

IEEE Standard for Wireless Multimedia Networks

IEEE Computer Society

Developed by the
LAN/MAN Standards Committee

IEEE Std 802.15.3™-2023
(Revision of IEEE Std 802.15.3-2016)



STANDARDS

IEEE Standard for Wireless Multimedia Networks

Developed by the

LAN/MAN Standards Committee
of the
IEEE Computer Society

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IEEE SA Standards Board

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Abstract: The protocol and compatible interconnection of data and multimedia communication equipment via 2.4 GHz, 60 GHz, and 300 GHz radio transmissions in a Wireless Personal Area Network (WPAN) using low-power and multiple modulation formats to support scalable data rates are defined in this standard. The Medium Access Control (MAC) sublayer protocol supports both isochronous and asynchronous data types.

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Introduction

This introduction is not part of IEEE Std 802.15.3-2023, IEEE Standard for Wireless Multimedia Networks.

IEEE Std 802.15.3 was originally developed to provide superior quality of service (QoS) over relatively medium range wireless links.

The idea of a high-rate addition to the IEEE 802.15™ family of standards was first proposed in November 1999 at the IEEE Plenary meeting in Kaua'i, HI. The IEEE 802.15.3 task group began its official work at the March 2000 IEEE Plenary meeting in Albuquerque, NM, creating a criteria document and evaluation method. The down-selection of MAC and PHY proposals was completed at the November 2000 IEEE 802 Plenary meeting in Tampa, FL, and the writing of the draft began in December 2000. After working on the draft for one year, the document was ready for the task group ballot process in December 2001. The draft received final Working Group approval at the November 2002 IEEE Plenary meeting in Kaua'i, HI, and began the sponsor ballot process following the meeting. The draft went through one sponsor ballot and two recirculations before it was submitted to the IEEE Standards Association Standards Board (IEEE SASB) for approval. The IEEE SASB approved IEEE 802.15.3 as an IEEE standard in June 2003.

IEEE Std 802.15.3-2003 defined an ad-hoc MAC that enabled simple and fast network formation, excellent QoS, strong security with 128-bit AES encryption in CCM mode, and methods to coexist with other wireless networks in the band. The PHY operated in the license exempt 2.4 GHz band with data rates of 11 Mb/s to 55 Mb/s at distances of greater than 70 m.

Interest in working on an amendment to fix and enhance IEEE Std 802.15.3 began at the September 2003 meeting in Singapore. A study group was formed at the November 2003 meeting in Albuquerque, which completed a project authorization request that was approved in March 2004. Work progressed quickly, and the first task group letter ballot was successfully completed in March 2005. After one recirculation, the draft began sponsor ballot in August 2005. The ballot was successful, and after a recirculation ballot to validate some minor changes, IEEE Std 802.15.3b was approved by the IEEE Standards Board on 6 December 2005, just over two years after the study group started.

IEEE Std 802.15.3b™-2005 fixed mistakes and added enhancements that improve the efficiency of the base standard. Some of the key changes/additions in this amendment are as follows:

- An improved definition of the medium access control (MAC) layer management entity (MLME) service access point (SAP).
- A new acknowledgment (ACK) policy, implied-ACK, that allows polling and a more efficient use of channel time.
- A method for relinquishing time in a channel time allocation (CTA) to allow another device (DEV) time to transmit data.
- The ability to assign device identifiers (DEVIDs) to group addresses to allow multicast connections.
- Faster recovery of network operations when the piconet coordinator (PNC) abruptly disconnects with the conditional handover and the next PNC processes.
- Multiple contention periods during a superframe.

In the July 2003 meeting in San Francisco, an interest group was formed to consider a millimeter wave (mmWave PHY) for the existing standard. A study group was formally created in the March 2004 IEEE 802 plenary meeting in Orlando and developed a project authorization request that was approved in March 2005. The first meeting as a task group was in May 2005 in Cairns, Australia, and the group worked steadily developing channel models and evaluation documents. The PHY modes were selected in November 2007 at the Atlanta meeting and draft progressed rapidly, entering Working Group letter ballot in June 2008. After three Working Group recirculation ballots, sponsor ballot started in March 2009. A total of three sponsor

recirculation ballots were held, leading to approval of IEEE Std 802.15.3c-2009 by the IEEE SA Standards Board on 11 September 2009.

Some of the key features of IEEE Std 802.15.3c™-2009 and additions are as follows:

- Operation in the 60 GHz band.
- New data rates, with the highest greater than 5 Gb/s.
- Beam forming negotiation for the transmitter to increase the communication range.
- MAC packet aggregation and the acknowledgment of individual subpackets to reduce retransmission overhead.

The PHY specifies three modes and one common mode. The three PHY modes are as follows:

- Single carrier (SC) mode optimized for low power and low complexity.
- High-speed interface (HSI) mode optimized for low-latency bidirectional data transfer.
- Audio/video (AV) mode optimized for the delivery of uncompressed, high-definition video and audio.

Interest in developing a wireless communication system at THz frequencies started in 2008 with the establishment of the THz Interest Group. In May 2014, Task Group 3d was formed, covering switched point-to-point connections operating in frequencies from 60 GHz up to the lower THz bands. The Application Requirements Document (ARD), Technical Requirements Documents (TRD), Channel modeling document, and Evaluation Criteria Document for close proximity scenarios were reviewed in July 2014. Discussions began to separate the close proximity efforts at 60 GHz from the other activities at the lower THz band in September 2014; a decision was made in November 2014 to split Task Group 3d into two, one optimized for ranges under 10 centimeters (Task Group 3e) and another covering several meters or more (Task Group 3d).

To support the development of these new amendments, the base standard needed to be revised to create a single document that incorporated the prior two amendments. A PAR was generated in July 2015 at the IEEE Plenary meeting in Waikoloa Village, HI. The PAR was approved by the IEEE SASB in September 2015 and the initial draft was completed soon thereafter (by the same Technical Editor who worked on the previous three documents). After two Working Group ballots, the sponsor ballot began in December 2015 and completed in February 2016 after two Sponsor ballot recirculations. IEEE Std 802.15.3-2016 was approved by the IEEE SA Standards Board in May 2016.

The first meeting of Task Group 3e was held in March 2015 in Berlin, Germany, where the Project Authorization Request (PAR) and Criteria for Standards Development (CSD) were approved. At the May 2015 meeting, the ARD and TRD were combined as a single Technical Guidance Document (TGD) and proposals were reviewed in the July and September 2015 sessions, including the selection of two PHY modes. The group entered Working Group letter ballot in January 2016. After two Working Group recirculation ballots, sponsor ballot started in July 2016. A total of three sponsor recirculation ballots were held, leading to approval of IEEE Std 802.15.3e-2017 by the IEEE SA Standards Board on 14 February 2017.

In November 2015, the required PAR change for Task Group 3d to limit the activities to the lower THz frequency ranges was approved. During the March 2016 meeting, the supporting documents were approved and the call for proposals was issued. Proposals were reviewed during the July and September 2016 meetings. The group entered Working Group letter ballot in January 2017. After one Working Group recirculation ballot, the sponsor ballot started in March 2017. A total of two sponsor ballot recirculation ballots were held, leading to approval of IEEE Std 802.15.3d-2017 by the IEEE SA Standards Board on 28 September 2017.

IEEE Std 802.15.3e-2017 is an amendment to IEEE Std 802.15.3-2016 that defines an alternative physical layer operating in the millimeter wave band along with the necessary MAC changes to support this PHY. Some of the key features and additions are as follows:

- Operation in the 60 GHz band.
- New data rates, with the highest reaching 100 Gb/s.
- Limiting communication range to 10 centimeters or less.
- Use of a pairnet structure and Stack ACK mechanism to simplify and optimize the MAC.
- Selectable PHY modes (single carrier and OOK) to achieve either high-speed operation or system simplicity.

IEEE Std 802.15.3d-2017 is an amendment to IEEE Std 802.15.3-2016 that defines an alternative physical layer (PHY) at the lower THz frequency range, between 252 GHz and 325 GHz, for switched point-to-point links, along with the necessary MAC changes to support this PHY. The amendment builds on the concept of pairnet, introduced in IEEE Std 802.15.3e-2017, and inherits the corresponding MAC changes defined there. Some of the key features and additions are as follows:

- Operation in the THz frequency band.
- Usage of eight different bandwidths between 2.16 GHz and 69.12 GHz.
- Designed for data rates of up to 100 Gb/s.
- Use of a pairnet structure supporting wireless links for intra-device communication (e.g., board-to-board communication), close proximity communication, wireless data centers, and backhaul/fronthaul links.
- Selectable PHY modes (single carrier and on-off keying) to achieve either ultra high-speed operation or system simplicity.

IEEE Std 802.15.3f-2017 is an amendment to IEEE Std 802.15.3-2016 that updates the channelization of the millimeter wave PHY to use the expanded unlicensed millimeter wave spectrum up to 71 GHz.

The PAR for a revision project was generated in November 2021 at the IEEE Plenary virtual meeting. The PAR was approved by the IEEE SASB in December 2021 and the initial draft was completed in September 2022. Apart from several small fixes, the new draft also includes several new features for the THz PHY, such as channel plans up to 450 GHz and two new modulation schemes. After three Working Group ballots, the sponsor ballot began in March 2023 and was completed in July 2023 following two Sponsor ballot recirculations. IEEE Std 802.15.3-2023 was approved by the IEEE-SA Standards Board in September 2023.

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IEEE Standard for ~~High Data Rate~~ Wireless Multi-media Networks

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1. Overview

1.1 Scope

This standard defines physical layer (PHY) and medium access control (MAC) sublayer specifications for high data rate wireless connectivity (typically over 200 Mb/s ~~Mbps~~) with fixed, portable, and moving devices. Data rates are high enough to satisfy a set of consumer multimedia industry needs, as well as to support emerging wireless switched point-to-point and high-rate close proximity point-to-point applications.

1.2 Purpose

The purpose of this standard is to provide for low complexity, low cost, low power consumption, and high data rate wireless connectivity among devices that support a variety of applications such as a set of consumer multimedia industry needs, wireless switched point-to-point applications in data centers, wireless backhaul/fronthaul intra-device communications, and a wide variety of additional use cases such as rapid large multimedia data downloads and file exchanges between two devices in close proximity, including between mobile devices and stationary devices (kiosks, ticket gates, etc.), and/or wireless data storage devices.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{6,7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

⁶ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷ The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

2. Normative references

The following referenced documents are indispensable for the application of this document (~~i.e., they must be understood and used; therefore, each referenced document is cited in the text and its relationship to this document is explained~~). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ANSI X3.66-1979: [American National Standard for](#) Advanced Data Communication Control Procedures (ADCCP).⁸¹

~~NIST FIPS Pub~~ 197: Advanced Encryption Standard (AES), Federal Information Processing Standards Publication 197, US Department of Commerce/ [NIST, May 9, 2023.](#)⁹~~N.I.S.T., November 26, 2001.~~⁵

IEEE Std 802[®]-~~2014~~, IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture.^{10, 11}~~2, 3~~

ISO/IEC 646:1991, Information technology—ISO 7-bit coded character set for information interchange.¹²⁴

⁸ This document is available at <https://nvlpubs.nist.gov/nistpubs/Legacy/FIPS/fipspub71-1980.pdf>

¹~~ANSI publications are available from the American National Standards Institute (<http://www.ansi.org>).~~

^{9, 5} NIST ~~FIPS~~ publications are available from the National Institute ~~of for~~ Standards and Technology (<https://www.nist.gov/>).

^{10, 2} IEEE publications are available from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>)

^{11, 3} The IEEE standards ~~or products~~ referred to in Clause 2 are trademarks ~~owned by belonging to~~ The Institute of Electrical and Electronics Engineers, ~~Incorporated Inc.~~

^{12, 4} ISO/IEC/~~IEEE~~ publications are available from the International Organization for Standardization (<https://www.iso.org/>) and The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>). (~~← <http://www.iso.ch/> and the International Electrotechnical Commission (<http://www.iec.ch/>).~~ ISO/IEC publications are also available in the United States from the American National Standards Institute (<http://www.ansi.org/>).

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For [the purposes of](#) this [document](#) ~~standard~~, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause. ¹⁴ ⁶

ad hoc network: A network typically created in a spontaneous manner. The principal characteristic of an ad hoc network is its limited temporal and spatial extent.

association: The service used to assign a device identifier to a device to enable communications in a piconet.

channel time allocation (CTA): A contiguous period of time in the superframe allocated by the piconet coordinator for communication between specified source and destination.

coexistence: The ability of one system to perform a task in a given shared environment where other systems have an ability to perform their tasks and may or may not be using the same set of rules.

data authentication: Authentication of the sender of the data and provision of data integrity.

data integrity: The assurance that the data has not been modified from its original form.

dBm: Decibels relative to a milliwatt.

device: An entity that implements an IEEE 802.15.3 conformant media access control and physical layer interface to the wireless medium.

¹³ This document available at <https://csrc.nist.gov/pubs/sp/800/38/d/final>.

¹⁴ ⁶IEEE Standards Dictionary Online is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page. ~~http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html~~

device address: The EUI-48 associated with device in an IEEE 802.15.3 piconet.

disassociation: The service that removes an existing association.

frame: Format of aggregated bits that are transmitted together in time.

guard interval: A time period placed at the front of a symbol for inter-symbol interference avoidance.

integrity code: A data string generated using a symmetric key that is typically appended to data in order to provide data integrity and source authentication similar to a digital signature.

interoperable: The ability of two systems to perform a given task using a single set of rules.

medium access control command data unit (MCDU): The unit of data exchanged between two peer medium access control entities using the services of the physical layer to implement the medium access control management protocol.

medium access control protocol data unit (MPDU): The unit of data exchanged between two peer medium access control entities using the services of the physical layer.

medium access control service data unit (MSDU): Information that is delivered as a unit between medium access control service access points.

pairnet: A network of at most two associated devices, one of which is capable of providing coordination.

pairnet associated period (PAP): Phase during which the pairnet devices are associated.

pairnet coordinator: An entity, which is a member of a pairnet, that has device functionality and also provides coordination and other services, e.g., quality of service, synchronization, association, via the wireless medium for associated devices.

pairnet device: An entity that may only operate in a pairnet and that implements an IEEE 802.15.3 conformant media access control and physical layer interface to the wireless medium.

pairnet setup period: Phase during which the pairnet beacon is active but pairnet devices are not yet associated.

payload protection: The generic term for providing security services on the contents of a data message, including confidentiality, integrity, and authentication.

piconet: A collection of one or more logically associated devices that share a single identifier with a common coordinator.

piconet coordinator (PNC): An entity that has device functionality and also provides coordination and other services, e.g., quality of service, synchronization, association, via the wireless medium for associated devices.

quality of service (QoS): A collective measure of the level of service (e.g., availability, latency, throughput, error rate) delivered between devices.

secure frame: A command or data frame in which cryptographic techniques are applied to provide encryption or integrity.

secure piconet: A piconet in which cryptographic techniques are implemented to provide security services.

stack acknowledgment (Stk-ACK): An acknowledgment method where the device receiving data returns the frame number to jump back to and starts retransmission when the received frame(s) are corrupted.

stream: A unidirectional, logical data connection between two devices that may or may not have quality of service requirements associated with it.

superframe: The basic time division of an IEEE 802.15.3 piconet containing a beacon, the channel time allocation period, and optionally the contention access period.

symmetric key: A secret key shared between two or more parties that may be used for encryption/decryption or integrity protection/integrity verification.

wireless medium: The medium used to implement the transfer of protocol data units between peer physical layer entities of a wireless personal area network.

3.2 Acronyms and abbreviations

AAS	asymmetric antenna system
ACK	acknowledgment
AES	advanced encryption standard
AS	application specific
ATP	association timeout period
AV	audio/visual
AWGN	additive white Gaussian noise
BBIFS	beam-forming beam-level interframe spacing
BCRD	bidirectional channel time allocation relinquish duration
BcstID	broadcast identifier
BER	bit error rate
BIFS	backoff interframe space
Blk-ACK	block acknowledgment
BPSK	binary phase-shift keying
BSID	beacon source identifier
BSIFS	beam-forming sector-level interframe spacing
BST	beam switching/steering and tracking

CAP	contention access period
CBC	cipher block chaining
CBC-MAC	cipher block chaining-message authentication code
CCA	clear channel assessment
CCM	counter mode encryption and cipher block chaining message authentication code
CES	channel estimation sequence
CID	Company ID
CMS	common mode signaling
CP	contention period
CRC	cyclic redundancy check
CSMA/CA	carrier sense multiple access with collision avoidance
CTA	channel time allocation
CTAP	channel time allocation period
CWB	continued wake beacon
DAMI	dual alternate mark inversion
DestID	destination identifier
DEV	device
DEVID	device identifier
Dly-ACK	delayed acknowledgment

DME	device management entity
DQPSK	differential quadrature phase-shift keying
DSPS	device synchronized power save
EEP	equal error protection
EIRP	equivalent isotropic radiated power
EPD	EtherType protocol discrimination
EVM	error vector magnitude
FCS	frame check sequence
FCSL	frame convergence sublayer
FEC	forward error correction
FER	frame error rate
GCM	Galois/counter mode
HCS	header check sequence
HR	high rate
HRCP	high-rate close proximity
HRP	high-rate physical layer
HRPDU	high-rate protocol data unit
HRS	high resolution
HSI	high-speed interface
ID	identifier

IE	information element
IFS	interframe space
Imm-ACK	immediate acknowledgment
Imp-ACK	implied acknowledgment
KO	key originator
LAN	local area network
LDPC	low-density parity check
LFSR	linear feedback shift register
LLC	logical link control
LLPS	low-latency power save
LQI	link quality indication
LRP	low-rate physical layer
LRPDU	low-rate protocol data unit
LSB	least significant bit
MAC	medium access control
MAN	metropolitan area network
MCDU	MAC command data unit
MCS	modulation and coding scheme
McstID	multicast identifier
MCTA	management channel time allocation

MIFS	minimum interframe space
MIMO	multiple-input, multiple-output
MLME	MAC layer management entity
mmWave	millimeter wave
MPDU	MAC protocol data unit
MPR	mandatory PHY rate
MR	medium rate
MSB	most significant bit
MSC	message sequence chart
MSDU	MAC service data unit
NAK	negative acknowledgment
NbrID	neighbor identifier
NLOS	non-line-of-sight
OFDM	orthogonal frequency-division multiplexing
OOK	on-off keying
OUI	organizationally unique identifier
PAL	protocol adaptation layer
PAN	personal area network
PAP	pairnet associated period
PCES	pilot channel estimation sequence

PCTM	pending channel time map
PDU	protocol data unit
PET	pattern estimation and tracking
PHY	physical layer
PIB	PAN information base
PLME	PHY layer management entity
PN	pseudo noise
PNC	piconet coordinator
PNCID	piconet coordinator identifier
PNID	piconet or pairnet identifier
PPRE	pilot preamble
~~PPDU~~	~~PHY protocol data unit~~
PRBS	pseudo-random binary ~~bit~~ sequence
PRC	pairnet coordinator
PRCID	pairnet coordinator identifier
PRDEV	pairnet DEV
PRNG	pseudo-random number generator
PS	power save
PSD	power spectral density
PSP	pairnet setup period

PSPS	piconet synchronized power save
PSRC	power source
PW	pilot word
QAM	quadrature amplitude modulation
QoS	quality of service
QPSK	quadrature phase-shift keying
QT	quasi-omni training
RF	radio frequency
RIFS	retransmission interframe space
RS	Reed Solomon
RSSI	received signal strength indication
RSSIR	received signal strength indication relative to sensitivity
RX	receive or receiver
SAP	service access point
SAS	symmetric antenna system
SC	single carrier
S-CAP	sub-contention access period
SDU	service data unit
SEC	security
SECID	security identifier

SFC	secure frame counter
SFD	start-of-frame delimiter
SIFS	short interframe space
SINR	signal-to-interference-plus-noise ratio
SISO	single-input, single-output
SNR	signal-to-noise ratio
SPS	synchronous power save
SrcID	source identifier
SSB	single side band
ST	sector training
STP	stream timeout period
Stk-ACK	stack acknowledgment
TCM	trellis coded modulation
TDMA	time division multiple access
TPC	transmit power control
TSD	transmit switched diversity
TU	time unit
TX	transmit or transmitter
UEP	unequal error protection
UnassocID	unassociated identifier

WAN	wide area network
WLAN	wireless local area network
~~WPAN~~	~~wireless personal area network~~

4. General description

4.1 Format conventions

4.1.1 Numbers

Numbers are represented in decimal (nnn), binary (0bnnn), or hexadecimal (0xnnn) notation with the number of digits indicated. For example, 0b001 is a 3-digit binary number of value 1 and 0x001 is a 3-digit hexadecimal number of value 1. Numbers encoded in fields are either signed or unsigned integers unless explicitly defined otherwise. Other formats (e.g., a field containing a floating point number) are stated in the field definition where applicable.

When represented in fields, numbers are expressed with least significant bit (LSB) leftmost and most significant bit (MSB) rightmost as shown in Figure 4-1 for an n -bit unsigned integer. (Note that this is the inverse of the number representations 0bnnn and 0xnnn and of common number representations used in mathematical notations.) For example, the number 0x47 would be represented in an 8-bit field as 1110 0010.

...

...

Bit:0	...	7	Bits 8–($n-2$)	$n-1$
LSB	...	—	Subsequent octets	MSB

(New)

Figure 4-1 – General number field format