
**Information technology —
Telecommunications and information
exchange between systems — Local
and metropolitan area networks —
Specific requirements —**

**Part 11:
Wireless LAN medium access control
(MAC) and physical layer (PHY)
specifications**

*Technologies de l'information — Télécommunications et échange
d'information entre systèmes — Réseaux locaux et métropolitains —
Exigences spécifiques —*

*Partie 11: Spécifications du contrôle d'accès du milieu sans fil (MAC)
et de la couche physique (PHY)*



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IEEE Std 802.11™-2016

(Revision of
IEEE Std 802.11-2012)

**IEEE Standard for Information technology—
Telecommunications and information exchange between systems
Local and metropolitan area networks—
Specific requirements**

Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

**Prepared by the 802.11 Working Group of the
LAN/MAN Standards Committee
of the
IEEE Computer Society**

**Approved 7 December 2016
IEEE-SA Standards Board**

Abstract: Technical corrections and clarifications to IEEE Std 802.11 for wireless local area networks (WLANs) as well as enhancements to the existing medium access control (MAC) and physical layer (PHY) functions are specified in this revision. Amendments 1 to 5 published in 2012 and 2013 have also been incorporated into this revision.

Keywords: 2.4 GHz, 256-QAM, 3650 MHz, 4.9 GHz, 5 GHz, 5.9 GHz, 60 GHz, advanced encryption standard, AES, audio, beamforming, carrier sense multiple access/collision avoidance, CCMP, channel switching, clustering, contention based access period, Counter mode with Cipher-block chaining Message authentication code Protocol, confidentiality, CSMA/CA, DFS, direct link, directional multi-gigabit, dynamic allocation of service period, dynamic extension of service period, dynamic frequency selection, dynamic truncation of service period, E911, EDCA, emergency alert system, emergency services, fast session transfer, forwarding, GCMP, generic advertisement service, high throughput, IEEE 802.11™, international roaming, interworking, interworking with external networks, LAN, local area network, MAC, management, measurement, medium access control, media-independent handover, medium access controller, mesh, MIH, millimeter-wave, MIMO, MIMO-OFDM, multi-band operation, multi-hop, multi-user MIMO, multiple input multiple output, network advertisement, network discovery, network management, network selection, noncontiguous frequency segments, OCB, path-selection, personal basic service set, PHY, physical layer, power saving, QoS, quality of service, quality-of-service management frame, radio, radio frequency, RF, radio resource, radio management, relay operation, spatial sharing, SSPN, subscriber service provider, television white spaces, TPC, transmit power control, video, wireless access in vehicular environments, wireless LAN, wireless local area network, WLAN, wireless network management, zero-knowledge proof

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Introduction

This introduction is not part of IEEE Std 802.11-2016, IEEE Standard for Information technology—Telecommunications and information exchange between systems—Local and metropolitan area network—Specific requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.

This revision gives users, in one document, the IEEE 802.11 standard for wireless local area networks (WLANs) with all of the amendments that have been published to date.

Incorporating published amendments

The original standard was published in 1997, revised in 1999 with MIB changes, and reaffirmed in 2003.

A revision was published in 2007, which incorporated into the 1999 edition the following amendments:

- IEEE Std 802.11a™-1999: High-speed Physical Layer in the 5 GHz Band (Amendment 1)
- IEEE Std 802.11b™-1999: Higher-Speed Physical Layer Extension in the 2.4 GHz Band (Amendment 2)
- IEEE Std 802.11b-1999/Corrigendum 1-2001: Higher-speed Physical Layer (PHY) extension in the 2.4 GHz band (Corrigendum 1 to Amendment 2)
- IEEE Std 802.11d™-2001: Specification for operation in additional regulatory domains (Amendment 3)
- IEEE Std 802.11g™-2003: Further Higher Data Rate Extension in the 2.4 GHz Band (Amendment 4)
- IEEE Std 802.11h™-2003: Spectrum and Transmit Power Management Extensions in the 5 GHz band in Europe (Amendment 5)
- IEEE Std 802.11i™-2004: Medium Access Control (MAC) Security Enhancements (Amendment 6)
- IEEE Std 802.11j™-2004: 4.9 GHz–5 GHz Operation in Japan (Amendment 7)
- IEEE Std 802.11e™-2005: Medium Access Control (MAC) Quality of Service Enhancements (Amendment 8)

A revision was published in 2012, which incorporated into the 2007 revision the following amendments:

- IEEE Std 802.11k™-2008: Radio Resource Measurement of Wireless LANs (Amendment 1)
- IEEE Std 802.11r™-2008: Fast Basic Service Set (BSS) Transition (Amendment 2)
- IEEE Std 802.11y™-2008: 3650–3700 MHz Operation in USA (Amendment 3)
- IEEE Std 802.11w™-2009: Protected Management Frames (Amendment 4)
- IEEE Std 802.11n™-2009: Enhancements for Higher Throughput (Amendment 5)
- IEEE Std 802.11p™-2010: Wireless Access in Vehicular Environments (Amendment 6)
- IEEE Std 802.11z™-2010: Extensions to Direct-Link Setup (DLS) (Amendment 7)
- IEEE Std 802.11v™-2011: Wireless Network Management (Amendment 8)
- IEEE Std 802.11u™-2011: Interworking with External Networks (Amendment 9)
- IEEE Std 802.11s™-2011: Mesh Networking (Amendment 10)

This revision is based on IEEE Std 802.11-2012, into which the following amendments have been incorporated:

- IEEE Std 802.11ae™-2012: Prioritization of Management Frames (Amendment 1)
- IEEE Std 802.11aa™-2012: MAC Enhancements for Robust Audio Video Streaming (Amendment 2)

- IEEE Std 802.11ad™-2012: Enhancements for Very High Throughput in the 60 GHz Band (Amendment 3)
- IEEE Std 802.11ac™-2013: Enhancements for Very High Throughput for Operation in Bands below 6 GHz (Amendment 4)
- IEEE Std 802.11af™-2013: Television White Spaces (TVWS) Operation (Amendment 5)

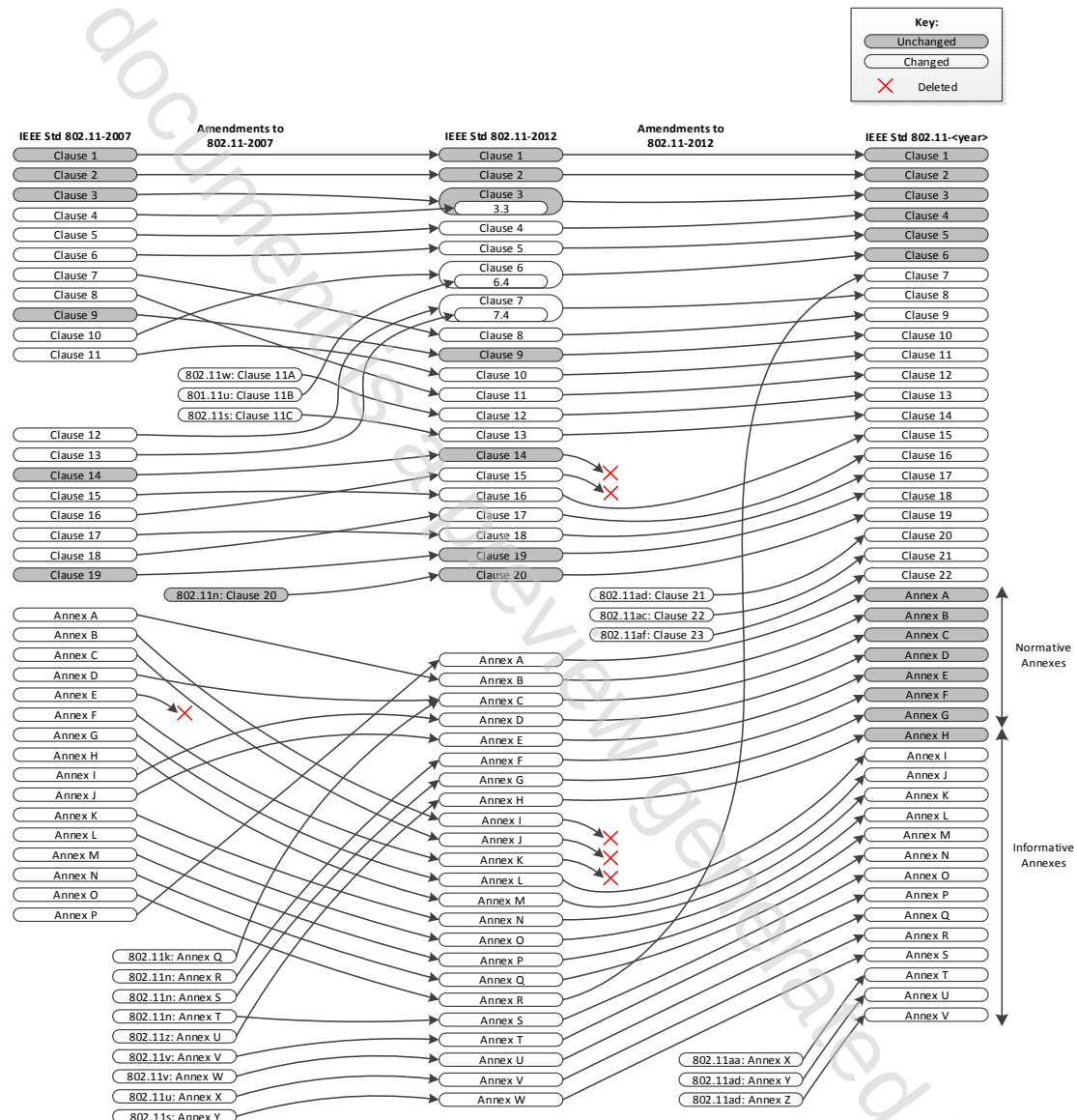
Technical corrections, clarifications, and enhancements

In addition, this revision specifies technical corrections and clarifications to IEEE Std 802.11 as well as enhancements to the existing medium access control (MAC) and physical layer (PHY) functions. In addition, this revision removes some features previously marked as obsolete and adds new indications of other obsolete features.

Renumbering of clauses and annexes

The numbering of certain clauses and annexes has been modified since IEEE Std 802.11-2012.

The evolution of this numbering is shown in Figure i.



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**IEEE Standard for Information technology—
Telecommunications and information exchange between systems
Local and metropolitan area networks—
Specific requirements**

**Part 11: Wireless LAN Medium Access Control
(MAC) and Physical Layer (PHY) Specifications**

1. Overview

1.1 Scope

The scope of this standard is to define one medium access control (MAC) and several physical layer (PHY) specifications for wireless connectivity for fixed, portable, and moving stations (STAs) within a local area.

1.2 Purpose

The purpose of this standard is to provide wireless connectivity for fixed, portable, and moving stations within a local area. This standard also offers regulatory bodies a means of standardizing access to one or more frequency bands for the purpose of local area communication.

1.3 Supplementary information on purpose

Specifically, in the context of IEEE 802.11™-compliant devices, this standard

- Describes the functions and services required by a device to operate within independent, personal, and infrastructure networks as well as the aspects of device mobility (transition) within those networks.
- Describes the functions and services that allow a device to communicate directly with another such device outside of an independent or infrastructure network.
- Defines the MAC procedures to support the MAC service data unit (MSDU) delivery services.
- Defines several PHY signaling techniques and interface functions that are controlled by the MAC.
- Permits the operation of a device within a wireless local area network (WLAN) that coexists with multiple overlapping IEEE 802.11 WLANs.
- Describes the requirements and procedures to provide data confidentiality of user information and MAC management information being transferred over the wireless medium (WM) and authentication of devices.
- Defines mechanisms for dynamic frequency selection (DFS) and transmit power control (TPC) that may be used to satisfy regulatory requirements for operation in any band.

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- Defines the MAC procedures to support local area network (LAN) applications with quality-of-service (QoS) requirements, including the transport of voice, audio, and video.
- Defines mechanisms and services for wireless network management of devices that include BSS transition management, channel usage and coexistence, collocated interference reporting, diagnostic, multicast diagnostic and event reporting, flexible multicast, efficient beacon mechanisms, proxy ARP advertisement, location, timing measurement, directed multicast, extended sleep modes, traffic filtering, and management notification.
- Defines functions and procedures aiding network discovery and selection by devices, information transfer from external networks using QoS mapping, and a general mechanism for the provision of emergency services.
- Defines the MAC procedures that are necessary for wireless multi-hop communication to support wireless LAN mesh topologies.
- Defines medium access control mechanisms to support the prioritization of Management frames.
- Defines mechanisms to improve audio video (AV) streaming QoS while maintaining data and voice performance.
- Defines the PHY signaling, MAC, and beamforming procedures required for operation with directional antenna patterns.

1.4 Word usage

In this document, the word *shall* is used to indicate a mandatory requirement. The word *should* is used to indicate a recommendation. The word *may* is used to indicate a permissible action. The word *can* is used for statements of possibility and capability.

The construction “x to y” or “x-y” represents an inclusive range (i.e., the range includes both values x and y).

The construction “up to y” represents an inclusive upper bound (i.e., the range includes the value y).

Any action specified as relating to a SAP primitive is to be interpreted as an action on an invocation or instance of that primitive.

If <x> represents a scalar field, scalar subfield, scalar parameter or scalar MIB attribute:

- if “<x> is” is used in a context that relates to the testing or setting the value of “<x>” this usage is to be interpreted as though written “the value of <x> is”
- “<x> indicate(s)” is to be interpreted as though written “the value of <x> indicate(s)”
- “indicated by <x>” is to be interpreted as though written “indicated by the value of <x>”
- “<x> that indicate” is to be interpreted as though written “<x> whose value indicates”

If <x> represents a frame, element, subelement, structured field, structured subfield, structured parameter or structured MIB attribute:

- “<x> indicate(s)” is to be interpreted as though written “the contents of <x> indicate”
- “indicated by <x>” is to be interpreted as though written “indicated by the contents of <x>”
- “<x> that indicate” is to be interpreted as though written “<x> whose contents indicate”

If <x> represents a SAP primitive:

- “<x> indicate(s)” is to be interpreted as though written “the (or an) invocation of <x> indicates”
- “indicated by <x>” is to be interpreted as though written “indicated by the (or an) invocation of <x>”

The construction of descriptions for uses of the SHA family of hash functions [HMAC-]SHA- $\langle 1, 256, 384 \rangle$ [- n] is used to refer to hash functions/HMACs where square brackets indicate optional information, and n is an integer indicating the length, in bits, of the output when truncating.

1.5 Terminology for mathematical, logical, and bit operations

Floor (x), also written as $\lfloor x \rfloor$, is the largest integer smaller than or equal to x . For example, Floor (2.3) is 2 and Floor (−2.3) is −3. The two parameter form, Floor (x , y), is the largest multiple of y smaller than or equal to x ; this operator is not used in this standard if y is negative. For example, Floor (3.3, 2) is 2 and Floor (−3.3, 2) is −4.

Ceil (x), also written as $\lceil x \rceil$ is the smallest integer larger than or equal to x . For example, Ceil (2.3) is 3 and Ceil (−2.3) is −2. The two parameter form, Ceil (x , y), is the smallest multiple of y larger than or equal to x ; this operator is not used in this standard if y is negative. For example, Ceil (2.3, 2) is 4 and Ceil (−2.3, 2) is −2.

Round (x) is the integer closest to x , rounding values with a fractional part of 0.5 away from zero. For example, Round (2.3) is 2, Round (2.5) is 3, Round (−2.3) is −2 and Round (−2.5) is −3.

$x \bmod y$ is the remainder when x is divided by y ; this operator is not used in this standard if y is negative; the result is positive even if x is negative. For example, $5 \bmod 3$ is 2 and $-5 \bmod 3$ is 1.

The symbol $\oplus$ represents bitwise exclusive OR (XOR).

$\log_2(x)$ is the logarithm of x to the base 2. For example, $\log_2(32)$ is 5.

Re (z) is the real part of complex number z . Im (z) is the imaginary part of complex number z (not including the factor i). For example, Re ($1 - 2i$) is 1 and Im ($1 - 2i$) is −2.

$x \&\& y$ is the short-circuiting Boolean AND.

$x \parallel y$ is the concatenation of x and y , except in code, where it sometimes is the short-circuiting Boolean OR (as determined by the context).

$!x$ is the Boolean NOT.

$x \gg y$ is x logically shifted right (i.e., zeros are inserted at the most significant end) by y ; this operator is not used in this standard if y is negative.

$x \ll y$ is x shifted left (i.e., zeros are inserted at the least significant end) by y ; this operator is not used in this standard if y is negative.

$x == y$ is Boolean equality.

$x != y$ is Boolean inequality.

$x \& y$, where x and y are numbers, is the bitwise AND of x and y .

$x | y$, where x and y are numbers, is the bitwise OR of x and y .

0x introduces a hexadecimal number. For example, 0x12 is 18 decimal.

$L(S, F, N)$ is bits F to $F+N-1$ of the bit string S starting from the left, using the IEEE 802.11 bit conventions from 9.2.2.

$\text{Truncate-}N(S)$ is bits 0 to $N-1$ of the bit string S starting from the left, using the IEEE 802.11 bit conventions from 9.2.2). Other bits are irretrievably deleted.

$\exp(x)$ is e to the power x , where e is the base of natural logarithms.

2. Normative references

The following referenced documents are indispensable for the application of this standard (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) at the time of publication of this standard applies.

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¹3GPP™ documents are available from the 3rd Generation Partnership Project Web site (<http://www.3gpp.org>).

²ETSI documents are available from the European Telecommunications Standards Institute (<http://www.etsi.org>).

³FIPS publications are available from the National Technical Information Service (NTIS) (<http://csrc.nist.gov>).

⁴The IEEE standards or products referred to in this clause are trademarks owned by The Institute of Electrical and Electronics Engineers, Inc.

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⁷ISO/IEC publications are available from the ISO Central Secretariat (<http://www.iso.ch/>). ISO/IEC publications are also available in the United States from the American National Standards Institute (<http://www ansi.org/>).

⁸See <http://www.currency-iso.org/en/home/tables/table-a1.html>

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3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this standard, the following terms and definitions apply. IEEE Standards Dictionary Online should be referenced for terms not defined in this clause.¹³

access control: The prevention of unauthorized usage of resources.

access point (AP): An entity that contains one station (STA) and provides access to the distribution services, via the wireless medium (WM) for associated STAs. An AP comprises a STA and a distribution system access function (DSAF).

access point (AP) reachability: An AP is reachable by a station (STA) if preauthentication messages can be exchanged between the STA and the target AP via the distribution system (DS).

NOTE—Preauthentication is defined in 12.6.10.2.¹⁴

additional authentication data (AAD): Data that are not encrypted, but are cryptographically protected.

admission control: An algorithm intended to prevent the violation of parameterized service commitments made by the network to admitted flows by controlling the admittance of a new flow into a resource constrained network.

aggregate medium access control (MAC) protocol data unit (A-MPDU): A structure that contains one or more MPDUs and is transported by a physical layer (PHY) as a single PHY service data unit (PSDU).

¹⁰ITU publications are available from the International Telecommunications Union (<http://www.itu.int/>).

¹¹NIST publications are available from the National Institute of Standards and Technology (<http://csrc.nist.gov/>).

¹²OMA publications are available from the Open Mobile Alliance (<http://openmobilealliance.org/>).

¹³IEEE Standards Dictionary Online is available at <http://ieeexplore.ieee.org/xpls/dictionary.jsp>.

¹⁴Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement the standard.