



Short Range Devices; Low Throughput Networks (LTN); Protocols for radio interface A

STANDARD UNDER REVIEW
(standard site only)
Full standard/catalog/standards/103-357-v1-1-2018-06
<https://standards.iteh.ai/catalog/standards/sls/4662-2ae-6ed5-4739-bc2e-9228484b249e/etsi-ts-103-357-v1-1-2018-06>

Reference

DTS/ERM-TG28-503

Keywords

interface, LTN, OSSS, protocol, radio, SRD, UNB

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Important notice

The present document can be downloaded from:

<http://www.etsi.org/standards-search>

The present document may be made available in electronic versions and/or in print. The content of any electronic and/or print versions of the present document shall not be modified without the prior written authorization of ETSI. In case of any existing or perceived difference in contents between such versions and/or in print, the only prevailing document is the print of the Portable Document Format (PDF) version kept on a specific network drive within ETSI Secretariat.

Users of the present document should be aware that the document may be subject to revision or change of status.

Information on the current status of this and other ETSI documents is available at

<https://portal.etsi.org/TB/ETSIDeliverableStatus.aspx>

If you find errors in the present document, please send your comment to one of the following services:

<https://portal.etsi.org/People/CommiteeSupportStaff.aspx>

Copyright Notification

No part may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm except as authorized by written permission of ETSI.

The content of the PDF version shall not be modified without the written authorization of ETSI.

The copyright and the foregoing restriction extend to reproduction in all media.

© ETSI 2018.

All rights reserved.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members.

3GPP™ and **LTE™** are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners.

oneM2M logo is protected for the benefit of its Members.

GSM® and the GSM logo are trademarks registered and owned by the GSM Association.

Contents

Intellectual Property Rights	9
Foreword.....	9
Modal verbs terminology.....	9
1 Scope	10
2 References	10
2.1 Normative references	10
2.2 Informative references.....	10
3 Definitions, symbols and abbreviations	11
3.1 Definitions.....	11
3.2 Symbols.....	12
3.3 Abbreviations	12
4 General description.....	15
5 Lfour family	15
5.1 Overview	15
5.2 MAC layer description	17
5.2.1 Overview	17
5.2.2 MAC format in UL	18
5.2.3 MAC function in UL.....	18
5.2.3.1 Assembling of MSDU.....	18
5.2.3.2 Assembling of Header Field.....	18
5.2.3.3 Insertion of Check Sum.....	18
5.2.3.4 Provisioning of PHY Parameter.....	18
5.2.3.4.1 PHY Mode.....	18
5.2.3.4.2 Repetitions.....	18
5.2.3.4.3 Encryption Parameters.....	19
5.2.3.4.4 PHY Parameters.....	19
5.2.3.4.5 Operation Band.....	19
5.2.3.4.6 Channel Access	19
5.2.3.4.7 Transmission Frame	19
5.2.4 MAC procedures.....	20
5.2.4.1 Overview.....	20
5.2.4.2 End-point Operation.....	20
5.2.4.2.1 Overview	20
5.2.4.2.2 Repetition Procedure	20
5.2.4.2.3 Frequency Selection Procedure	20
5.2.4.2.4 Transmission Start Time Selection Procedure.....	21
5.2.4.2.5 Channel Assessment Procedure.....	21
5.3 PHY layer description	22
5.3.1 Overview	22
5.3.2 PHY format in UL	23
5.3.3 PHY function in UL.....	23
5.3.3.1 Forward Error Correction.....	23
5.3.3.2 Rate Matching	24
5.3.3.3 Encryption.....	26
5.3.3.4 Synchronization Signal Insertion	27
5.3.3.5 Interleaving	28
5.3.3.5.1 Mode A Interleaver.....	28
5.3.3.5.2 Mode B and C Interleaver	28
5.3.3.6 Scrambling	29
5.3.3.7 Modulation	29
5.3.3.7.1 Introduction	29
5.3.3.7.2 Primary Modulation.....	29
5.3.3.7.3 Secondary Modulation.....	30
5.3.4 PHY Procedures.....	30

5.3.4.1	Overview	30
5.3.4.2	Synchronous Pattern-1	30
5.3.4.2.1	Frame structure	30
5.3.4.2.2	Time and frequency hopping	31
5.3.4.2.3	Pseudo-random seed generation	33
5.4	Radio characteristics	34
5.4.1	Overview	34
5.4.2	Band-plan	34
6	Telegram splitting ultra narrow band (TS-UNB) family	35
6.1	Overview	35
6.1.1	General description	35
6.1.2	Modes of operation	37
6.2	Link Layer	38
6.2.1	Link Layer Overview	38
6.2.2	Link Layer Format	38
6.2.2.1	Link Layer Protocol Data Unit (LPDU)	38
6.2.2.2	Control Segment	39
6.2.2.2.1	Overview	39
6.2.2.2.2	Attach Request	39
6.2.2.2.3	Attach Accept	39
6.2.2.2.4	Detach Request	40
6.2.2.2.5	Detach Accept	40
6.2.2.2.6	DLRX Status Query	40
6.2.2.2.7	DLRX Status Response	40
6.2.2.2.8	Link Adaptation Request	41
6.2.2.2.9	Link Adaptation Confirm	41
6.2.2.3	End-point Info Field	41
6.2.3	Link Layer Procedures	42
6.2.3.1	End-point Attachment	42
6.2.3.1.1	Introduction	42
6.2.3.1.2	End-point Configuration	42
6.2.3.1.3	Class Z end-point Attachment	42
6.2.3.1.4	Class A end-point Attachment	43
6.2.3.2	End-point Detachment	43
6.3	MAC Layer	44
6.3.1	Byte and Processing Order	44
6.3.2	Fixed MAC Mode	44
6.3.2.1	Overview	44
6.3.2.2	MAC Formats in UL	45
6.3.2.2.1	MAC Protocol Data Unit (MPDU)	45
6.3.2.2.2	MAC Header	46
6.3.2.2.3	Address	46
6.3.2.2.4	MPDUCNT	46
6.3.2.2.5	MAC Payload Format (MPF)	46
6.3.2.2.6	MAC Payload	46
6.3.2.2.7	SIGN	46
6.3.2.3	MAC Formats in DL	47
6.3.2.3.1	MAC Protocol Data Unit (MPDU)	47
6.3.2.3.2	MAC Header	47
6.3.2.3.3	MAC Payload Format (MPF)	47
6.3.2.3.4	MAC Payload	47
6.3.2.3.5	SIGN	47
6.3.2.4	MAC Functions in UL	47
6.3.2.4.1	Addressing	47
6.3.2.4.2	Packet Counter	48
6.3.2.4.3	Attachment Counter	48
6.3.2.4.4	Payload Encryption	48
6.3.2.4.5	Authentication	48
6.3.2.5	MAC Functions in DL	48
6.3.2.5.1	Addressing	48
6.3.2.5.2	Packet Counter	49

6.3.2.5.3	Payload Encryption	49
6.3.2.5.4	Authentication	49
6.3.2.6	Common MAC function	49
6.3.2.6.1	Encryption	49
6.3.2.6.2	CMAC generation	50
6.3.2.7	MAC Procedures	50
6.3.2.7.1	Scheduling	50
6.3.2.7.2	Transmission Acknowledgment	51
6.3.3	Variable MAC mode	51
6.3.3.1	Overview	51
6.3.3.2	MPDU Format	52
6.3.4	MAC Types	52
6.3.4.1	MAC type WMBUS	52
6.3.4.1.1	Overview	52
6.3.4.1.2	MAC Formats	52
6.3.4.1.3	MAC functions	53
6.3.4.1.4	MAC procedures	53
6.4	PHY Layer	53
6.4.1	PHY Overview	53
6.4.2	PHY Formats in UL	53
6.4.2.1	Radio-burst	53
6.4.2.1.1	Burst Data Unit (BDU)	53
6.4.2.1.2	Sync-burst Data Unit (SBDU)	53
6.4.2.2	Radio Frame	54
6.4.2.2.1	Overview	54
6.4.2.2.2	Core frame	54
6.4.2.2.3	Extension frame	54
6.4.2.3	PHY Payload	54
6.4.2.3.1	Introduction	54
6.4.2.3.2	Header CRC	55
6.4.2.3.3	Payload CRC	55
6.4.2.3.4	Packet Size Indicator (PSI)	55
6.4.2.3.5	PHY Service Data Unit (PSDU)	55
6.4.2.3.6	MMode	55
6.4.3	PHY Formats in DL	55
6.4.3.1	Radio-burst	55
6.4.3.1.1	DL-SB Mode	55
6.4.3.1.2	DL-TS Mode	56
6.4.3.2	Radio frame	57
6.4.3.2.1	Core frame	57
6.4.3.2.2	Extension frame	57
6.4.3.3	PHY Payload	58
6.4.3.3.1	Core frame	58
6.4.3.3.2	Extension frame	59
6.4.4	PHY Functions in UL	59
6.4.4.1	Modulation	59
6.4.4.2	Symbol mapping	59
6.4.4.2.1	Overview	59
6.4.4.2.2	UL-ULP Symbol rate	60
6.4.4.2.3	UL-ER Symbol rate	60
6.4.4.3	Data Whitening	60
6.4.4.4	CRC	60
6.4.4.4.0	General	60
6.4.4.4.1	Payload CRC	60
6.4.4.4.2	Header CRC	60
6.4.4.5	Forward Error Correction	61
6.4.4.6	Interleaving	61
6.4.4.6.1	Introduction	61
6.4.4.6.2	Bit assignment to sub-packets	61
6.4.4.6.3	Bit placing within Burst Data Unit	62
6.4.5	PHY Functions in DL	63
6.4.5.1	Modulation	63

6.4.5.1.1	DL-SB Mode	63
6.4.5.1.2	DL-TS Mode	63
6.4.5.2	Data Whitening	63
6.4.5.2.1	Core frame.....	63
6.4.5.2.2	Extension frame.....	63
6.4.5.3	CRC.....	63
6.4.5.3.1	Core frame.....	63
6.4.5.3.2	Extension frame.....	63
6.4.5.4	Forward Error Correction.....	63
6.4.5.4.1	DL-SB Mode	63
6.4.5.4.2	DL-TS Mode	64
6.4.5.5	Interleaving	64
6.4.5.5.1	DL-SB Mode	64
6.4.5.5.2	DL-TS Mode	64
6.4.6	Commonly used PHY Functions	66
6.4.6.1	Introduction.....	66
6.4.6.2	CRC.....	67
6.4.6.3	FEC	67
6.4.7	PHY Procedures.....	67
6.4.7.1	TSMA Schemes	67
6.4.7.1.1	Overview	67
6.4.7.1.2	Frame Repetition	69
6.4.7.1.3	Downlink repetition.....	70
6.4.7.1.4	Radio burst time	70
6.4.7.1.5	Frame time and frequency offset.....	71
6.4.7.1.6	Uplink TSMA Pattern.....	72
6.4.7.1.7	Downlink TSMA pattern.....	75
6.5	Radio Characteristics.....	76
6.5.1	Spectrum Use.....	76
6.5.2	Channel access.....	76
6.5.3	End-point	77
6.5.3.1	Carrier Frequency Tolerance	77
6.5.4	Base station	77
6.5.4.1	Carrier Frequency Tolerance	77
6.5.4.2	Receiver	77
6.5.4.2.1	Receiver Bandwidth	77
7	Dynamic Downlink Ultra Narrow Band (DD-UNB) family.....	77
7.1	System overview	77
7.1.1	System elements	77
7.1.1.1	Architecture.....	77
7.1.1.2	Service Centre	77
7.1.1.3	Base station	78
7.1.1.4	End-points	78
7.1.2	Protocol Overview	78
7.1.2.1	Introduction.....	78
7.1.2.2	Protocol Termination Points.....	78
7.1.2.3	System Addressing and Identities	80
7.1.3	Upper Layer Principles	80
7.1.4	Layer 3 (NET) Overview	80
7.1.5	Layer 2 (DLL) Overview	81
7.1.5.1	Overview.....	81
7.1.5.2	MAC Sublayer	81
7.1.6	Layer 1 (PHY) Overview.....	81
7.1.6.1	Frequency use	81
7.1.6.2	A-interface Downlink and Uplink timing	81
7.1.6.3	A"-Interface (Relay Operation) timing	83
7.1.6.4	Frequency and Time Synchronization.....	83
7.2	Network Layer.....	83
7.3	Data Link Layer	83
7.3.1	DLL introduction.....	83
7.3.2	MAC sub-layer	83

7.3.2.1	MAC on A-interface UL - Data Subframe	83
7.3.2.1.1	General	83
7.3.2.1.2	UL throttle	83
7.3.2.1.3	Time domain.....	83
7.3.2.1.4	Frequency domain	84
7.3.2.2	MAC on A-interface UL - Ack Subframe.....	84
7.3.2.2.1	General	84
7.3.2.2.2	Time domain.....	84
7.3.2.2.3	Frequency domain	84
7.3.2.3	MAC on A"-interface UL.....	84
7.3.2.3.1	General	84
7.3.2.3.2	Time domain.....	85
7.3.3	Encryption and Authentication	85
7.4	Physical Layer	85
7.4.1	PHY Format.....	85
7.4.1.1	Timing and Frame Formats	85
7.4.1.1.1	Introduction	85
7.4.1.1.2	A-interface Frame Formats.....	87
7.4.1.1.3	A"-interface Subframe Formats.....	87
7.4.1.1.4	Synchronization and Frame Offset	87
7.4.1.1.5	Battery saving.....	88
7.4.1.2	Physical Channels	88
7.4.2	L1 PDUs and SDUs	89
7.4.2.1	Overview.....	89
7.4.2.2	Sync PDU.....	90
7.4.2.3	Broadcast PDU.....	91
7.4.2.4	Wakeup PDU	92
7.4.2.5	Multicast L1 SDU and PDU.....	92
7.4.2.6	Control L1 SDU and PDU	93
7.4.2.6.1	Overview	93
7.4.2.6.2	A-interface Downlink and A"-interface.....	93
7.4.2.6.3	A-interface Uplink.....	94
7.4.2.7	Connection L1 SDU and PDU	94
7.4.2.7.1	Connection L1 SDU	94
7.4.2.7.2	A-interface Downlink and A"-interface.....	95
7.4.2.7.3	A-interface Uplink.....	95
7.4.2.8	Acknowledge L1 SDU	95
7.4.2.8.1	Ack Message Format.....	95
7.4.2.8.2	Acknowledge on A"-interface and A-interface DL	96
7.4.2.8.3	Acknowledge on A-interface UL.....	97
7.4.3	PHY Functions.....	98
7.4.3.1	Channel Processing	98
7.4.3.2	Channel Coding.....	100
7.4.3.3	Data-Burst Building	101
7.4.3.3.1	Introduction	101
7.4.3.3.2	A-interface DL.....	101
7.4.3.3.3	A-interface UL Data	102
7.4.3.3.4	A-interface UL Ack.....	102
7.4.3.3.5	A"-interface DL.....	102
7.4.3.3.6	A"-interface UL Data data-burst.....	102
7.4.3.3.7	A"-interface UL Ack data-burst	103
7.4.3.3.8	Bit order.....	103
7.4.3.4	Power Control	103
7.4.3.5	High Interference Mode	104
7.4.4	PHY Procedures.....	104
7.4.4.1	Synchronization and Frequency Scanning	104
7.4.4.2	Base Selection	104
7.4.4.3	Transmit Duty-Cycle Control.....	104
7.4.4.4	A-interface Downlink Transmission Control - Frame Structure	104
7.4.4.5	A"-interface Downlink Transmission Control - Subframe Structure	104
7.4.4.6	Uplink Transmission Control	104
7.4.4.7	PHY Measurements	104

7.4.4.8	Noise Measurement.....	104
7.4.4.9	Base-System Group (BSGP).....	105
7.5	Radio characteristics.....	105
7.5.1	Frequency Structure - Radio Mode 0.....	105
7.5.2	Modulation - Radio Mode 0.....	106
7.5.2.1	General.....	106
7.5.2.2	A-interface DL and A"-interface (UL and DL) modulation.....	106
7.5.2.3	A-interface UL modulation.....	106
7.5.3	Radio-Burst Power Ramping.....	107
Annex A (informative): Generic end-point system block diagram		108
A.1	Overview.....	108
A.2	uC.....	108
A.3	Baseband Processor.....	109
A.4	TCXO.....	109
A.5	Timing Sequencer & Controller.....	109
A.6	Modulation Filter.....	109
A.7	PLL.....	109
A.8	Power Amplifier.....	109
A.9	Demodulator.....	109
A.10	Summary.....	109
Annex B (informative): TS-UNB Profiles.....		110
B.1	Overview.....	110
B.2	EU0 Profile.....	110
B.2.1	Spectrum Use.....	110
B.2.2	Mode of operation.....	110
B.3	EU1 Profile.....	111
B.3.1	Spectrum Use.....	111
B.3.2	Mode of operation.....	111
B.4	EU2 Profile.....	111
B.4.1	Spectrum Use.....	111
B.4.2	Mode of operation.....	112
B.5	US0 Profile.....	112
B.5.1	Spectrum Use.....	112
B.5.2	Mode of operation.....	112
History.....		113

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The information pertaining to these essential IPRs, if any, is publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: "*Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards*", which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (<https://ipr.etsi.org/>).

Pursuant to the ETSI IPR Policy, no investigation, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the [ETSI Drafting Rules](#) (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

1 Scope

The present document specifies the radio protocols of three radio technologies, referred to as "families". It contains an implementable description of physical and MAC/link protocol layers. It concludes with a section on implementation commonalities between the three LTN families.

NOTE 1: ETSI TR 103 249 [i.8] describes LTN use cases and system characteristics.

NOTE 2: ETSI TS 103 358 [i.9] specifies the architecture of LTN systems.

NOTE 3: Based on the above documents, radio technologies have been developed with a focus on different subsets of applications, where the optimal balance of technical parameters differs.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at <https://docbox.etsi.org/Reference/>.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

[1] IEEE™ Std 802.15.4-2011: "IEEE Standard for Local and metropolitan area networks; Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)".

[2] Publication 197 (2001): "Specification for the Advanced Encryption Standard (AES)", NIST Processing Standards".

NOTE: Available at: <http://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.197.pdf>.

[3] NIST Special Publication 800-38B (2005): "Recommendation for Block Cipher Modes of Operation: "the CMAC Mode for Authentication".

NOTE: Available at: <https://csrc.nist.gov/publications/detail/sp/800-38b/final>.

[4] ISO/IEC 29192-2:2012: "Information technology - Security techniques - Lightweight cryptography - Part 2: Block ciphers".

[5] CEN EN 13757-4:2013: "Communication systems for meters and remote reading of meters - Part 4: Wireless meter readout (Radio meter reading for operation in SRD bands)".

[6] IEEE™ Guidelines for Use of Extended Unique Identifier (EUI), Organizationally Unique Identifier (OUI), and Company ID (CID).

NOTE: Available at: <http://standards.ieee.org/develop/regauth/tut/eui.pdf>.

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

- [i.1] ERC Recommendation 70-03 (Tromsø 1997 and subsequent amendments): "Relating to the use of short range devices (SRD)", Recommendation adopted by the Frequency Management, Regulatory Affairs and Spectrum Engineering Working Groups, Version of 21 October 2016.
 - [i.2] ETSI EN 300 220-1 (V2.4.1) (05-2012): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1 000 MHz frequency range with power levels ranging up to 500 mW; Part 1: Technical characteristics and test methods".
 - [i.3] CFR Title 47 Part 15 section 15.247: "Operation within the bands 902-928 MHz, 2400-2483.5 MHz, and 5725-5850 MHz".
 - [i.4] ARIB STD-T108: "920 MHz-Band Telemeter, Telecontrol and data transmission radio equipment", Version 1.0 of February 14th 2012.
 - [i.5] Recommendation for Block Cipher Modes of Operation (Methods and Techniques), Morris Dworkin, NIST Special Publication 800-38A, Edition 2001.
- NOTE: Available at: <http://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-38A.pdf>.
- [i.6] IETF RFC 4493: "The AES-CMAC Algorithm", 2006.
- NOTE: Available at: <https://tools.ietf.org/html/rfc4493>.
- [i.7] CEN EN 13757-7:2018: "Communication systems for meters - Part 7: Transport and security services".
 - [i.8] ETSI TR 103 249 (V1.1.1) (10-2017): "Low Throughput Network (LTN); Use Cases and System Characteristics".
 - [i.9] ETSI TS 103 358 (V1.1.1) (06-2018): "Short range devices; Low Throughput Networks (LTN) Architecture; LTN Architecture".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

CLEFIA: A lightweight block cipher defined in ISO/IEC 29192-2 [4].

data-burst: sequence of consecutive radio bursts transmitted by an LTN entity

network element: term used to refer to a node in the DD-UNB system. It can refer to an EP, RP, OEP, BS, or SC

orphan end-point: EP which is connected through a relay point

radio-burst: radio transmission over the air which starts with a ramp up, finishes with a ramp down and which has a continuous centre frequency and constant transmission power (apart from modulation)

radio-frame: area in time and frequency plane containing all radio bursts belonging to one packet

sub-packet: fragment of a packet after telegram splitting

subframe: portion of the basic 24 s frame which is allocated to a specific link, direction and content (i.e. A or A"-interface with DL, UL data or UL Ack)

superframe: set of 64 consecutive frames

TSMA carrier: transmission carrier within the LTN channel on which a radio burst is transmitted

TSMA pattern: time and frequency transmission scheme of a radio frame

3.2 Symbols

For the purposes of the present document, the following symbols apply:

$\Delta f_{\text{slowchirp}}$	Frequency difference between the start and end of secondary modulated PPDU as a result of chirp
ΔT	Symbol duration
B_c	Carrier spacing
$BW_{\text{UL-Ch}}$	Bandwidth of UL channel used by EP in band of operation
C_{RB}	Radio-burst carrier number of TSMA pattern
C_{offset}	Carrier offset of radio frame
dB	decibel
f_0	Start frequency of a radio frame
f_c	Channel centre frequency
f_h	Frequency of high tone
f_l	Frequency of low tone
f_{offset}	Additional pseudorandom radio frequency offset to the centre frequency
f_{RB}	Carrier frequency of a radio burst
n_b	Number of PSDU data bytes
$N_{\text{repetitions}}$	Number of repetitions of a PPDU
n_{ts}	Timeslot offset of radio frame
P_{TSDL}	Downlink TSMA pattern number
P_{TX}	Transmission power
S_{TOTAL}	Total number of sub-packets in a radio frame
S_C	Number of sub-packets in core frame
S_E	Number of sub-packets in extension frame
S_{RF}	Timeslot offset of radio frame
T_0	Start time of the radio frame transmission
T_{DN}	DL Interblock Distance
T_{PPDU}	PPDU duration in seconds
T_{RB}	Time difference between two consecutive radio bursts in number of symbols
T_{SB}	Sync-burst time
$T_{\text{tx-gap}}$	Repetition gap between PPDUs in seconds

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AC	Acknowledge Codeword
ACK	Acknowledge
AES	Advanced Encryption Standard
BC	Broadcast
BCH	Bose–Chaudhuri–Hocquenghem code
BDU	Block Data Unit
BFSK	Binary Frequency Shift Keying
BPSK	Binary Phase Shift Keying
BS	Base Station
BSGP	Base-System Group
BSID	Base Station ID
BT	Bandwidth-bit period product

BW	Bandwidth
CC	Control Codeword
CI	Control Information
CMAC	Cipher-based Message Authentication Code
CPU	Central Processing Unit
CRC	Cyclic Redundancy Check
DAPCH	Downlink Acknowledge Physical Channel
DATA_A	Data field A of a TS burst
DATA_B	Data field B of a TS burst
DATA_C	Data field C of a TS burst
DBPCH	Downlink Broadcast Physical Channel
DC	Duty Cycle
DCPCH	Downlink Control Physical Channel
DD-UNB	Dynamic Downlink Ultra Narrowband
DL	Downlink
DL-ER	Downlink, Extended Reach for TS-UNB
DLL	Data Link Layer
DLRX	Downlink Receive (status)
DL-SB	Downlink Single Burst (Basic profile)
DMPCH	Downlink Multicast Physical Channel
DPG	Downlink Pattern Group
DSP	Digital Signal Processing
DSPCH	Downlink Sync Physical Channel
DWPCH	Downlink Wakeup Physical Channel
DXPCH	Downlink Connection Physical Channel
EFI	Extension Frame Indicator
EP	End-Point
EPID	End-Point Identifier
ER	Extended Reach
EUI	Extended Unique Identifier
FEC	Forward Error Correction
FMAC	Frequency Medium Access Control
FSK	Frequency Shift Keying
GFSK	Gaussian Frequency Shift Keying
GMSK	Gaussian Minimum Shift Keying
GP	Grid Position
GPS	Global Positioning System
IC	Integrated Circuit
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IPv6	Internet Protocol version 6
ISO	International Organization for Standardization
IV	Initialization Vector (payload encryption)
LAPCH	Local Acknowledge Physical Channel
LBPCH	Local Downlink Broadcast Physical Channel
LBT	Listen Before Talk
LCPCH	Local Control Physical Channel
LDPC	Low Density Parity Check
LFSR	Linear Feedback Shift Register
LMPCH	Local Multicast Physical Channel
LPDU	Link Layer Protocol Data Unit
LSB	Least Significant Bit
LSPCH	Local Sync Physical Channel
LTN	Low Throughput Network
LWPCH	Local Wakeup Physical Channel
LXPCH	Local Connection Physical Channel
MAC	Medium Access Control
MC	Multicast
MCL	Minimum Coupling Loss
MMODE	MAC MODE
MPDU	MAC Protocol Data Unit