one broadcast SAP as well as one SAP for each mobile private SAP currently known by the fixed equipment to be in the communications zone.

Each mobile equipment shall contain one broadcast SAP, and if required for uplink transmissions, one private SAP. In addition to that, it may contain one or more multicast SAPs.

The broadcast SAP establishment is defined in B.3.2, the mobile private SAP establishment in B.3.3 and the fixed private SAP establishment in B.3.4.

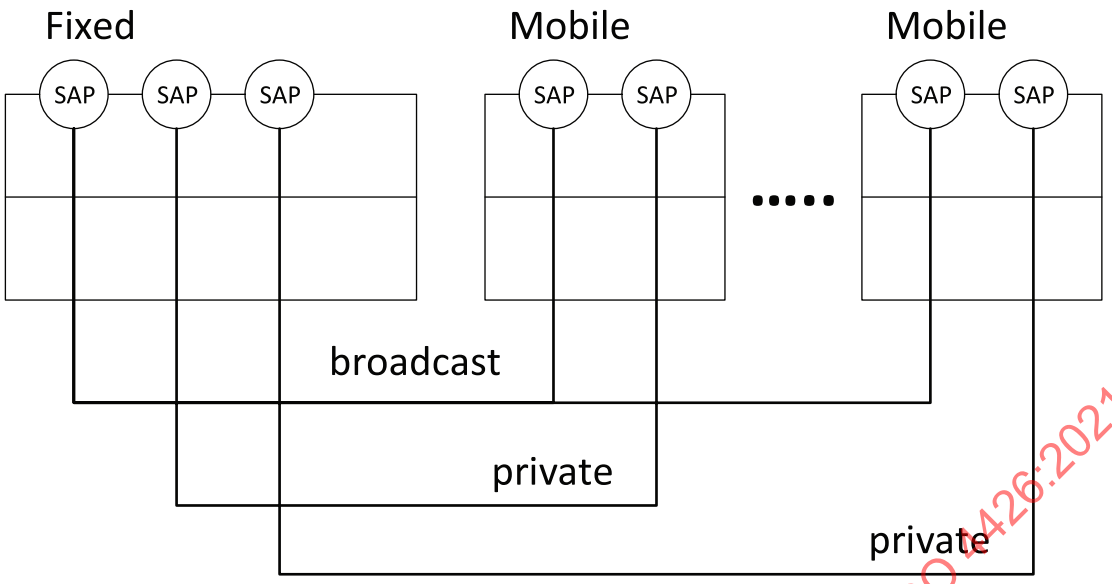


Figure B.7 — Link addressing overview

Mobile equipment arriving in the communication zone is, in many cases, not fully powered, but is in a sleep mode. However, in the following subclauses, the mobile equipment is described as if it were always fully powered.

B.3.2 Broadcast SAP establishment

There shall be a broadcast SAP in every fixed and mobile equipment.

The broadcast SAP shall always be active.

B.3.3 Mobile private SAP establishment

The mobile private SAP is created by the data link layer on request from the application layer.

The private LID associated with this SAP is generated at the application layer.

The mobile data link entity shall use its private LID in all uplink transmissions.

B.3.4 Fixed private SAP establishment

When a fixed equipment data link entity receives a frame containing a private LID not known to it, a corresponding SAP shall be created.

NOTE Deletion of fixed private SAPs is under the responsibility of upper layers or applications.

B.4 Medium Access Control (MAC) sublayer

B.4.1 Overview

The MAC sublayer is responsible for controlling the use of the physical medium by the MAC sublayer entity residing in the fixed equipment and the MAC sublayer entity residing in the mobile equipment.

The mobile MAC sublayer offers the M-MA-DATA primitives to the mobile LLC sublayer. The fixed MAC sublayer offers the F-MA-DATA primitives to the fixed LLC sublayer.

The medium access control is characterized by:

— half duplex mode;

— asynchronous time division multiple access (TDMA).

The medium access control is unbalanced, in that the fixed equipment is always in control of the physical medium, granting access to the physical medium to either:

— the fixed MAC (downlink window); or

— one mobile MAC exclusively (private uplink window); or

— any mobile MAC, according to certain rules (public uplink window).

The mobile MAC can also request access to the medium.

B.4.2 MAC service primitives

B.4.2.1 General

The MAC sublayer offers the following primitives to the LLC sublayer:

— MA-DATA.request;

— MA-DATA.indication.

These are shown in Figure B.8.

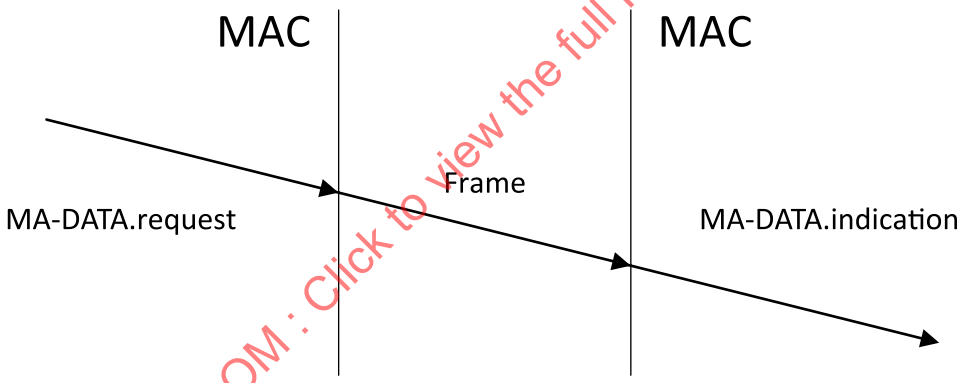


Figure B.8 — MAC services and primitives

B.4.2.2 Fixed MAC service primitives

B.4.2.2.1 F-M-DATA.request

The primitive shall be passed from the LLC sublayer to the MAC sublayer to request that an LPDU be transmitted to a mobile SAP in the first available downlink window.

The primitive shall provide the following parameters:

F-MA-DATA.request(LID, LPDU, RR)

The LID shall be the LID of the mobile SAP for which the frame is intended.

It may be a private LID, the broadcast LID or a multicast LID.

The LPDU may be null (in this case no LPDU shall be included in the frame transmitted).

The response request (RR) shall indicate whether or not the fixed equipment shall allocate an uplink window in immediate connection to the downlink frame transmitted.

B.4.2.2.2 F-M-DATA.indication

The primitive shall be passed from the MAC sublayer to the LLC sublayer to indicate the successful reception of a valid frame from a mobile SAP.

The primitive shall provide the following parameters:

F-MA-DATA.indication (LID, LPDU)

The LID shall be the content of the link address field of the frame received.

The LPDU shall not be null.

B.4.2.3 Mobile MAC service primitives

B.4.2.3.1 F-MA-DATA.request

The primitive shall be passed from the LLC sublayer to the MAC sublayer to request that an LPDU is transmitted to the fixed SAP in an uplink window.

The primitive shall provide the following parameters

M-MA-DATA.request(LID, LPDU)

The LID shall be the private LID of the mobile SAP.

The LPDU may be null, in which case no LPDU shall be included in the frame transmitted.

NOTE The uplink window can be public or private, as described in B.4.3.4.

B.4.2.3.2 M-MA-DATA.indication

The primitive shall be passed from the MAC sublayer to the LLC sublayer to indicate the successful reception of a valid frame from a fixed SAP.

The primitive shall provide the following parameters

M-MA-DATA.indication(LID, LPDU)

The LID shall be the content of the link address field of the frame received.

The LPDU shall not be null.

B.4.3 Window management

B.4.3.1 Overview

Uplink windows allocated by the fixed equipment are indicated by the MAC control field of the downlink frame and follow immediately after the downlink window containing the frame.

The distinction between allocation of public and private uplink windows is made by the fixed equipment by means of the LID of the frame allocating the uplink window. A public uplink window is allocated if the link address field contains a broadcast LID while a private uplink window is allocated if the link address field contains a private LID.

Figure B.9 gives an overview of window management.

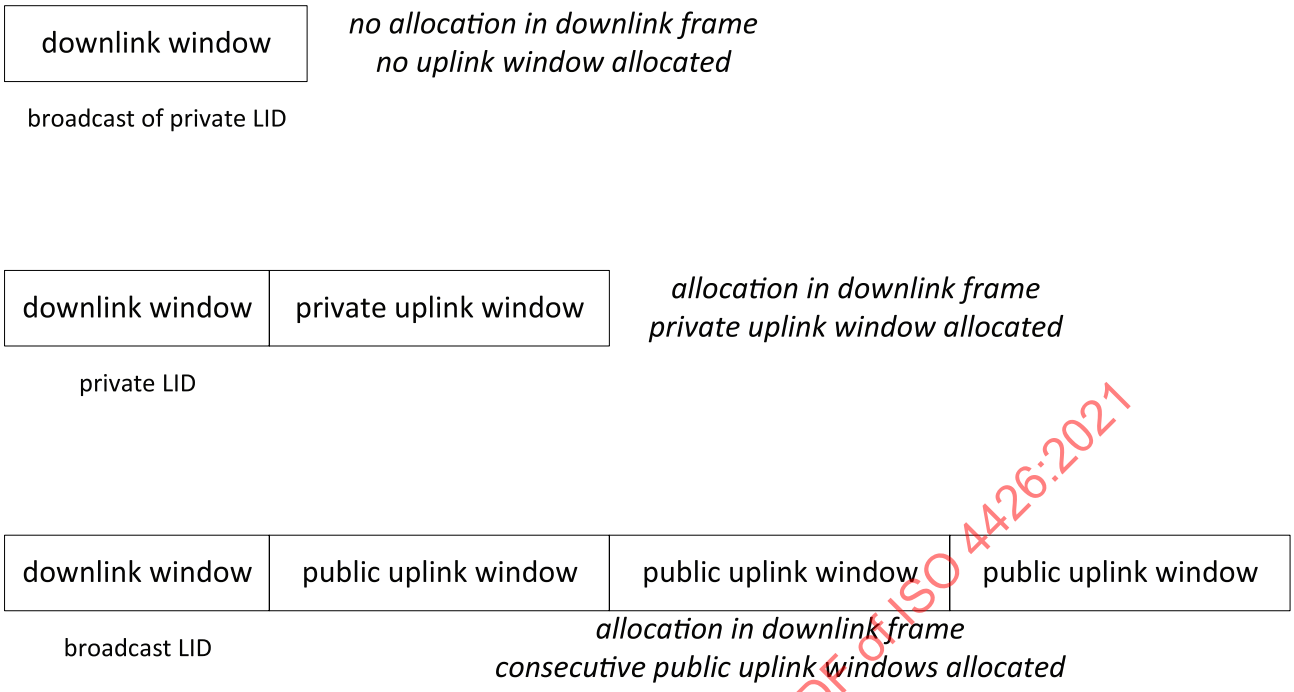


Figure B.9 — Window management overview

B.4.3.2 MAC control field

B.4.3.2.1 General

The MAC control field is used to:

— indicate whether the frame contains an LPDU;

— indicate the transmission direction;

— allocate public and private windows;

— request for private windows;

— specify the type of LPDU.

The MAC control field has the length of one octet. The content of the MAC control field is different on the downlink and on the uplink. Bits that are not specified are reserved for future use.

B.4.3.2.2 MAC control field of the downlink

The MAC control field of the downlink shall be used by frames transmitted by the fixed equipment. The format is described in Figure B.10.

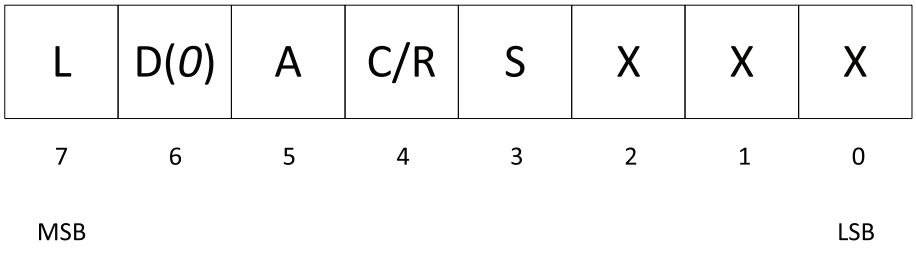


Figure B.10 — MAC control field of the downlink

The following applies for Figure B.10:

L The LPDU existence bit shall be used to indicate whether the frame contains an LPDU.

0 = frame contains no LPDU
1 = frame contains an LPDU

NOTE Minimum LPDU consists of an LLC control field only.

D The direction identifier bit shall be used to identify the link direction.

0 = downlink direction.

A The medium allocation bit shall be used to allocate medium (see B.4.3.4).

0 = no uplink window is allocated by the fixed equipment
1 = uplink window is allocated by the fixed equipment

NOTE The allocation can be a private uplink window or N5 public uplink windows

C/R The LLC Command/Response bit shall be used to identify the LPDU as command or response. The LLC Command/Response bit shall be ignored if the LPDU existence bit is set to *0*. (For the use of the C/R bit see B.5.3.2).

0 = command LPDU
1 = response LPDU

S The MAC sequence bit shall be used to distinguish between first allocation of a private uplink window and reallocation of a private uplink window (see B.4.4.2).

X Reserved, shall be set to *0*.

B.4.3.2.3 MAC control field of the uplink

The MAC control field of the uplink shall be used by frames transmitted by the mobile equipment. The format is described in Figure B.11.

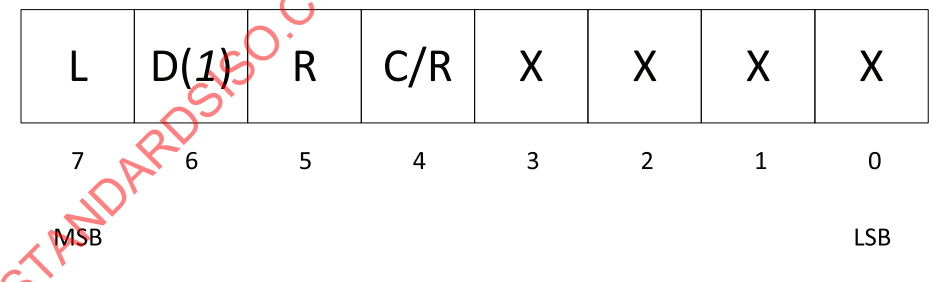


Figure B.11 — MAC control field of the uplink

The following applies for Figure B.11:

L The LPDU existence bit shall be used to indicate whether the frame contains an LPDU.

0 = frame contains no LPDU
1 = frame contains an LPDU

D The direction identifier bit shall be used to identify the link direction.

1 = uplink direction.

R The medium request bit shall be used to request uplink window (see B.4.4.3).

0 = no window is requested by mobile equipment
1 = window is requested by the mobile equipment

C/R The LLC Command/Response bit shall be used to identify the LPDU as command or response. The LLC Command/Response bit shall be ignored if the LPDU existence bit is set to *0*. (For the use of the C/R bit see B.5.3.2).

0 = command LPDU
1 = response LPDU

X Reserved, shall be set to *0*.

B.4.3.3 Downlink windows

The fixed equipment allocates a downlink window simply by transmitting a frame.

A downlink window starts at the start of the first bit of the preamble and ends at the end of the last bit of the end flag of the downlink Layer 2 frame transmitted.

NOTE Trailing bits defined at the physical layer are not part of the window.

A downlink window shall not start before T1 after the end of the previous window if the previous window is an uplink window.

A downlink window shall not start before T2 after the end of the previous window if the previous window is a downlink window.

A Layer 2 frame transmitted in a downlink window shall consist of not more than N2 octets.

See Figure B.12 and Figure B.13 for the timing of the downlink window.

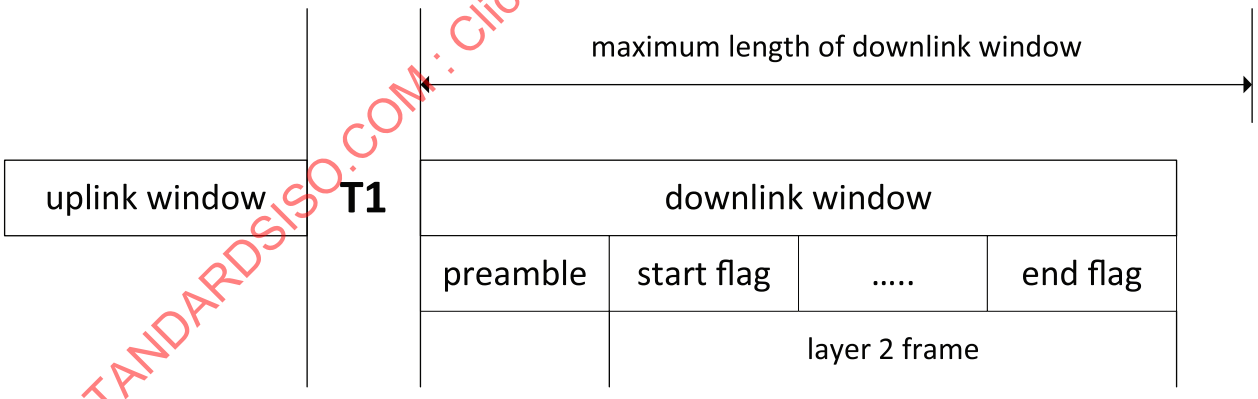


Figure B.12 — Timing of downlink window after uplink window

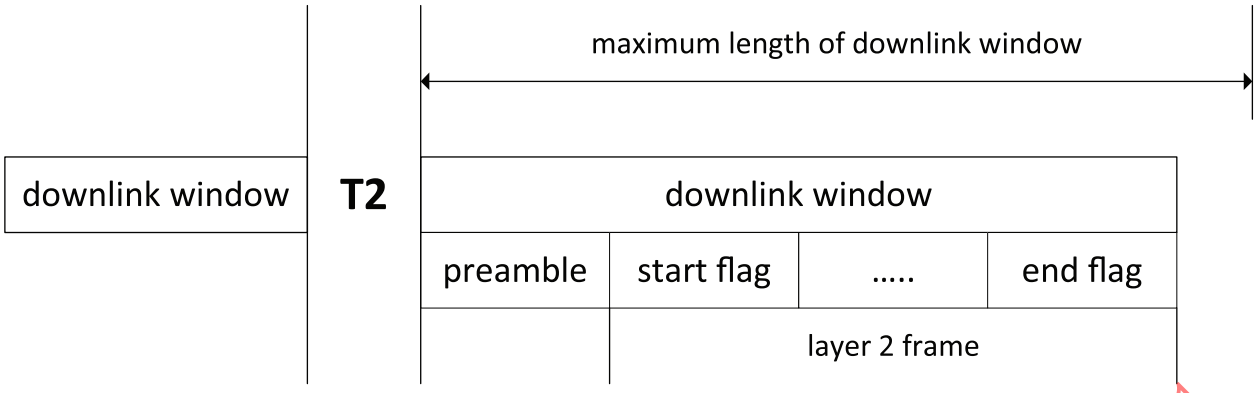


Figure B.13 — Timing of downlink window after downlink window

NOTE The maximum duration in time of the downlink window can be calculated from N2 (see Table B.8), taking bit rate and zero bit insertion into account.

B.4.3.4 Uplink windows

B.4.3.4.1 General

The fixed equipment allocates one or more uplink windows immediately following a downlink frame by setting the A bit of the MAC control field of the downlink frame to *1*. There are two kinds of uplink windows, private uplink windows and public uplink windows.

A private uplink window may only be used by one mobile equipment, while public uplink windows may be used by any mobile equipment according to certain rules described in B.4.3.4.4.

If the LID of the allocating downlink frame is a private LID, the allocated uplink window is a private uplink window. If the LID of the allocating downlink frame is a broadcast LID, the allocated uplink windows are public uplink windows.

Each allocating downlink frame may thus allocate either:

a) one private uplink window; or

b) N5 consecutive public uplink windows.

B.4.3.4.2 Private uplink windows

A private uplink window may only be used by the mobile equipment having a private LID equal to the LID of the frame allocating the window.

A private uplink window starts T3 after the end of the downlink window containing the frame allocating the uplink window.

A private uplink window ends:

a) T4a after the start of the window, if no mobile equipment has started transmitting before that time; or

b) at the end of the last bit of the end flag of the uplink Layer 2 frame transmitted; and

c) no later than the maximum time of private uplink windows, defined by N3.

Figure B.14 shows the timing for the private uplink window.

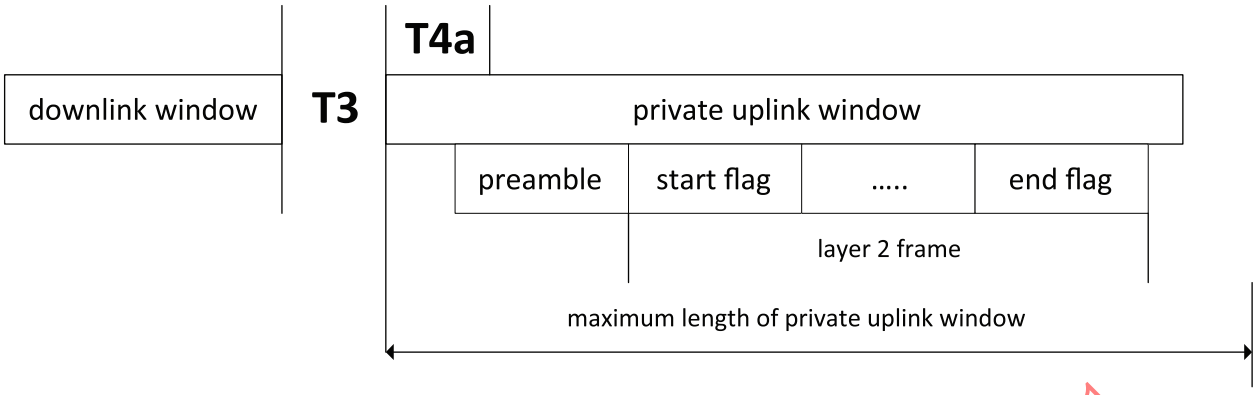


Figure B.14 — Private uplink window timing

B.4.3.4.3 Public uplink windows

Each downlink frame can simultaneously allocate N5 public uplink windows.

A public uplink window may be used by any mobile equipment according to certain rules given in B.4.3.4.4.

A public uplink window starts:

a) T3 after the end of the downlink window containing the frame allocating the window if the public uplink window is the first window after the downlink window; or

b) immediately after the end of the previous window if that window is a public uplink window.

A public uplink window ends T5 after the start of that window.

The transmission of the first bit of the preamble of the Layer 2 frame in a public uplink window shall start before T4b after the start of that window.

A Layer 2 frame transmitted in a public uplink window shall consist of not more than N4 octets.

See Figure B.15 for the timing of the public uplink window.

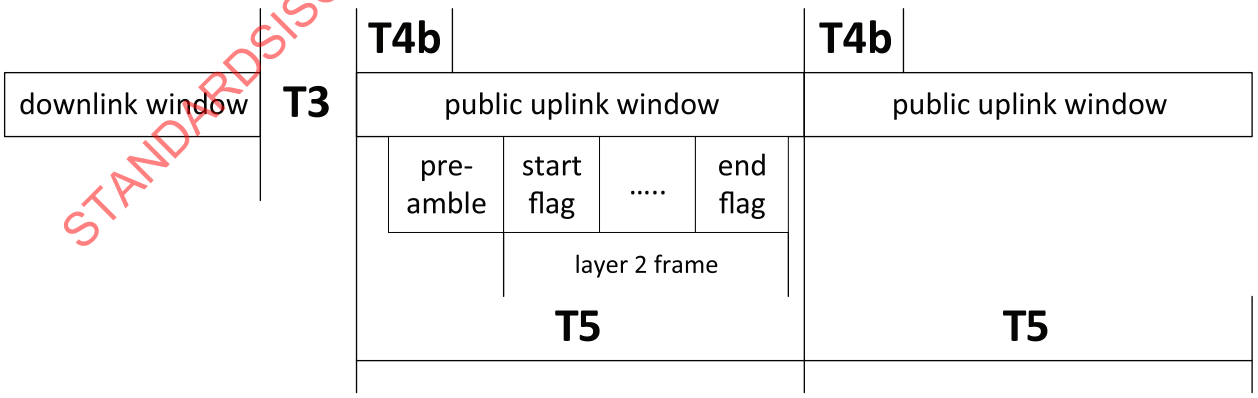


Figure B.15 — Public uplink window timing

B.4.3.4.4 Public uplink window selection

The public uplink window selection mechanism is a (pseudo-)random mechanism. The probability of selecting one out of N5 public uplink windows shall be 1/N5. If a pseudo-random mechanism is used, an appropriate seeding of the algorithm shall be taken into account.

B.4.4 MAC elements of procedure

B.4.4.1 Private medium response flag

In each mobile equipment there is a private medium response flag. It shall be set to zero each time a private uplink window is requested and incremented for each public uplink window allocation received.

After a private uplink window request, the corresponding private uplink window allocation and subsequent reallocations by the fixed equipment shall take place before the private medium response flag reaches the value *1*.

B.4.4.2 Fixed equipment MAC procedures

B.4.4.2.1 Frame reception

B.4.4.2.1.1 Validity of frame

The MAC sublayer shall inspect all received frames to assess their validity.

A received frame shall be considered valid if:

a) the frame is correctly delimited by start and end flags according to B.2.2; and

b) the frame (after deletion of zero bits inserted for transparency) contains a number of bits corresponding exactly to an integer number of octets;

c) the frame contains a valid link address field according to B.2.3 containing the private LID of an SAP; and

d) the frame contains an MAC control field according to B.4.3.2; and

e) the frame does not consist of too many octets (parameters N3 and N4 respectively); and

f) the frame contains a valid FCS field according to B.2.6.

If the frame received is not valid it shall be discarded. If a non-valid frame is received in a private uplink window, reallocation may be undertaken according to B.4.4.2.2.3.

B.4.4.2.1.2 Information transfer

The L bit of a received valid frame being set to *1* shall indicate that the frame contains an LPDU. The start and end flags, the FCS, the link address field and the MAC control field shall be removed from the frame. The LPDU and the contents of the link address field shall then be passed to the LLC sublayer in an F-MA-DATA.indication.

B.4.4.2.1.3 Private uplink window request

The R bit of a received valid frame being set to *1* shall indicate that the remote mobile SAP indicated by the link address field is requesting a private uplink window to be allocated to it. The fixed equipment shall allocate a private uplink window to that SAP before the private medium response flag (see B.4.4.1) has reached the value *1*.

B.4.4.2.2 Frame transmission

B.4.4.2.2.1 Information transfer

As a result of an F-MA-DATA.request an LPDU can be pending. The fixed equipment shall then construct a frame according to the frame format in B.2.

The L bit of the MAC control field shall be set to *1* and the D bit shall be set to *0*.

The A bit and the S bit shall be set according to B.4.4.2.2.2 and B.4.4.2.2.3.

The frame shall then be passed to the lower layer.

B.4.4.2.2.2 Private uplink window allocation

The fixed equipment shall allocate a private uplink window to a remote mobile SAP if an outgoing LPDU contains a command to that SAP, which requires an immediate response.

The fixed equipment may allocate a private uplink window to a remote mobile SAP if a private uplink window has been requested from (but not yet granted to) that SAP.

The fixed equipment may allocate a private uplink window to a remote mobile SAP if a private uplink window previously allocated to that SAP contained no valid uplink frame (reallocation).

When a private uplink window is allocated, the A bit of the allocating frame shall be set to *1*. The link address field of the allocating frame shall contain the private LID of a remote SAP to which the private uplink window is allocated.

In the first private uplink allocation for a new SAP, the S bit shall be set to *0*. If a private uplink window allocation to a mobile equipment is either the first response to a private uplink window request from that mobile equipment, or is the result of an F-MA-DATA.request, then the value of the S bit transmitted shall be the complement of the value of the S bit of the previous private uplink window allocation.

B.4.4.2.2.3 Private uplink window reallocation

Each time a private uplink window is allocated by the fixed equipment, a transmission is expected from the mobile equipment, to which the window is allocated.

If no valid frame was received by the fixed equipment it may reallocate the private uplink window as long as the corresponding private medium response flag has not reached the value *1*.

The S bit of the MAC control field shall then have the same value as it had on the first occasion that that window was allocated.

B.4.4.2.2.4 Public uplink window allocation

When public uplink windows are allocated, the A bit of the allocating frame shall be set to *1*. The link address field of the allocating frame shall contain the broadcast LID. The number of consecutive public uplink windows simultaneously allocated shall be N5.

B.4.4.3 Mobile equipment MAC procedures

B.4.4.3.1 Frame reception

B.4.4.3.1.1 Validity of frame

The MAC sublayer shall inspect all received frames to assess their validity.

A received frame shall be considered valid if:

a) the frame is correctly delimited by start and end flags according to B.2.2; and

b) the frame contains a valid link address field according to B.2.3 which contains either the LID of the private SAP of this mobile equipment, or the broadcast LID, or a multicast LID known by this mobile equipment; and

c) the frame contains a MAC control field according to B.4.3.2; and

d) the frame does not consist of more octets than are given by parameter N2; and

e) the frame contains a valid FCS field according to B.2.6.

If the frame received is not valid it shall be discarded.

B.4.4.3.1.2 Information transfer

If the L bit of a received valid frame is set to *1* this shall indicate that the frame contains an LPDU. The start and end flags, the FCS, the link address field and the MAC control field shall be removed from the frame. The LPDU and the contents of the link address field shall then be passed to the LLC sublayer in an M-MA-DATA.indication.

B.4.4.3.1.3 Private uplink window allocation

If the A bit of the received frame equals *1* and the LID is private, a private uplink window is allocated by the received frame.

If the L-bit of the received frame equals *0*, indicating that no LPDU is present, the value of the S-bit shall be used to distinguish between allocation and reallocation.

If the allocation is a new allocation, i.e. not a reallocation, the private uplink window shall be used for transmitting a pending LPDU.

If the allocation is a reallocation, the mobile equipment shall use the private uplink window for retransmitting the frame transmitted in the previous private uplink window.

B.4.4.3.1.4 Public uplink window allocation

If the A bit of the received frame equals *1* and the LID is the broadcast LID, a public uplink window is allocated by the received frame. The number of simultaneously allocated consecutive public uplink windows is indicated by parameter N5.

The mobile equipment may transmit in the public uplink window selected as described in B.4.3.4.3.

B.4.4.3.2 Frame transmission

B.4.4.3.2.1 Information transfer

As a result of an M-MA-DATA.request an LPDU may be pending.

The mobile equipment shall then construct a frame according to the frame format of B.2.

The L bit and the D bit of the MAC control field shall be set to *1*.

The R bit shall be set according to B.4.4.3.2.2.

The mobile equipment shall then transmit the frame according to the following rules:

a) if the LPDU contains an LLC command and if a private uplink window is allocated before, the mobile equipment shall transmit the frame in the private uplink window. If the FE sends a private window reallocation, the previously sent frame shall be transmitted. If the fixed equipment sends a private window allocation, the pending frame shall be transmitted;

b) if the LPDU contains an LLC response, the mobile equipment shall transmit the frame in the first private uplink window allocated.

If the frame is transmitted in a private uplink window, it shall be kept pending at least until the private medium response flag has reached the value *1*.

B.4.4.3.2.2 Private uplink window request

The mobile equipment can request that a private uplink window be allocated to it by the fixed equipment.

There are three cases:

a) if the mobile equipment has a command frame to transmit and has not requested a private uplink window for that frame, it shall request a private uplink window by transmitting a frame with the L bit of the MAC control field set to *0* and the R bit set to *1*;

b) if the mobile equipment has a frame to transmit and has already requested a private uplink window for that frame it shall retransmit the request after the private medium response flag has reached the value *1*;

c) if the mobile equipment has a frame to transmit in a private uplink window and still has an LPDU pending it shall request (another) private uplink window by setting the R bit of the MAC control field of the transmitted frame to *1*.

B.5 Logical Link Control (LLC) sublayer

B.5.1 Overview

B.5.1.1 General

The LLC generates command PDUs and response PDUs for transmission, and interprets received command PDUs and response PDUs. Specific responsibilities assigned to an LLC include:

a) initiation of control signal interchange;

b) organization of data flow;

c) interpretation of received command PDUs and generation of appropriate response PDUs; and

d) actions regarding error control and error recovery functions in the LLC sublayer.

To satisfy a broad range of potential applications, two types of data link control operation are included.

B.5.1.2 Unacknowledged connectionless-mode service

The unacknowledged connectionless-mode data transfer service provides the means by which application layer entities can exchange link service data units (LSDUs) without the establishment of a data link level connection on an unacknowledged base. The data transfer can be point-to-point, multicast, or broadcast.

Unacknowledged operation provides an unacknowledged connectionless-mode service across a data link with minimum protocol complexity. This type of operation can be useful when higher layers provide any essential recovery and sequencing services so that these do not need replicating in the data link layer. In addition, this type of operation can prove useful in applications where it is not essential to guarantee the delivery of every data link layer data unit and for some initial data transfer.

B.5.1.3 Acknowledged connectionless-mode service

The acknowledged connectionless-mode data unit exchange services provide the means by which application layer entities can exchange link service data units (LSDUs) which are acknowledged at the LLC sublayer, without the establishment of a data link connection. The services provide a means by which an application layer entity at one station can transmit a data unit to another station, request a previously prepared data unit from another station, or exchange data units with another station. The data unit transfer is point-to-point.

Acknowledged operation provides an acknowledged connectionless-mode data unit exchange service, which permits a station both to transmit data and to request the return of data at the same time. Although the exchange service is connectionless, in-sequence delivery is guaranteed for data transmitted by the initiating station.

B.5.2 LLC service primitives

B.5.2.1 General

This subclause specifies the services required of the LLC sublayer by the SDTC application layer, as viewed from the application layer, to allow an application layer entity to exchange packets with remote peer application layer entities. The services are described in an abstract way and do not imply any particular implementation or any exposed interface.

Two forms of service are provided

1) unacknowledged connectionless-mode; and

2) acknowledged connectionless-mode.

B.5.2.2 Unacknowledged connectionless data transfer

The primitives associated with unacknowledged connectionless-mode data transfer are:

DL-UNITDATA.request

DL-UNITDATA.indication

The DL-UNITDATA.request primitive is passed from the application layer to the LLC sublayer to request that an LSDU be transmitted using unacknowledged connectionless-mode procedures. The DL-UNITDATA.indication primitive is passed from the LLC sublayer to the application layer to indicate the arrival of an LSDU.

Table B.1 shows a list of LLC service primitives offered by the LLC sublayer to the application layer for unacknowledged connectionless-mode data transmission.

Table B.1 — LLC service primitives offered by the LLC sublayer to the application layer for unacknowledged connectionless-mode data transmission

Name	Description
DL-UNITDATA.request (LID, data, RR)	Passed from the application layer to the LLC sublayer to request transmission of an LSDU. The LID either shall be a private LID, a multicast LID or a broadcast LID. Multicast and broadcast LID are only possible at the FE. The response request RR shall be passed directly to the FE-MAC and shall be used to enable a direct response from the ME-LLC by setting the A bit of the MAC control field. Thus, RR is not available at the ME.
DL-UNITDATA.indication (LID, data)	Passed from the LLC sublayer to the application layer to indicate the arrival of an LSDU. The LID shall be equal to the LID received in the corresponding DL-UNITDATA.request frame.

B.5.2.3 Acknowledged connectionless data transfer

The primitives associated with the acknowledged connectionless-mode data unit transmission service are:

DL-DATA-ACK.request

DL-DATA-ACK.indication

DL-DATA-ACK-STATUS.indication

The DL-DATA-ACK.request primitive is passed from the application layer to the LLC sublayer to request that an LSDU be transmitted to a remote LLC using acknowledged connectionless-mode data unit transmission procedures. The DL-DATA-ACK.indication primitive is passed from the LLC sublayer to the application layer to indicate the arrival of a command PDU, except in the case where this PDU is used only for Data Link Echo. The DL-DATA-ACK-STATUS.indication primitive is passed from the LLC sublayer to the application layer to convey the results of the previous associated DL-DATA-ACK.request primitive.

Table B.2 shows a list of LLC service primitives offered by the LLC sublayer to the application layer for acknowledged connectionless mode data transmission.

Table B.2 — LLC service primitives offered by the LLC sublayer to the application layer for acknowledged connectionless mode data transmission

Name	Description
DL-DATA-ACK.request (LID, data)	Passed from the FE application layer to the FE-LLC sublayer to request transmission of an LSDU to the specified ME. The LID shall be a private LID of an ME.
DL-DATA-ACK.indication (LID,data)	Passed from the ME-LLC sublayer to the ME application layer to indicate the arrival of a non-null and non-duplicate LSDU from the FE. The LID shall be the private LID of the ME.
DL-DATA-ACK-STATUS.indication (LID, status)	Passed from the FE-LLC sublayer to the FE application layer to indicate the success or failure of the previous associated acknowledged connectionless-mode data unit transmission request. The LID shall be a private LID of an ME. The status parameter indicates success or failure.

B.5.2.4 Acknowledged connectionless data exchange

The primitives associated with the acknowledged connectionless-mode data unit exchange service are:

DL-REPLY.request

DL-REPLY.indication

DL-REPLY-STATUS.indication.

The DL-REPLY.request primitive is passed from the application layer to the LLC sublayer to request that an LSDU be returned from a remote station or that LSDUs be exchanged between stations using acknowledged connectionless-mode data unit exchange procedures. The DL-REPLY.indication primitive is passed from the LLC sublayer to the application layer to indicate the arrival of a command PDU. The DL-REPLY-STATUS.indication primitive is passed from the LLC sublayer to the application layer to convey the results of the previous associated DL-REPLY.request primitive.

The primitives associated with reply data unit preparation are:

DL-REPLY-UPDATE.request

DL-REPLY-UPDATE-STATUS.indication.

The DL-REPLY-UPDATE request primitive is passed from the application layer to the LLC sublayer with an LSDU to be held by LLC and transmitted at a later time when requested to do so by some other station. The DL-REPLY-UPDATE-STATUS.indication primitive is passed from the LLC sublayer to the application layer to convey the results of the previous associated DL-REPLY-UPDATE request primitive.

Table B.3 shows a list of LLC service primitives offered by the LLC sublayer to the application layer for acknowledged connectionless mode data exchange.

Table B.3 — LLC service primitives offered by the LLC sublayer to the application layer for acknowledged connectionless mode data exchange

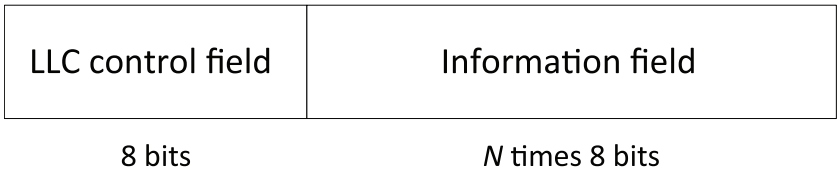
Name	Description
DL-REPLY.request (LID, data)	Passed from the FE application layer to the FE-LLC sublayer to request transmission of a previously prepared data unit from the specified ME (in case of null data parameter) or to exchange data units with the specified ME. The LID shall be a private LID of an ME.
DL-REPLY.indication (LID, data)	Passed from the ME-LLC sublayer to the ME application layer to indicate either a request of an LSDU from the FE or an exchange of LSDUs with the FE. The LID shall be the private LID of the ME. Every new request of an LSDU from the FE will delete any previously prepared data.
DL-REPLY-STATUS.indication (LID, data, status)	Passed from the FE-LLC sublayer to the FE application layer to indicate the success or failure of the previous acknowledged connectionless mode data unit exchange request and to pass data if available. The LID shall be a private LID of an ME. The status parameter indicates success or failure.
DL-REPLY-UPDATE.request (LID, data)	Passed from the ME application layer to the ME-LLC sublayer to request preparation of an LSDU for future access. A subsequent DL-REPLY-UPDATE.request service primitive serves to replace the currently associated LSDU with a new LSDU. The LID shall be the private LID of the ME. The data parameter specifies the link service data unit to be held by the LLC sublayer in preparation for transfer at a later time when requested.
DL-REPLY-UPDATE-STATUS.indication (LID, status) (not mandatory)	Passed from the ME-LLC sublayer to the ME application layer to indicate the success or failure of the previous associated data unit preparation request (DL-REPLY-UPDATE.request). The LID shall be the private LID of the ME. The status parameter indicates success or failure. The effect of receipt of this primitive by the ME-L7 is not specified. Thus, this indication is not mandatory.

NOTE A data link layer request containing a valid command is considered to be successful even if the requested data cannot be provided within link turnaround time. In this case, a late response will occur. A failure will occur if the command is not understood by the ME.

B.5.3 LPDU format

B.5.3.1 General

All LPDUs shall conform to the format shown in Figure B.16.



Key

N number of octets; an integer value equal to or greater that 0 (the upper limit of *N* is given by N2, N3 or N4)

NOTE The LLC control field is specified in B.5.3.3.

Figure B.16 — LPDU format

B.5.3.2 C/R bit

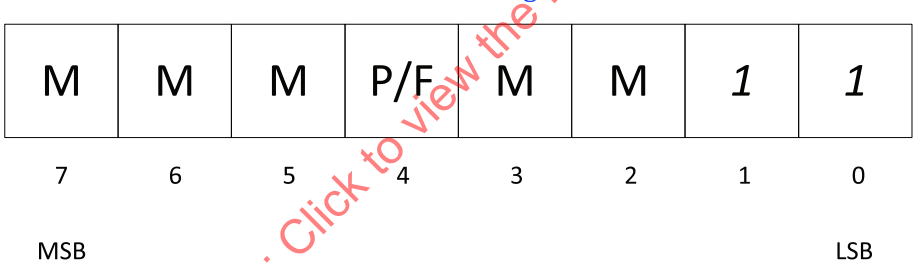
The Command/Response (C/R) bit shall be handled according to B.4.3.2.

B.5.3.3 LLC control field

B.5.3.3.1 General

The LLC control field shall consist of one octet that shall be used to designate command and response.

The format defined for the control field is described in Figure B.17.



Key

M Modifier function bits

P/F poll bit – used in command LPDU transmission:
P=1: poll, P=0: no poll
final bit – used in response LPDU transmission:
F=1: final, F=0; no final

NOTE 1 The two least significant bits are set to *1*.

NOTE 2 The control field shown in Figure B.17 utilizes a subset of the LLC control field format of ISO/IEC 8802-2.

Figure B.17 — LLC control field

B.5.3.3.2 Unacknowledged connectionless

The LLC control field encoding for unacknowledged connectionless operation is shown in Figure B.18.

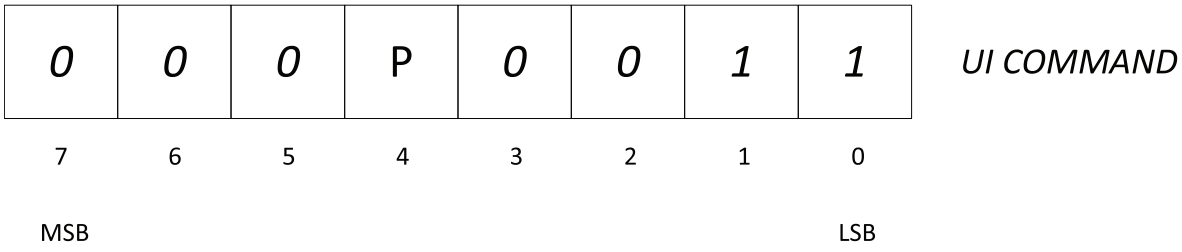


Figure B.18 — UI command, LLC control field

B.5.3.3.3 Acknowledged connectionless

The LLC control field encoding for acknowledged connectionless operation is shown in Figure B.19.

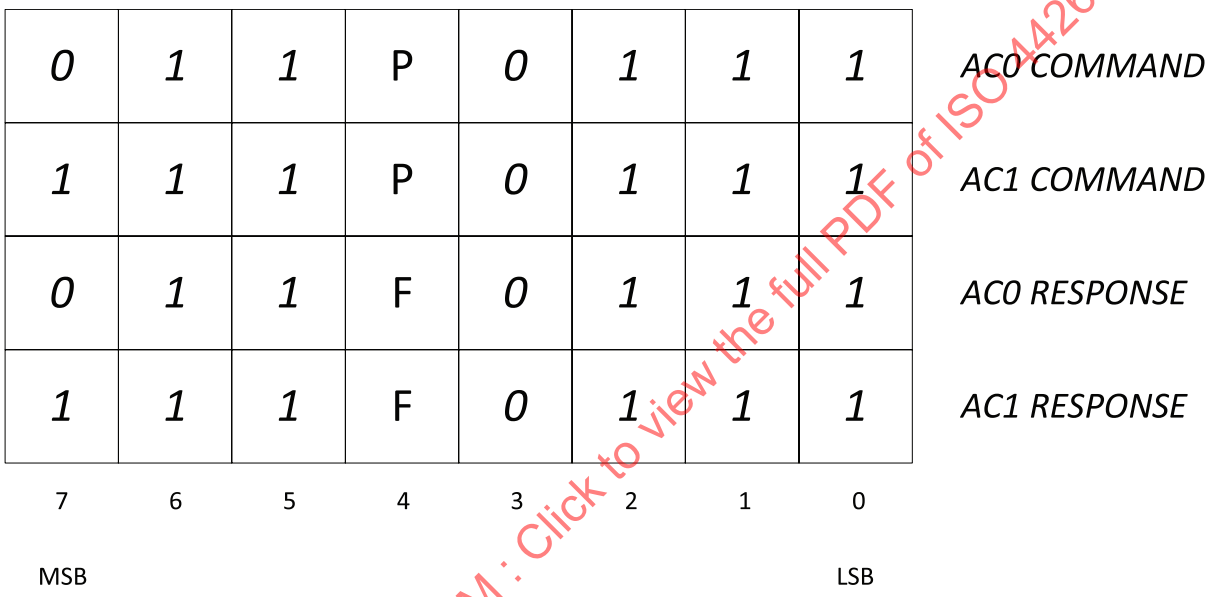


Figure B.19 — ACn command and response, LLC control field

The MSB of the LLC control field for ACn commands and responses is the N bit.

B.5.3.4 LLC Status Subfield

Every ACn response PDU shall contain a status subfield in its information field. The remainder of the information field may be either null or non-null; if non-null it shall contain an LSDU as shown in Figure B.20.

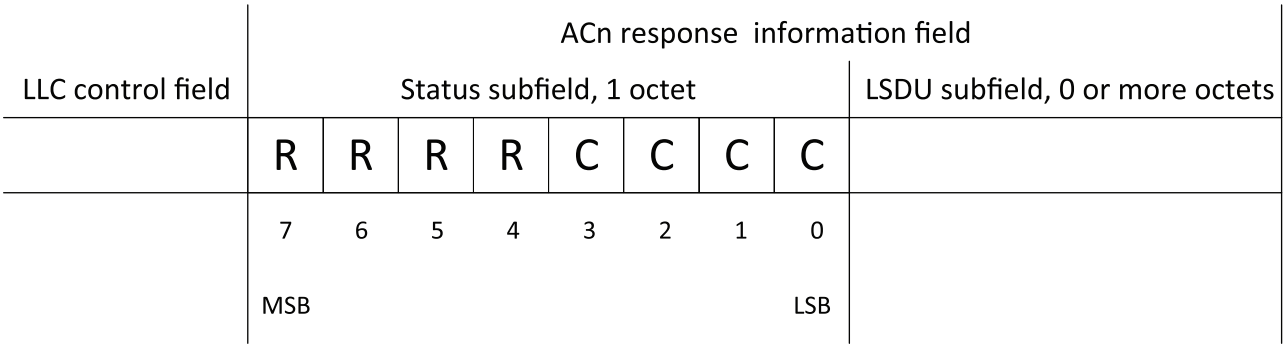


Figure B.20 — ACn response information field format

The code returned in the CCCC part of the status subfield indicates the success or failure of information passage in the command PDU. The code returned in the RRRR part of the status subfield indicates the success or failure of information passage in the response PDU. Table B.4 shows ACn response status subfield values; all values not shown in Table B.4 are reserved for future use.

Table B.4 — ACn response status subfield RRRRCCCC values

R R R R C C C C	Mnemonic	Hex	Description
0 0 0 0 0 0 0 0	OK_OK	0	Command accepted / Response LSDU present
0 0 1 1 0 0 0 0	NE_OK	30	Command accepted / Response LSDU not yet available
0 1 0 0 0 0 0 0	NR_OK	40	Command accepted / Response LSDU not requested

B.5.3.5 Information field

The information field shall consist of any integral number (including zero) of octets.

B.5.3.6 Invalid LPDU

An invalid LPDU shall be defined as one which meets at least one of the following conditions:

a) it is identified as invalid by the MAC sublayer;

b) it is not an integral number of octets in length;

c) its length is 0 (no control field);

d) it does not contain a valid command or response control field as defined by this standard;

e) it does contain an acknowledged connectionless LLC command or response control field, and the LID is either of type multicast or of type broadcast;

f) it does contain an acknowledged connectionless response control field, and no ACn response status subfield in its information field.

Invalid LPDUs shall be ignored.

B.5.4 LLC elements of procedure

B.5.4.1 Overview

This subclause defines the commands and associated responses. B.5.4.2 and B.5.4.3 contain the definitions of the set of commands and responses (listed below) for each of the control field formats for unacknowledged and acknowledged operation, respectively. The C/R bit, located in bit four of the MAC control field, is used to distinguish between commands and responses. Table B.5 shows the commands and responses.

Table B.5 — Commands and responses

Commands		Responses	
UI	Unnumbered Information	None	
AC0	Acknowledged Connectionless Information, Sequence *0*	AC0	Acknowledged Connectionless Acknowledge, Sequence *0*
AC1	Acknowledged Connectionless Information, Sequence *1*	AC1	Acknowledged Connectionless Acknowledge, Sequence *1*

B.5.4.2 Unacknowledged commands

B.5.4.2.1 General

On the downlink, the UI command PDU shall be used to transmit information to one or more mobile SAP(s) (private, multicast or broadcast LID). On the uplink, the UI command PDU shall be used to transmit information to one fixed SAP (private LID).

The use of the UI command PDU is not dependent on the existence of a data link connection between the destination and source LLCs, and its use does not affect the state variables of the acknowledged operation. There is no LLC response PDU to the UI command PDU.

B.5.4.2.2 Transmitting UI commands

Upon being passed a DL-UNITDATA.request primitive from the application layer, the LLC shall transmit a UI command PDU which contains the LSDU and which has the P bit set to *0*.

The C/R bit in the MAC control field shall be used to identify that a command is contained in the PDU.

B.5.4.2.3 Receiving UI commands

If the received LPDU is valid and not null, then the LSDU shall be passed to the application layer in a DL-UNITDATA.indication primitive.

Reception of the UI command PDU shall not be acknowledged by the logical data link procedures. The data contained in a UI PDU can be lost if a logical data link exception occurs during the transmitting of the command PDU.

B.5.4.3 Acknowledged commands/responses

B.5.4.3.1 General

The ACn command PDU shall be used to transmit information or to request information, without the prior establishment of a data link connection. Use of the ACn command PDU is not dependent upon the existence of a data link connection between the destination and source. Reception of an ACn command PDU shall be acknowledged by an ACn response PDU at the earliest opportunity. The information field in the ACn command PDU may be either null (having zero length) or non-null, and if non-null shall contain a link service data unit. The ACn command shall have a private LID.

The ACn response PDU shall be used to reply to an ACn command PDU. Responses shall be made at the earliest opportunity. The ACn response PDU shall identify the responding LLC and shall be transmitted to the originating LLC. The ACn response PDU shall always contain a status subfield in its information field (see B.5.3.4).

The source LLC may retransmit an acknowledged command PDU for recovery purposes but it shall not transmit a new acknowledged command PDU while waiting for an acknowledgement of a previous PDU with the same LID. Acknowledged connectionless information exchange shall not interfere with any unacknowledged connectionless operation.

The N bit in successive PDUs provides a one-bit sequence number, which allows the LLC which receives a command PDU to distinguish between a new PDU and a retransmission of the previous PDU.

Further, the LLC that receives an acknowledgement PDU can ensure that the acknowledgement refers to the last transmitted command PDU. A previously received acknowledgement, which incurred excessive delay, is thus ignored.

B.5.4.3.2 State variables

B.5.4.3.2.1 General

Acknowledged operation defines state information which shall be maintained at the stations involved in the information exchange. Each station shall maintain for each SAP, a one-bit sequence number for transmitting and another for receiving.

Therefore, mobile equipment has to maintain one pair of send and receive sequence numbers if using acknowledged connectionless operation.

A fixed equipment has to maintain, for each mobile equipment using acknowledged connectionless operation in the communication zone, one pair of send and receive sequence numbers.

B.5.4.3.2.2 Transmit sequence state variable, V_{tx}

The LLC shall be able to maintain one transmit sequence state variable, V_{tx}, for each unique SAP used for transmitting acknowledged connectionless command PDUs. This variable shall take on the values of *0* and *1*. The set of V_{tx} variables permit the LLC to ensure that a received acknowledgement applies to the currently outstanding transmission and allows the receiver to detect duplicate frames. V_{tx} shall be created with the establishment of a new private LID.

B.5.4.3.2.3 Receive sequence state variable, V_{rx}

The LLC shall be able to maintain one receive sequence state variable, V_{rx}, for each unique SAP associated with received acknowledged connectionless command PDUs. This variable contains the complement of the N bit of the last received acknowledged command with the associated LID. V_{rx} allows the LLC to differentiate between an acknowledged connectionless command PDU received for the first time, and a received PDU which is a retransmission of a previously received PDU. V_{rx} shall be created with the establishment of a new private LID.

NOTE In EN 12795[2], the state variable V_{rx} was named V(RI).

B.5.4.3.2.4 Procedure for link set-up

The transmit sequence state variable, V_{tx}, and the receive state variable, V_{rx}, shall be created and deleted together with the creation and deletion of the corresponding SAP.

NOTE 1 In EN 12795[2] the state variable V_{tx} was named V(SI).

The transmit sequence state variable, V_{tx}, shall be created with a value of *0*. The receive sequence state variable, V_{rx}, shall be created with an undefined value.

NOTE 2 No sequence number resynchronization is defined since it is assumed that the state variables are not deleted (e.g. by power down, reset) in one communication zone.

B.5.4.3.3 Procedure for the use of the P/F bit

LLC shall set the P bit in an ACn command PDU to *0* if the command PDU is not a request for the remote LLC to return an LSDU in its acknowledgement. Thus, the P bit is set to *0* when data is to be passed only from the transmitting station to the receiving station, or when the command PDU is to be passed only for the purpose of the Data Link Echo command.

LLC shall set the P bit in an ACn command PDU to *1* if the command PDU is a request for the remote LLC to return an LSDU in its acknowledgement. Setting the P bit to *1* allows data to be passed in both directions.

When transmitting an ACn response PDU, the LLC shall set the F bit equal to the P bit in the received ACn command PDU and include a non-null LSDU subfield only if the F bit is a *1*.

Table B.6 and Table B.7 summarize the functions performed by ACn command and response PDUs according to the state of the P/F bit and the presence of a non-null LSDU.

Table B.6 — Summary of ACn command functionality

P	LSDU	Function
0	null	Data Link Echo
0	non-null	Transmitting data
1	null	(Not allowed)
1	non-null	Exchanging data

Table B.7 — Summary of ACn response functionality

F	LSDU	Function
0	null	Acknowledgement, no data requested
0	non-null	(Not allowed)
1	null	Acknowledgement, requested data unavailable
1	non-null	Acknowledgement with requested data

B.5.4.3.4 Transmitting ACn commands

Information transfer from an initiating LLC to a responding LLC shall be accomplished by transmitting the ACn command. Transmitting an ACn command is allowed at any time to any receiving LLC provided that the transmitting LLC is not currently awaiting an ACn response PDU from that LLC.

Upon being passed a DL-DATA-ACK.request primitive from the application layer, the LLC shall transmit an ACn command PDU containing the LSDU and with the P bit set to *0*.

Upon being passed a DL-REPLY.request primitive from the application layer, the LLC shall transmit an ACn command PDU containing the LSDU and with the P bit set to *1*.

When an ACn command PDU is constructed, the value of V_{tx} shall be used to select the LLC control field code of the PDU. When V_{tx} is *0* the LLC control field code shall be AC0, and when V_{tx} is *1* the LLC control field code shall be AC1.

When the LLC transmits a command PDU, it shall start an acknowledgement timer for that transmission and increment an internal transmission count variable. If no ACn response PDU is received before the acknowledgement timer expires, the transmitting LLC shall retransmit the command, increment the internal transmission count variable, and reset and restart the acknowledgement timer.

If a response is still not received, the retransmission procedure shall be repeated until the value of the internal transmission count variable is equal to the value of the logical link parameter N11, as described in B.5.4.3.8, at which time an unsuccessful status shall be reported to the application layer using the related STATUS.indication primitive.

The acknowledgement timer and the internal transmission count shall be maintained separately for each acknowledged connectionless information exchange between a pair of transmitting and receiving LLCs.

The maximum value for the acknowledgement timer is N13.

The maximum value for the internal transmission count variable is N11.

B.5.4.3.5 Receiving ACn commands

B.5.4.3.5.1 General

Upon receipt of an ACn command PDU, the LLC shall compare the V_{rx} receive state variable with the N bit of the received LPDU from that SAP.

If the comparison shows equality, the received PDU is recognized to be a non-duplicate. Otherwise, the received PDU is recognized to be a duplication of the most recently received ACn command PDU.

B.5.4.3.5.2 Non-duplicate ACn command

If the received LPDU is valid and not null and the P bit is *0* then the LSDU shall be passed to the application layer in a DL-DATA-ACK.indication primitive.

If the P bit is *1*, the LSDU shall be passed to the application layer in a DL-REPLY.indication primitive.

The state variable V_{rx} of the SAP associated with the received command PDU shall be set to equal the complement of the N bit of the received PDU.

LLC shall acknowledge the receipt of a non-duplicate ACn command PDU by transmitting to the originator of the command an ACn response PDU which has the N bit set to the (new) value of the V_{rx}.

If the P bit in the received command PDU is *0*, the response PDU shall be transmitted with the F bit set to *0* and with only a status subfield in the information field.

If the P bit in the command PDU is *1*, the response PDU shall be transmitted with the F bit set to *1*, and with the information field containing the LSDU previously associated with the SAP, if it is available.

If the LSDU is not available, it may be transmitted later (see Annex D).

B.5.4.3.5.3 Duplicate ACn commands

The LLC-procedures upon the reception of a duplicate ACn command PDU are the same as those for the nonduplicate PDU with the following exceptions.

The V_{rx} state variable is not affected by the reception of a duplicate command PDU.

The DL-DATA-ACK.indication primitive is not issued, regardless of the P bit in the command PDU.

If an LSDU is received in the command PDU, it shall not be passed to the application layer.

B.5.4.3.6 Transmitting ACn responses

An AC0 response PDU shall be transmitted only upon the reception of an AC1 command.

An AC1 response PDU shall be transmitted only upon the reception of an AC0 command.

The response shall be transmitted to the transmitter of the associated command PDU.

The ACn status subfields shall be set according to B.5.3.4.

B.5.4.3.7 Receiving acknowledgement

After transmitting an ACn command PDU to a remote LLC, the transmitting LLC shall expect to receive an acknowledgement in the form of an ACn PDU from the LLC to which the command PDU was transmitted.

AC0 commands shall receive an AC1 acknowledgement and vice versa.

Upon receiving such a response PDU, the LLC shall compare the N bit in the response PDU with the current value of the transmit sequence state variable, V_{tx}.

If the comparison shows inequality, the response is considered valid and the LLC shall stop the acknowledgement timer associated with the transmission for which the acknowledgement was received and reset the internal transmission count to zero. The V_{tx} state variable shall be complemented.

The LLC shall pass a DL-DATA-ACK-STATUS.indication primitive or a DL-REPLY-STATUS.indication primitive to the application layer, depending on which request primitive is being confirmed. In the case that an LSDU was returned in the ACn response PDU, the LSDU shall be passed to the application layer.

LLC shall pass the status to the application layer based on the status subfield in the response PDU.

If the comparison of the N bit in the response PDU with the current value of the transmit sequence state variable V_{tx} shows equality, the ACn response PDU shall be considered invalid. The LLC shall take no further action and shall continue to expect to receive a valid ACn response PDU. The acknowledgement timer shall not be affected.

B.5.4.3.8 Maximum number of transmissions, N11

N11 is a logical link parameter that indicates the maximum number of times that an ACn command PDU is transmitted by LLC when trying to accomplish a successful information exchange. Normally, N11 is set large enough to overcome the loss of a PDU due to link error conditions. The value of N11 may be set to *1* so that LLC does not itself re-queue a PDU to the MAC sublayer, but the application layer may initiate retransmissions.

B.5.4.3.9 Acknowledgement time, N13

The acknowledgement time is a logical link parameter that determines the period of the acknowledgement timers, and as such shall define the time interval during which the LLC shall expect to receive an ACn response PDU from a specific LLC from which the LLC is awaiting a response PDU. The acknowledgement time shall take into account any delay introduced by the MAC sublayer and whether the timer is started at the beginning or at the end of the transmitting of the ACn command PDU by the LLC. The proper operation of the procedure shall require that the acknowledgement time shall be greater than the normal time between the transmitting of an ACn command PDU and the reception of the corresponding ACn response PDU.

The unit for the acknowledgement time is defined MAC specific. The public uplink windows allocated are used for this timing purpose.

B.5.4.4 Bit order

Commands and responses shall be delivered to or received from the MAC sublayer with the least significant bit first (i.e., the first bit of an octet that is delivered or received shall have the weight 2^0).

The information field shall be delivered to the MAC sublayer in the same bit order as received from the application layer.

The information field shall be delivered to the application layer in the same bit order as received from the MAC sublayer.

B.6 Data link layer parameters

Table B.8 shows data link layer parameter values.

Table B.8 — Data link layer parameters

N1	not used	
N2	maximum number of octets in frame in downlink window	128 octets
N3	maximum number of octets in frame in private uplink window	128 octets
N4	maximum number of octets in frame in public uplink window	9 octets
N5	number of simultaneously allocated public uplink windows	3
N6	not used	
N7	not used	
N8	not used	
N9	not used	
N10	not used	
N11	maximum number of retransmissions	see B.5.4.3.4
N12	maximum private medium response time	1
N13	maximum value for acknowledgement timer	1; see B.5.4.3.4 and B.5.4.3.9
T1	minimum uplink to downlink link-turn-around time	32 µs
T2	minimum downlink to downlink window time	0 µs
T3	downlink to uplink link-turn-around time	160 µs
T4a	maximum time to start of transmission in private uplink window	320 µs
T4b	maximum time to start of transmission in public uplink window	32 µs
T5	time duration of public uplink window	448 µs

B.7 Data link layer overhead

Table B.9 indicates, for the different command and response frames, the amount of overhead introduced by the data link layer. The overhead is in number of octets.

For the calculations a *4*-octet length of private LID has been assumed.

0-bit insertion, as described in B.2.8, is excluded.

Table B.9 — Data link layer overhead

	Pure MAC frame		**Frame containing UI command PDU**		**ACn**	
	Broadcast LID	**Private LID**	**Broadcast LID**	**Private LID**	**Command**	**Response**
Framing (Flag/FCS)	4	4	4	4	4	4
Link address field	1	4	1	4	4	4
MAC control field	1	1	1	1	1	1
LLC control field	—	—	1	1	1	1
Status subfield	—	—	—	—	—	1
Layer 2 total overhead	6	9	7	10	10	11

B.8 Evolution of the MAC sequence bit

The example illustrated in Table B.10 shows how lost frames can be handled and how the MAC sequence bit S evolves.

Table B.10 — Behaviour of MAC sequence bit — Example 1

FE		ME	FE		ME	Remarks
BST, S=0	→		*Variant:*			
BST, S=0	→					
…						
BST, S=0	→					
	←	PrWRq				MAC Ctrl = 60 Hex
BST, S=0	→					
	←	PrWRq				Variant: PrWA does not come through before the next BST transmission.
PrWA, S=0	→		PrWA, S=0	→		S=0 since first allocation to a new LID.
PrWA, S=0	→		PrWA, S=0	→		
			…			
			PrWA, S=0	→		
			BST	→		
				←	PrWRq	
			PrWA, S=1	→		
	←	VST (UI)		←	VST (UI)	Mac Ctrl = C0, LLC Ctrl = 03
PrWA, S=u	→		*Variant:*			S remains unchanged to previous value.
PrWA, S=u	→					
…						
BST, S=0	→					
	←	PrWRq				
PrWA, S=t	→					
	←	VST (UI)				Variant: Unknown EFC application.
			UI (release)	→		
			BST	→		
				←	PrWRq	
			UI (release)	→	(END)	ME released. End of transaction.
AC0 (GET1), PrWA, S=t	→					An ME receives no AC command before the next BST, it reconnects with PrWRq.
AC0 (GET1), PrWA, S=t	→					ME has received an application command and stops reconnecting.

Key

→	downlink
←	uplink
shaded field	"frame lost on the link"
S=u	S bit unchanged against previous value for the same LID
S=t	S bit is toggled

The example illustrated in Table B.11 shows responses when ME asks for a private window to send pending data.

Table B.11 — Behaviour of MAC sequence bit — Example 2

FE		ME	FE		ME	Remarks
	←	AC1, no LSDU				LLC status = 30, APDU requested but not yet available.
BST	→					
	←	PrWRq				
PrWA, S=t	→					
	←	UI (X.resp)				Application data received by FE.
Key						
→	downlink					
←	uplink					
S=t	S bit is toggled					

If, after the AC1 frame from the ME, the FE receives nothing for a long time, the AC command is reissued; see Table B.12. (Still AC0, since it is no new command, there was no application layer response yet. The S bit is toggled since it is a new allocation).

Table B.12 — Behaviour of MAC sequence bit — Example 3

FE		ME	FE		ME	Remarks
AC0 (GET 1) PrWA, S=t	→					
	←	AC1 (X.resp)				Application data received by FE.
Key						
→	downlink					
←	uplink					
S=t	S bit is toggled					

The example illustrated in Table B.13 shows responses when ME waits for FE retry to send pending data.

Table B.13 — Behaviour of MAC sequence bit — Example 4

FE		ME	FE		ME	Remarks
	←	AC1 (X.resp = Processing)				
AC0 (GET 1) PrWA, S=t	→					AC1 since an application layer response was already received.
	←	AC0 (X.resp = data)				Application data received by FE.
Key						
→	downlink					
←	uplink					
S=t	S bit is toggled					

B.9 Address establishment

This clause discusses an example of how a communications session between a fixed equipment and a mobile equipment unit could be set up and initialized.

The basic underlying assumptions are that the fixed side periodically broadcasts a beacon service table, BST, containing information on communication parameters, communication profiles and available applications. The BST is transmitted as unnumbered information, UI, with the broadcast address. The frame containing the BST also contains an uplink window allocation, and, since the address is broadcast, it is a public uplink window allocation.

The mobile unit waits, until it hears the BST. The BST is addressed to the data link user, the application layer, and it is interpreted there. The first action in the application layer is to generate a new link address if the interpretation of the BST indicates that the mobile has arrived at a new beacon. The next action is to read or generate a vehicle service table (VST), containing information on communication parameters, communication profiles and available applications in the mobile, and to issue a DL-UNITDATA.request containing the VST.

The interpretation of the BST has also provided the mobile interlayer management with the necessary information on number of, and length of, public uplink windows, etc.

The LLC sublayer discards any state information relating to the earlier SAP and creates a new SAP with the new link address and new state information. The LLC sublayer then issues an MA-DATA.request containing the VST to the MAC sublayer.

The MAC sublayer constructs the frame containing the VST, realizes that the frame is too long for the public uplink window that is available and constructs a request for a private window using the new link address. It then selects a public uplink window according to the random delay counter and transmits the request for a private window in this public uplink window.

The fixed equipment MAC responds to the request for private window by allocating a private uplink window to the mobile with the indicated link address. In that private uplink window, the mobile transmits the pending frame containing the VST.

When the frame is correctly received in the fixed MAC, the result will be an MA-DATA.indication to the fixed LLC. The fixed LLC will study the link address and find that it is new, create a new SAP for that link address and issue a DL-UNITDATA.indication.

The sequence of frames/windows can be depicted as in Figure B.21.

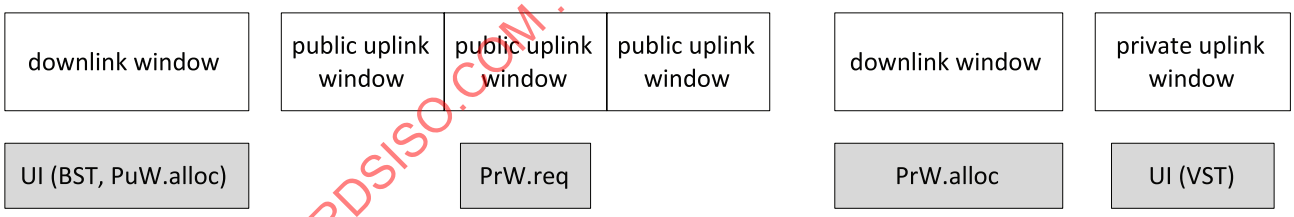


Figure B.21 — BST – VST exchange for newly arrived mobile equipment — Windows

The following applies for Figure B.21:

— number of simultaneously allocated public windows = 3;

— random delay counter = 2;

— maximum random delay counter = 3.

The sequence of service primitives and frames can also be depicted as in Figure B.22.

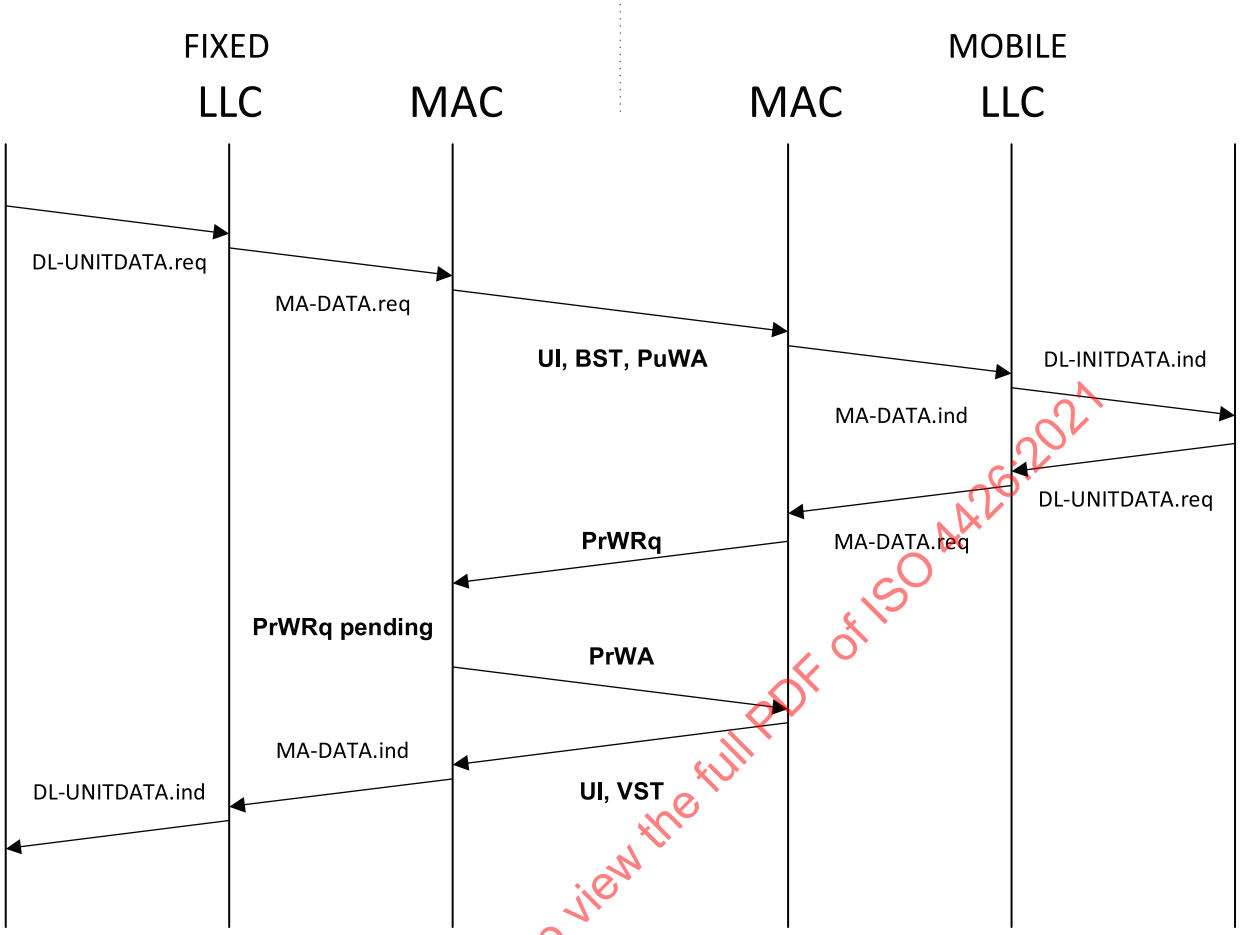


Figure B.22 — BST – VST exchange for newly arrived mobile equipment — Primitives

In any SDTC communication, the unreliability of the link should be taken into account. It is therefore necessary to investigate the possibilities to recover from loss of frames also in the early phases of communication. If the frame transmitted on the uplink in the public uplink window is lost (due to contention or for other reasons) the mobile equipment will not know until the private uplink window allocation timer has expired. Since the maximum value of the timer is 1, the mobile will expect a private window allocation before the next public window allocation, which occurs at the next transmission of the BST (see Figure B.23).

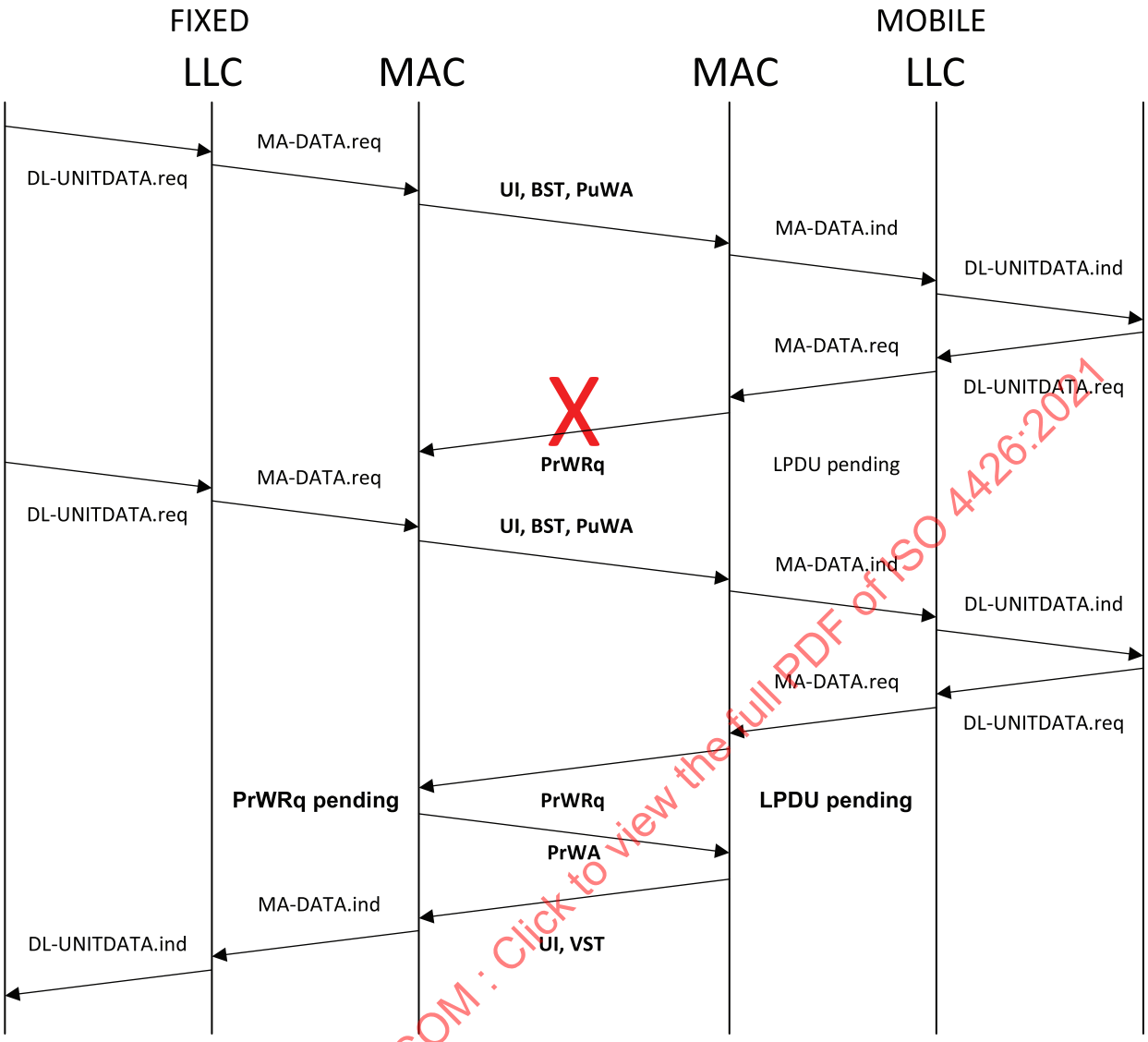


Figure B.23 — BST – VST exchange when private window request is lost

If the frame transmitted on the downlink allocating the private uplink window is lost, the mobile will not transmit in the private window allocated and the fixed side can reallocate the private uplink window to increase the probability of getting the data (see Figure B.24).

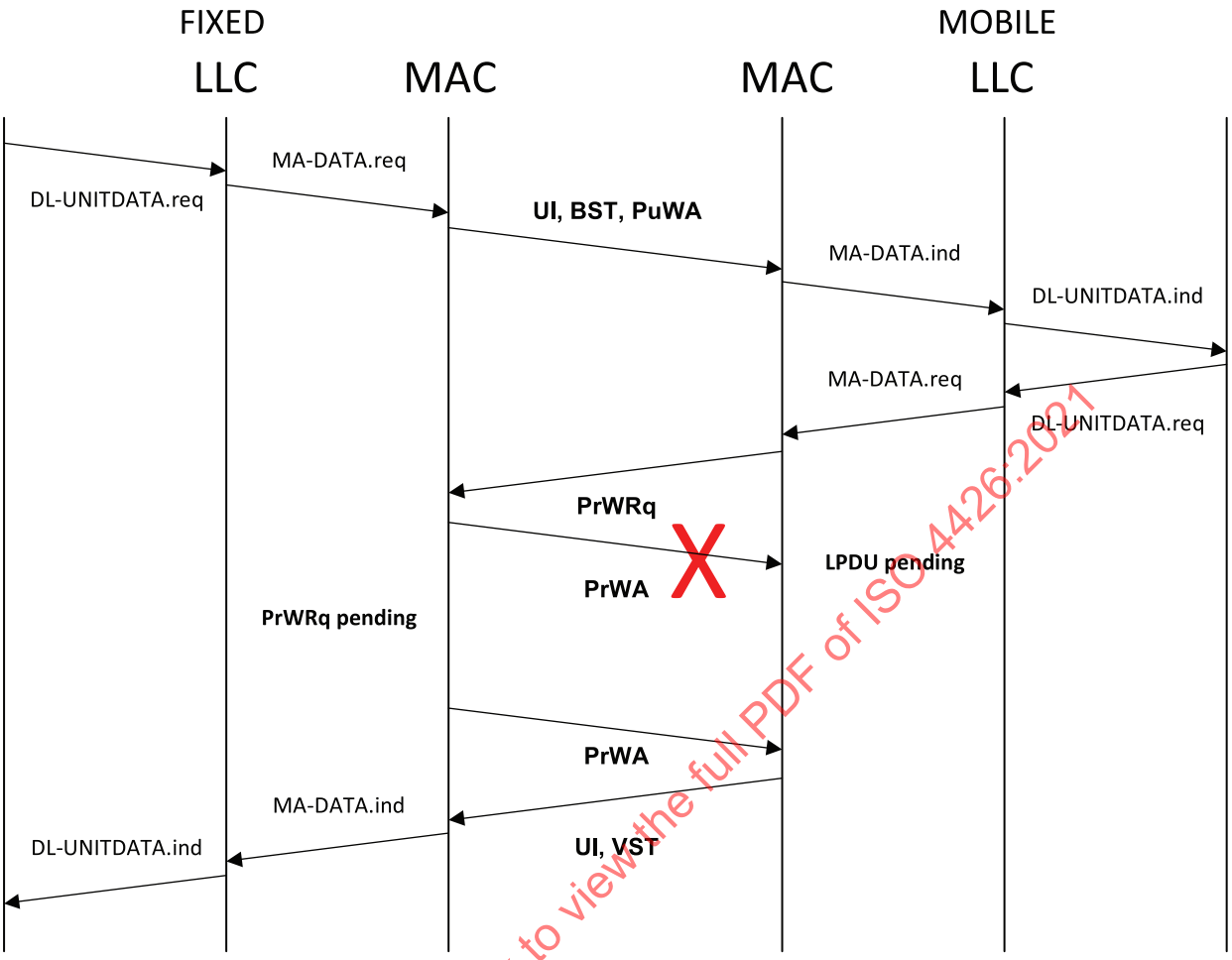


Figure B.24 — BST – VST exchange when a private window allocation is lost

If the UI frame containing the VST, transmitted on the uplink, is lost, the fixed side will not receive a valid frame in the private window allocated and it can then reallocate the private uplink window (see Figure B.25).

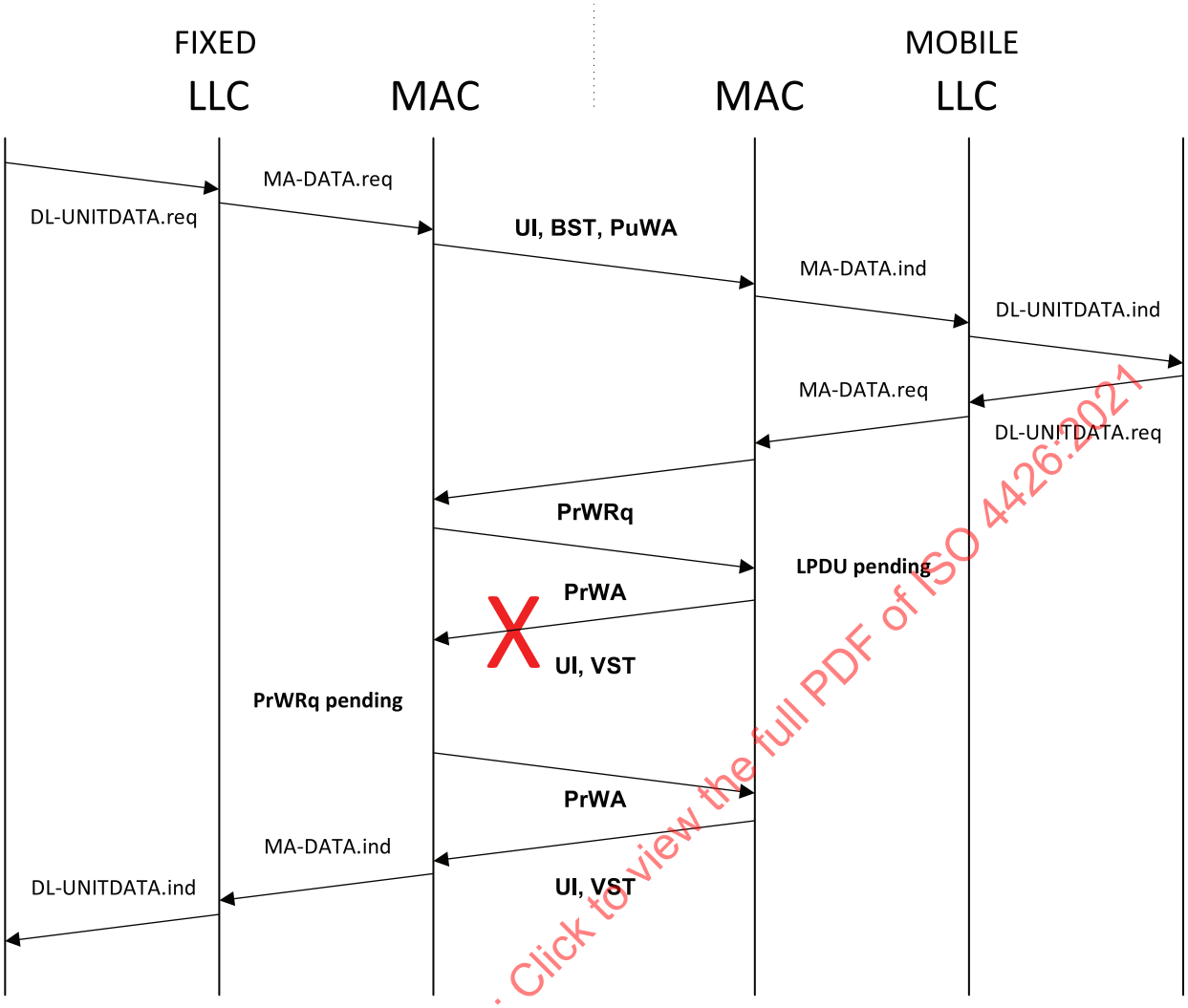


Figure B.25 — BST – VST exchange when VST is lost

B.10 State transitions

A predecessor of EN 12795 contained an incomplete specification of state transitions for the data link layer. This specification was removed. Private initiatives finalized the state transitions and published them in DSRC documents, e.g. the DSRC Tutorial published by ESF GmbH [24]. An Industry group published an extended state transition specification covering a complete DSRC OBU in a GSS document which is no longer officially available[25]. This GSS state transition specification is now available in ISO 15509[6].

Annex C
(normative)

SDTC application layer

C.1 Overview and relation to CEN EN 12834

This annex specifies the SDTC application layer core which provides communication tools for the European SDT application. These tools consist of kernels that can be used by the SDT application process via service primitives. The SDT application process, including application data and application-specific functions, are outside the scope of document.

NOTE 1 SDT application process specific specifications are provided in ISO 15638-9.

The SDTC application layer uses services provided by the SDTC data link layer, and covers the functionality of intermediate layers of the OSI basic reference model specified in ISO/IEC 7498-1.

The following subjects are covered by this annex:

— application layer structure and framework;

— services to enable data transfer and remote operations;

— application multiplexing procedure;

— fragmentation procedure;

— concatenation and chaining procedures;

— common encoding rules to translate data from abstract syntax ASN.1, (ISO/IEC 8824-1), into transfer syntax, (ISO/IEC 8825-2), and vice versa;

— communication initialization and release procedures;

— broadcast service support;

— SDTC management support including communication profile handling.

NOTE 2 It is outside the scope of this annex to define a security policy. Some transport mechanisms for security related data are provided.

This annex provides specifications equivalent to those published in EN 12834[3], and as used in the specification for the Digital Tachograph; see ISO 15638-9, Reference [21] and Reference [22].

C.2 identifies the technical requirements for the SDTC application layer specified in EN 12834[3] based on ISO 15628, which contains equivalent specifications as provided in EN 12834[3].

The terms "SDTC" and "DSRC" used in this annex are synonymous in terms of their applicability for the SDT.