

ANSI/IEEE Std 802.11, 1999 Edition (R2003)

**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**

Sponsor

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ANSI/IEEE Std 802.11, 1999 Edition

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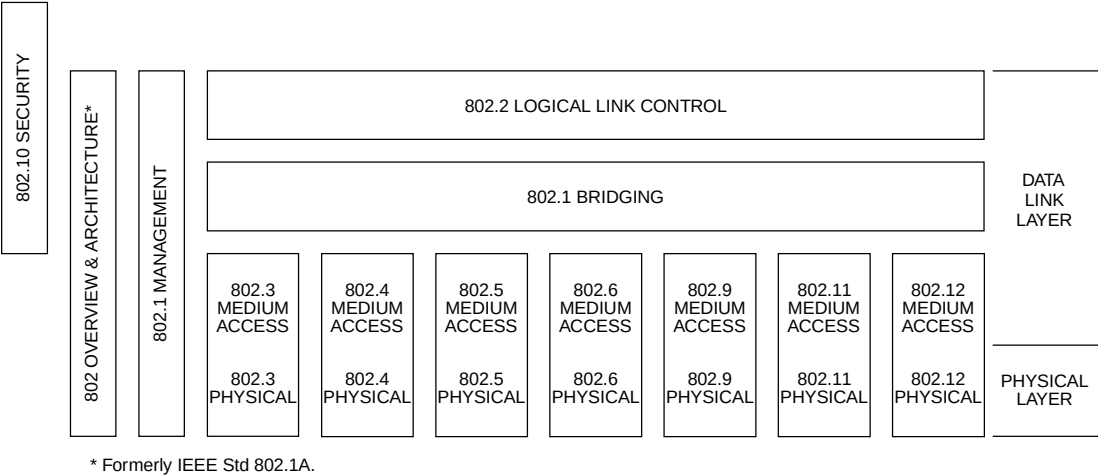
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Introduction to ANSI/IEEE Std 802.11, 1999 Edition

(This introduction is not a part of ANSI/IEEE Std 802.11, 1999 Edition or of ISO/IEC 8802-11: 1999, but is included for information purpose only.)

This standard is part of a family of standards for local and metropolitan area networks. The relationship between the standard and other members of the family is shown below. (The numbers in the figure refer to IEEE standard numbers.)



This family of standards deals with the Physical and Data Link layers as defined by the International Organization for Standardization (ISO) Open Systems Interconnection (OSI) Basic Reference Model (ISO/IEC 7498-1: 1994). The access standards define seven types of medium access technologies and associated physical media, each appropriate for particular applications or system objectives. Other types are under investigation.

The standards defining the access technologies are as follows:

- IEEE Std 802 *Overview and Architecture.* This standard provides an overview to the family of IEEE 802 Standards.
- ANSI/IEEE Std 802.1B and 802.1k [ISO/IEC 15802-2] *LAN/MAN Management.* Defines an OSI management-compatible architecture, and services and protocol elements for use in a LAN/MAN environment for performing remote management.
- ANSI/IEEE Std 802.1D [ISO/IEC 15802-3] *Media Access Control (MAC) Bridges.* Specifies an architecture and protocol for the interconnection of IEEE 802 LANs below the MAC service boundary.
- ANSI/IEEE Std 802.1E [ISO/IEC 15802-4] *System Load Protocol.* Specifies a set of services and protocol for those aspects of management concerned with the loading of systems on IEEE 802 LANs.
- IEEE Std 802.1F *Common Definitions and Procedures for IEEE 802 Management Information*
- ANSI/IEEE Std 802.1G [ISO/IEC 15802-5] *Remote Media Access Control (MAC) Bridging.* Specifies extensions for the interconnection, using non-LAN communication technologies, of geographically separated IEEE 802 LANs below the level of the logical link control protocol.
- ANSI/IEEE Std 802.2 [ISO/IEC 8802-2] *Logical Link Control*

- ANSI/IEEE Std 802.3 [ISO/IEC 8802-3] *CSMA/CD Access Method and Physical Layer Specifications*
- ANSI/IEEE Std 802.4 [ISO/IEC 8802-4] *Token Passing Bus Access Method and Physical Layer Specifications*
- ANSI/IEEE Std 802.5 [ISO/IEC 8802-5] *Token Ring Access Method and Physical Layer Specifications*
- ANSI/IEEE Std 802.6 [ISO/IEC 8802-6] *Distributed Queue Dual Bus Access Method and Physical Layer Specifications*
- ANSI/IEEE Std 802.9 [ISO/IEC 8802-9] *Integrated Services (IS) LAN Interface at the Medium Access Control (MAC) and Physical (PHY) Layers*
- ANSI/IEEE Std 802.10 *Interoperable LAN/MAN Security*
- IEEE Std 802.11 [ISO/IEC DIS 8802-11] *Wireless LAN Medium Access Control (MAC) and Physical Layer Specifications*
- ANSI/IEEE Std 802.12 [ISO/IEC DIS 8802-12] *Demand Priority Access Method, Physical Layer and Repeater Specifications*

In addition to the family of standards, the following is a recommended practice for a common Physical Layer technology:

- IEEE Std 802.7 *IEEE Recommended Practice for Broadband Local Area Networks*

The following additional working group has authorized standards projects under development:

- IEEE 802.14 *Standard Protocol for Cable-TV Based Broadband Communication Network*

Conformance test methodology

An additional standards series, identified by the number 1802, has been established to identify the conformance test methodology documents for the 802 family of standards. Thus the conformance test documents for 802.3 are numbered 1802.3.

ANSI/IEEE Std 802.11, 1999 Edition [ISO/IEC 8802-11: 1999]

This standard is a revision of IEEE Std 802.11-1997. The Management Information Base according to OSI rules has been removed, many redundant management items have been removed, and Annex D has been completed with the Management Information Base according to SNMP. Minor changes have been made throughout the document.

This standard defines the protocol and compatible interconnection of data communication equipment via the “air”, radio or infrared, in a local area network (LAN) using the carrier sense multiple access protocol with collision avoidance (CSMA/CA) medium sharing mechanism. The medium access control (MAC) supports operation under control of an access point as well as between independent stations. The protocol includes authentication, association, and reassociation services, an optional encryption/decryption procedure, power management to reduce power consumption in mobile stations, and a point coordination function for time-bounded transfer of data. The standard includes the definition of the management information base (MIB) using Abstract Syntax Notation 1 (ASN.1) and specifies the MAC protocol in a formal way, using the Speci-

The infrared implementation of the PHY supports 1 Mbit/s data rate with an optional 2 Mbit/s extension. The radio implementations of the PHY specify either a frequency-hopping spread spectrum (FHSS) supporting 1 Mbit/s and an optional 2 Mbit/s data rate or a direct sequence spread spectrum (DSSS) supporting both 1 and 2 Mbit/s data rates.

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**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 develop a medium access control (MAC) and physical layer (PHY) specification for wireless connectivity for fixed, portable, and moving stations within a local area.

1.2 Purpose

The purpose of this standard is to provide wireless connectivity to automatic machinery, equipment, or stations that require rapid deployment, which may be portable or hand-held, or which may be mounted on moving vehicles 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.

Specifically, this standard

- Describes the functions and services required by an IEEE 802.11 compliant device to operate within ad hoc and infrastructure networks as well as the aspects of station mobility (transition) within those networks.
- Defines the MAC procedures to support the asynchronous MAC service data unit (MSDU) delivery services.
- Defines several PHY signaling techniques and interface functions that are controlled by the IEEE 802.11 MAC.
- Permits the operation of an IEEE 802.11 conformant device within a wireless local area network (LAN) that may coexist with multiple overlapping IEEE 802.11 wireless LANs.
- Describes the requirements and procedures to provide privacy of user information being transferred over the wireless medium (WM) and authentication of IEEE 802.11 conformant devices.

2. Normative references

The following standards contain provisions which, through references in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below.

IEEE Std 802-1990, IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture.¹

IEEE Std C95.1-1991 (Reaff 1997), IEEE Standard Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

ISO/IEC 7498-1: 1994, Information technology—Open Systems Interconnection—Basic Reference Model: The Basic Model.²

ISO/IEC 8802-2: 1998, Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 2: Logical link control.

ISO/IEC 8824-1: 1995, Information technology—Abstract Syntax Notation One (ASN.1): Specification of basic notation.

ISO/IEC 8824-2: 1995, Information technology—Abstract Syntax Notation One (ASN.1): Information object specification.

ISO/IEC 8824-3: 1995, Information technology—Abstract Syntax Notation One (ASN.1): Constraint specification.

ISO/IEC 8824-4: 1995, Information technology—Abstract Syntax Notation One (ASN.1): Parameterization of ASN.1 specifications.

ISO/IEC 8825-1: 1995, Information technology—ASN.1 encoding rules: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER).

ISO/IEC 8825-2: 1996, Information technology—ASN.1 encoding rules: Specification of Packed Encoding Rules (PER).

ISO/IEC 15802-1: 1995, Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Common specifications—Part 1: Medium Access Control (MAC) service definition.

ITU Radio Regulations, volumes 1–4.³

ITU-T Recommendation X.210 (11/93), Information technology—Open systems interconnection—Basic Reference Model: Conventions for the definition of OSI services (*common text with ISO/IEC*).

ITU-T Recommendation Z.100 (03/93), CCITT specification and description language (SDL).

ITU-T Recommendation Z.105 (03/95), SDL combined with ASN.1 (SDL/ASN.1).

¹IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (<http://www.standards.ieee.org/>).

²ISO and ISO/IEC publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembe, CH-1211, Genève 20, Switzerland/Suisse (<http://www.iso.ch/>). They are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

³ITU-T publications are available from the International Telecommunications Union, Place des Nations, CH-1211, Geneva 20, Switzerland/Suisse (<http://www.itu.int/>). They are also available in the United States from the U.S. Department of Commerce, Technology Administration, National Technical Information Service (NTIS), Springfield, VA 22161, USA.

3. Definitions

3.1 access control: The prevention of unauthorized usage of resources.

3.2 access point (AP): Any entity that has station functionality and provides access to the distribution services, via the wireless medium (WM) for associated stations.

3.3 ad hoc network: A network composed solely of stations within mutual communication range of each other via the wireless medium (WM). An ad hoc network is typically created in a spontaneous manner. The principal distinguishing characteristic of an ad hoc network is its limited temporal and spatial extent. These limitations allow the act of creating and dissolving the ad hoc network to be sufficiently straightforward and convenient so as to be achievable by nontechnical users of the network facilities; i.e., no specialized “technical skills” are required and little or no investment of time or additional resources is required beyond the stations that are to participate in the ad hoc network. The term *ad hoc* is often used as slang to refer to an independent basic service set (IBSS).

3.4 association: The service used to establish access point/station (AP/STA) mapping and enable STA invocation of the distribution system services (DSSs).

3.5 authentication: The service used to establish the identity of one station as a member of the set of stations authorized to associate with another station.

3.6 basic service area (BSA): The conceptual area within which members of a basic service set (BSS) may communicate.

3.7 basic service set (BSS): A set of stations controlled by a single coordination function.

3.8 basic service set (BSS) basic rate set: The set of data transfer rates that all the stations in a BSS will be capable of using to receive frames from the wireless medium (WM). The BSS basic rate set data rates are preset for all stations in the BSS.

3.9 broadcast address: A unique multicast address that specifies all stations.

3.10 channel: An instance of medium use for the purpose of passing protocol data units (PDUs) that may be used simultaneously, in the same volume of space, with other instances of medium use (on other channels) by other instances of the same physical layer (PHY), with an acceptably low frame error ratio due to mutual interference. Some PHYs provide only one channel, whereas others provide multiple channels. Examples of channel types are as shown in the following table:

Single channel	n-channel
Narrowband radio-frequency (RF) channel	Frequency division multiplexed channels
Baseband infrared	Direct sequence spread spectrum (DSSS) with code division multiple access

3.11 clear channel assessment (CCA) function: That logical function in the physical layer (PHY) that determines the current state of use of the wireless medium (WM).

3.12 confidentiality: The property of information that is not made available or disclosed to unauthorized individuals, entities, or processes.

3.13 coordination function: The logical function that determines when a station operating within a basic service set (BSS) is permitted to transmit and may be able to receive protocol data units (PDUs) via the wireless medium (WM). The coordination function within a BSS may have one point coordination function (PCF) and will have one distributed coordination function (DCF).

3.14 coordination function pollable: A station able to (1) respond to a coordination function poll with a data frame, if such a frame is queued and able to be generated, and (2) interpret acknowledgments in frames sent to or from the point coordinator.

3.15 deauthentication: The service that voids an existing authentication relationship.

3.16 directed address: *See: unicast frame.*

3.17 disassociation: The service that removes an existing association.

3.18 distributed coordination function (DCF): A class of coordination function where the same coordination function logic is active in every station in the basic service set (BSS) whenever the network is in operation.

3.19 distribution: The service that, by using association information, delivers medium access control (MAC) service data units (MSDUs) within the distribution system (DS).

3.20 distribution system (DS): A system used to interconnect a set of basic service sets (BSSs) and integrated local area networks (LANs) to create an extended service set (ESS).

3.21 distribution system medium (DSM): The medium or set of media used by a distribution system (DS) for communications between access points (APs) and portals of an extended service set (ESS).

3.22 distribution system service (DSS): The set of services provided by the distribution system (DS) that enable the medium access control (MAC) to transport MAC service data units (MSDUs) between stations that are not in direct communication with each other over a single instance of the wireless medium (WM). These services include transport of MSDUs between the access points (APs) of basic service sets (BSSs) within an extended service set (ESS), transport of MSDUs between portals and BSSs within an ESS, and transport of MSDUs between stations in the same BSS in cases where the MSDU has a multicast or broadcast destination address or where the destination is an individual address, but the station sending the MSDU chooses to involve DSS. DSSs are provided between pairs of IEEE 802.11 MACs.

3.23 extended rate set (ERS): The set of data transfer rates supported by a station (if any) beyond the extended service set (ESS) basic rate set. This set may include data transfer rates that will be defined in future physical layer (PHY) standards.

3.24 extended service area (ESA): The conceptual area within which members of an extended service set (ESS) may communicate. An ESA is larger than or equal to a basic service area (BSA) and may involve several basic service sets (BSSs) in overlapping, disjointed, or both configurations.

3.25 extended service set (ESS): A set of one or more interconnected basic service sets (BSSs) and integrated local area networks (LANs) that appears as a single BSS to the logical link control layer at any station associated with one of those BSSs.

3.26 Gaussian frequency shift keying (GFSK): A modulation scheme in which the data is first filtered by a Gaussian filter in the baseband and then modulated with a simple frequency modulation.

3.27 independent basic service set (IBSS): A BSS that forms a self-contained network, and in which no access to a distribution system (DS) is available.

3.28 infrastructure: The infrastructure includes the distribution system medium (DSM), access point (AP), and portal entities. It is also the logical location of distribution and integration service functions of an extended service set (ESS). An infrastructure contains one or more APs and zero or more portals in addition to the distribution system (DS).

3.29 integration: The service that enables delivery of medium access control (MAC) service data units (MSDUs) between the distribution system (DS) and an existing, non-IEEE 802.11 local area network (via a portal).

3.30 medium access control (MAC) management protocol data unit (MMPDU): The unit of data exchanged between two peer MAC entities to implement the MAC management protocol.

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

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

3.33 minimally conformant network: An IEEE 802.11 network in which two stations in a single basic service area (BSA) are conformant with ISO/IEC 8802-11: 1999.

3.34 mobile station: A type of station that uses network communications while in motion.

3.35 multicast: A medium access control (MAC) address that has the group bit set. A multicast MAC service data unit (MSDU) is one with a multicast destination address. A multicast MAC protocol data unit (MPDU) or control frame is one with a multicast receiver address.

3.36 network allocation vector (NAV): An indicator, maintained by each station, of time periods when transmission onto the wireless medium (WM) will not be initiated by the station whether or not the station's clear channel assessment (CCA) function senses that the WM is busy.

3.37 point coordination function (PCF): A class of possible coordination functions in which the coordination function logic is active in only one station in a basic service set (BSS) at any given time that the network is in operation.

3.38 portable station: A type of station that may be moved from location to location, but that only uses network communications while at a fixed location.

3.39 portal: The logical point at which medium access control (MAC) service data units (MSDUs) from a non-IEEE 802.11 local area network (LAN) enter the distribution system (DS) of an extended service set (ESS).

3.40 privacy: The service used to prevent the content of messages from being read by other than the intended recipients.

3.41 reassociation: The service that enables an established association [between access point (AP) and station (STA)] to be transferred from one AP to another (or the same) AP.

3.42 station (STA): Any device that contains an IEEE 802.11 conformant medium access control (MAC) and physical layer (PHY) interface to the wireless medium (WM).

3.43 station basic rate: A data transfer rate belonging to the extended service set (ESS) basic rate set that is used by a station for specific transmissions. The station basic rate may change dynamically as frequently as

each medium access control (MAC) protocol data unit (MPDU) transmission attempt, based on local considerations at that station.

3.44 station service (SS): The set of services that support transport of medium access control (MAC) service data units (MSDUs) between stations within a basic service set (BSS).

3.45 time unit (TU): A measurement of time equal to 1024 μ s.

3.46 unauthorized disclosure: The process of making information available to unauthorized individuals, entities, or processes.

3.47 unauthorized resource use: Use of a resource not consistent with the defined security policy.

3.48 unicast frame: A frame that is addressed to a single recipient, not a broadcast or multicast frame. *Syn:* directed address.

3.49 wired equivalent privacy (WEP): The optional cryptographic confidentiality algorithm specified by IEEE 802.11 used to provide data confidentiality that is subjectively equivalent to the confidentiality of a wired local area network (LAN) medium that does not employ cryptographic techniques to enhance privacy.

3.50 wireless medium (WM): The medium used to implement the transfer of protocol data units (PDUs) between peer physical layer (PHY) entities of a wireless local area network (LAN).

4. Abbreviations and acronyms

ACK	acknowledgment
AID	association identifier
AP	access point
ATIM	announcement traffic indication message
BSA	basic service area
BSS	basic service set
BSSID	basic service set identification
CCA	clear channel assessment
CF	contention free
CFP	contention-free period
CID	connection identifier
CP	contention period
CRC	cyclic redundancy code
CS	carrier sense
CTS	clear to send
CW	contention window
DA	destination address
DBPSK	differential binary phase shift keying
DCE	data communication equipment
DCF	distributed coordination function
DCLA	direct current level adjustment
DIFS	distributed (coordination function) interframe space
DLL	data link layer
Dp	desensitization
DQPSK	differential quadrature phase shift keying
DS	distribution system
DSAP	destination service access point
DSM	distribution system medium

DSS	distribution system service
DSSS	direct sequence spread spectrum
DTIM	delivery traffic indication message
ED	energy detection
EIFS	extended interframe space
EIRP	equivalent isotropically radiated power
ERS	extended rate set
ESA	extended service area
ESS	extended service set
FC	frame control
FCS	frame check sequence
FER	frame error ratio
FH	frequency hopping
FHSS	frequency-hopping spread spectrum
FIFO	first in first out
GFSK	Gaussian frequency shift keying
IBSS	independent basic service set
ICV	integrity check value
IDU	interface data unit
IFS	interframe space
IMp	intermodulation protection
IR	infrared
ISM	industrial, scientific, and medical
IV	initialization vector
LAN	local area network
LLC	logical link control
LME	layer management entity
LRC	long retry count
lsb	least significant bit
MAC	medium access control
MDF	management-defined field
MIB	management information base
MLME	MAC sublayer management entity
MMPDU	MAC management protocol data unit
MPDU	MAC protocol data unit
msb	most significant bit
MSDU	MAC service data unit
N/A	not applicable
NAV	network allocation vector
PC	point coordinator
PCF	point coordination function
PDU	protocol data unit
PHY	physical (layer)
PHY-SAP	physical layer service access point
PIFS	point (coordination function) interframe space
PLCP	physical layer convergence protocol
PLME	physical layer management entity
PMD	physical medium dependent
PMD-SAP	physical medium dependent service access point
PN	pseudo-noise (code sequence)
PPDU	PLCP protocol data unit
ppm	parts per million
PPM	pulse position modulation
PRNG	pseudo-random number generator

PS	power save (mode)
PSDU	PLCP SDU
RA	receiver address
RF	radio frequency
RSSI	received signal strength indication
RTS	request to send
RX	receive or receiver
SA	source address
SAP	service access point
SDU	service data unit
SFD	start frame delimiter
SIFS	short interframe space
SLRC	station long retry count
SME	station management entity
SMT	station management
SQ	signal quality (PN code correlation strength)
SRC	short retry count
SS	station service
SSAP	source service access point
SSID	service set identifier
SSRC	station short retry count
STA	station
TA	transmitter address
TBTT	target beacon transmission time
TIM	traffic indication map
TSF	timing synchronization function
TU	time unit
TX	transmit or transmitter
TXE	transmit enable
UCT	unconditional transition
WAN	wide area network
WDM	wireless distribution media
WDS	wireless distribution system
WEP	wired equivalent privacy
WM	wireless medium

5. General description

5.1 General description of the architecture

This subclause presents the concepts and terminology used within the ISO/IEC 8802-11: 1999 document (referred to throughout the text as IEEE 802.11). Specific terms are defined in Clause 3. Illustrations convey key IEEE 802.11 concepts and the interrelationships of the architectural components. IEEE 802.11 uses an architecture to describe functional components of an IEEE 802.11 LAN. The architectural descriptions are not intended to represent any specific physical implementation of IEEE 802.11.

5.1.1 How wireless LAN systems are different

Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard.

5.1.1.1 Destination address does not equal destination location

In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.

5.1.1.2 The media impact the design

The physical layers used in IEEE 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs

- a) Use a medium that has neither absolute nor readily observable boundaries outside of which stations with conformant PHY transceivers are known to be unable to receive network frames.
- b) Are unprotected from outside signals.
- c) Communicate over a medium significantly less reliable than wired PHYs.
- d) Have dynamic topologies.
- e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other).
- f) Have time-varying and asymmetric propagation properties.

Because of limitations on wireless PHY ranges, wireless LANs intended to cover reasonable geographic distances may be built from basic coverage building blocks.

5.1.1.3 The impact of handling mobile stations

One of the requirements of IEEE 802.11 is to handle *mobile* as well as *portable* stations. A *portable* station is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* stations actually access the LAN while in motion.

For technical reasons, it is not sufficient to handle only portable stations. Propagation effects blur the distinction between portable and mobile stations; stationary stations often appear to be mobile due to propagation effects.

Another aspect of mobile stations is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a station's receiver will always be powered on.

5.1.1.4 Interaction with other IEEE 802 layers

IEEE 802.11 is required to appear to higher layers [logical link control (LLC)] as a current style IEEE 802 LAN. This requires that the IEEE 802.11 network handle station mobility within the MAC sublayer. To meet reliability assumptions (that LLC makes about lower layers), it is necessary for IEEE 802.11 to incorporate functionality that is untraditional for MAC sublayers.

5.2 Components of the IEEE 802.11 architecture

The IEEE 802.11 architecture consists of several components that interact to provide a wireless LAN that supports station mobility transparently to upper layers.

The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 1 shows two BSSs, each of which has two stations that are members of the BSS.

It is useful to think of the ovals used to depict a BSS as the coverage area within which the member stations of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) If a station moves out of its BSS, it can no longer directly communicate with other members of the BSS.

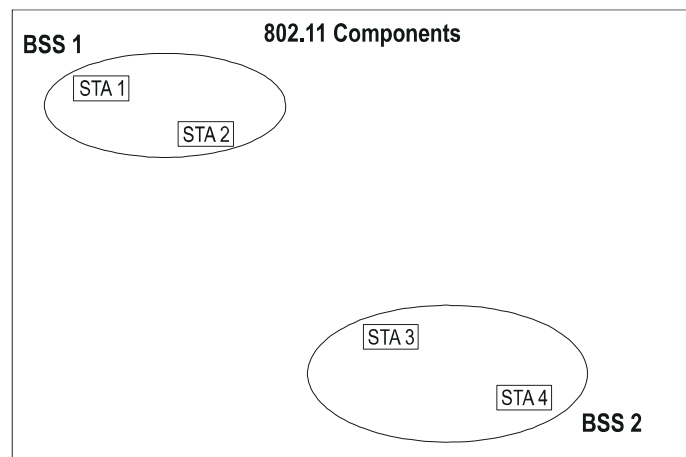


Figure 1—Basic service sets

5.2.1 The independent BSS as an ad hoc network

The independent BSS (IBSS) is the most basic type of IEEE 802.11 LAN. A minimum IEEE 802.11 LAN may consist of only two stations.

Figure 1 shows two IBSSs. This mode of operation is possible when IEEE 802.11 stations are able to communicate directly. Because this type of IEEE 802.11 LAN is often formed without pre-planning, for only as long as the LAN is needed, this type of operation is often referred to as an *ad hoc network*.

5.2.1.1 STA to BSS association is dynamic

The association between a STA and a BSS is dynamic (STAs turn on, turn off, come within range, and go out of range). To become a member of an infrastructure BSS, a station shall become “associated.” These associations are dynamic and involve the use of the distribution system service (DSS), which is described in 5.3.2.

5.2.2 Distribution system concepts

PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.

Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the *distribution system* (DS).

IEEE 802.11 logically separates the wireless medium (WM) from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.

Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.

The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.

An access point (AP) is a STA that provides access to the DS by providing DS services in addition to acting as a STA.

Figure 2 adds the DS and AP components to the IEEE 802.11 architecture picture.

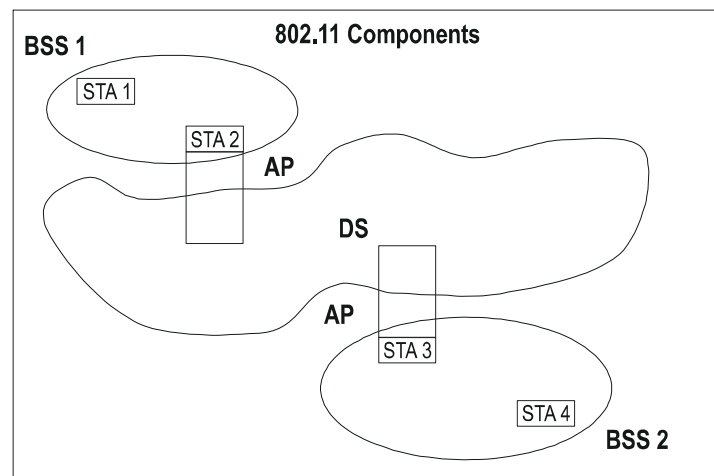


Figure 2—Distribution systems and access points

Data move between a BSS and the DS via an AP. Note that all APs are also STAs; thus they are addressable entities. The addresses used by an AP for communication on the WM and on the DSM are not necessarily the same.

5.2.2.1 Extended service set (ESS): The large coverage network

The DS and BSSs allow IEEE 802.11 to create a wireless network of arbitrary size and complexity. IEEE 802.11 refers to this type of network as the *extended service set* network.

The key concept is that the ESS network appears the same to an LLC layer as an IBSS network. Stations within an ESS may communicate and mobile stations may move from one BSS to another (within the same ESS) transparently to LLC.

Nothing is assumed by IEEE 802.11 about the relative physical locations of the BSSs in Figure 3.

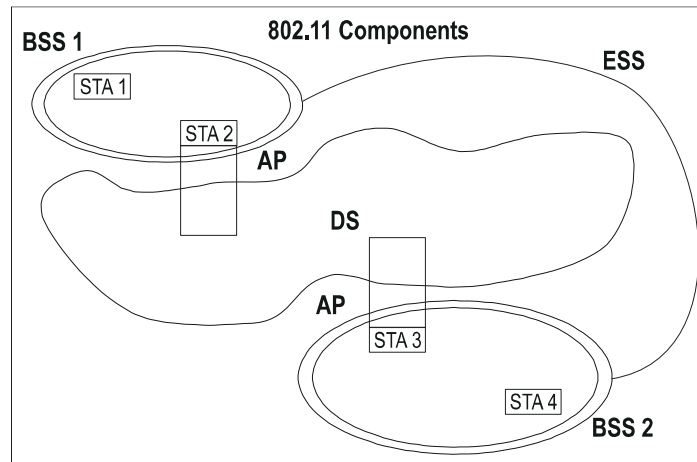


Figure 3—Extended service set

All of the following are possible:

- The BSSs may partially overlap. This is commonly used to arrange contiguous coverage within a physical volume.
- The BSSs could be physically disjointed. Logically there is no limit to the distance between BSSs.
- The BSSs may be physically collocated. This may be done to provide redundancy.
- One (or more) IBSS or ESS networks may be physically present in the same space as one (or more) ESS networks. This may arise for a number of reasons. Two of the most common are when an ad hoc network is operating in a location that also has an ESS network, and when physically overlapping IEEE 802.11 networks have been set up by different organizations.

5.2.3 Area concepts

For wireless PHYs, well-defined coverage areas simply do not exist. Propagation characteristics are dynamic and unpredictable. Small changes in position or direction may result in dramatic differences in signal strength. Similar effects occur whether a STA is stationary or mobile (as moving objects may impact station-to-station propagation).

Figure 4 shows a signal strength map for a simple square room with a standard metal desk and an open doorway. Figure 4 is a static snapshot; the propagation patterns change dynamically as stations and objects in the environment move. In Figure 4 the dark (solid) blocks in the lower left are a metal desk and there is a doorway at the top right of the figure. The figure indicates relative differences in field strength with different intensities and indicates the variability of field strength even in a static environment.

While the architecture diagrams show sharp boundaries for BSSs, this is an artifact of the pictorial representation, not a physical reality. Since dynamic three-dimensional field strength pictures are difficult to draw, well-defined shapes are used by IEEE 802.11 architectural diagrams to represent the coverage of a BSS.

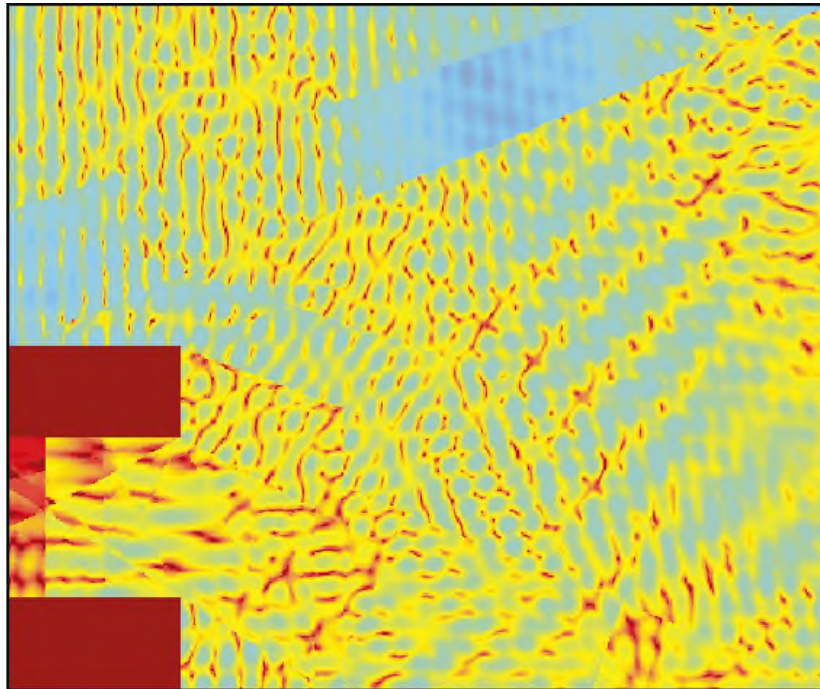


Figure 4—A representative signal intensity map

Further description difficulties arise when attempting to describe collocated coverage areas. Consider Figure 5, in which STA 6 could belong to BSS 2 or BSS 3.

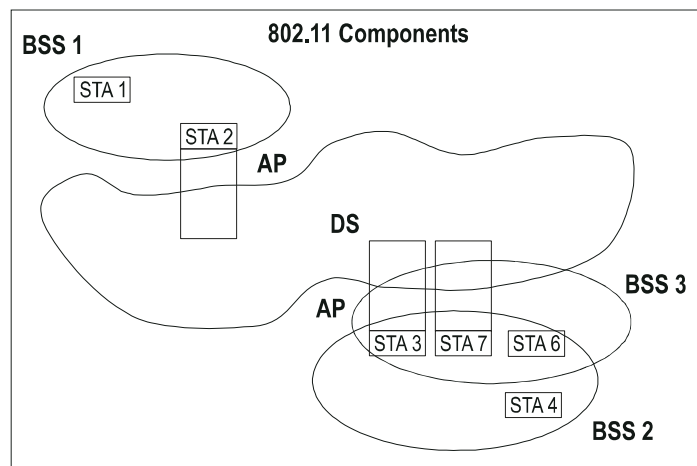


Figure 5—Collocated coverage areas

While the concept of sets of stations is correct, it is often convenient to talk about areas. For many topics the concept of area is sufficient. *Volume* is a more precise term than area, though still not technically correct. For historical reasons and convenience, this standard uses the common term *area*.

5.2.4 Integration with wired LANs

To integrate the IEEE 802.11 architecture with a traditional wired LAN, a final *logical* architectural component is introduced—a *portal*.

A portal is the logical point at which MSDUs from an integrated non-IEEE 802.11 LAN enter the IEEE 802.11 DS. For example, a portal is shown in Figure 6 connecting to a wired IEEE 802 LAN.

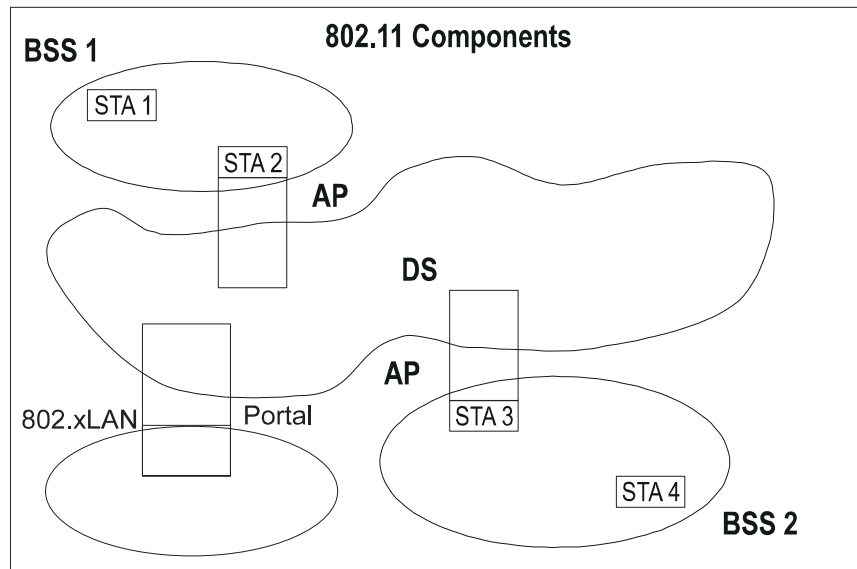


Figure 6—Connecting to other IEEE 802 LANs

All data from non-IEEE 802.11 LANs enter the IEEE 802.11 architecture via a portal. The portal provides logical integration between the IEEE 802.11 architecture and existing wired LANs. It is possible for one device to offer both the functions of an AP and a portal; this could be the case when a DS is implemented from IEEE 802 LAN components.

In IEEE 802.11, the ESS architecture (APs and the DS) provides traffic segmentation and range extension. Logical connections between IEEE 802.11 and other LANs are via the portal. Portals connect between the DSM and the LAN medium that is to be integrated.

5.3 Logical service interfaces

The IEEE 802.11 architecture allows for the possibility that the DS may not be identical to an existing wired LAN. A DS may be created from many different technologies including current IEEE 802 wired LANs. IEEE 802.11 does not constrain the DS to be either data link or network layer based. Nor does IEEE 802.11 constrain a DS to be either centralized or distributed in nature.

IEEE 802.11 explicitly does not specify the details of DS implementations. Instead, IEEE 802.11 specifies *services*. The services are associated with different components of the architecture. There are two categories of IEEE 802.11 service—the station service (SS) and the distribution system service (DSS). Both categories of service are used by the IEEE 802.11 MAC sublayer.

The complete set of IEEE 802.11 architectural services are as follows:

- a) Authentication
- b) Association
- c) Deauthentication
- d) Disassociation
- e) Distribution
- f) Integration
- g) Privacy
- h) Reassociation
- i) MSDU delivery

This set of services is divided into two groups: those that are part of every STA, and those that are part of a DS.

5.3.1 Station service (SS)

The service provided by stations is known as the *station service*.

The SS is present in every IEEE 802.11 station (including APs, as APs include station functionality). The SS is specified for use by MAC sublayer entities. All conformant stations provide SS.

The SS is as follows:

- a) Authentication
- b) Deauthentication
- c) Privacy
- d) MSDU delivery

5.3.2 Distribution system service (DSS)

The service provided by the DS is known as the *distribution system service*.

These services are represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the services are used to cross media and address space logical boundaries. This is the convenient place to show the services in the picture. The physical embodiment of various services may or may not be within a physical AP.

The DSSs are provided by the DS. They are accessed via a STA that also provides DSSs. A STA that is providing access to DSS is an AP.

The DSSs are as follows:

- a) Association
- b) Disassociation
- c) Distribution
- d) Integration
- e) Reassociation

DSSs are specified for use by MAC sublayer entities.

Figure 7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.

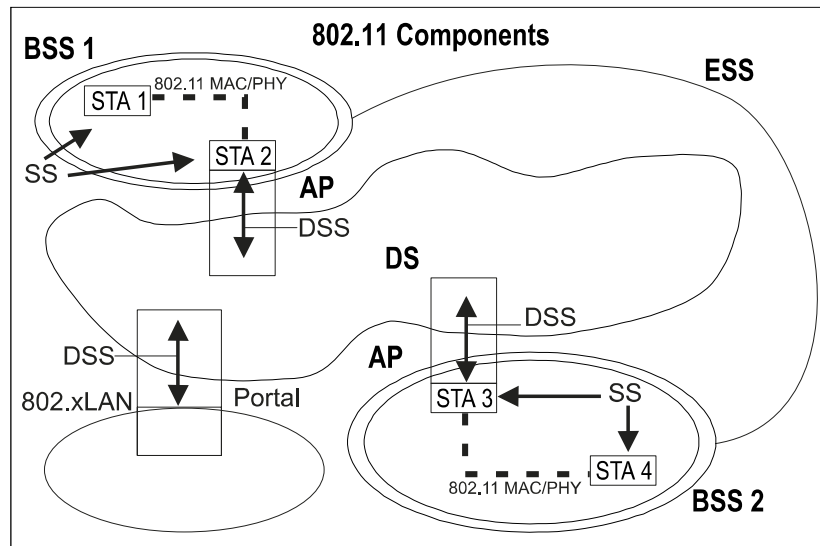


Figure 7—Complete IEEE 802.11 architecture

5.3.3 Multiple logical address spaces

Just as the IEEE 802.11 architecture allows for the possibility that the WM, DSM, and an integrated wired LAN may all be different physical media, it also allows for the possibility that each of these components may be operating within different address spaces. IEEE 802.11 only uses and specifies the use of the WM address space.

Each IEEE 802.11 PHY operates in a single medium—the WM. The IEEE 802.11 MAC operates in a single address space. MAC addresses are used on the WM in the IEEE 802.11 architecture. Therefore, it is unnecessary for the standard to explicitly specify that its addresses are “WM addresses.” This is assumed throughout this standard.

IEEE 802.11 has chosen to use the IEEE 802 48-bit address space (see 7.1.3.3.1). Thus IEEE 802.11 addresses are compatible with the address space used by the IEEE 802 LAN family.

The IEEE 802.11 choice of address space implies that for many instantiations of the IEEE 802.11 architecture, the wired LAN MAC address space and the IEEE 802.11 MAC address space may be the same. In those situations where a DS that uses MAC level IEEE 802 addressing is appropriate, all three of the logical address spaces used within a system could be identical. While this is a common case, it is not the only combination allowed by the architecture. The IEEE 802.11 architecture allows for all three logical address spaces to be distinct.

A multiple address space example is one in which the DS implementation uses network layer addressing. In this case, the WM address space and the DS address space would be different.

The ability of the architecture to handle multiple logical media and address spaces is key to the ability of IEEE 802.11 to be independent of the DS implementation and to interface cleanly with network layer mobility approaches. The implementation of the DS is unspecified and is beyond the scope of this standard.

5.4 Overview of the services

There are nine services specified by IEEE 802.11. Six of the services are used to support MSDU delivery between STAs. Three of the services are used to control IEEE 802.11 LAN access and confidentiality.

This subclause presents the services, an overview of how each service is used, and a description of how each service relates to other services and the IEEE 802.11 architecture. The services are presented in an order designed to help build an understanding of the operation of an IEEE 802.11 ESS network. As a result, the SSSs and DSSs are intermixed in order (rather than being grouped by category).

Each of the services is supported by one or more MAC frame types. Some of the services are supported by MAC management messages and some by MAC data messages. All of the messages gain access to the WM via the IEEE 802.11 MAC sublayer medium access method specified in Clause 9.

The IEEE 802.11 MAC sublayer uses three types of messages—*data*, *management*, and *control* (see Clause 7). The data messages are handled via the MAC data service path.

MAC management messages are used to support the IEEE 802.11 services and are handled via the MAC management service data path.

MAC control messages are used to support the delivery of IEEE 802.11 data and management messages.

The examples here assume an ESS network environment. The differences between the ESS and the IBSS network environments are discussed separately in 5.6.

5.4.1 Distribution of messages within a DS

5.4.1.1 Distribution

This is the primary service used by IEEE 802.11 STAs. It is conceptually invoked by every data message to or from an IEEE 802.11 STA operating in an ESS (when the frame is sent via the DS). Distribution is via a DSS.

Refer to the ESS network in Figure 7 and consider a data message being sent from STA 1 to STA 4. The message is sent from STA 1 and received by STA 2 (the “input” AP). The AP gives the message to the distribution service of the DS. It is the job of the distribution service to deliver the message within the DS in such a way that it arrives at the appropriate DS destination for the intended recipient. In this example, the message is distributed to STA 3 (the “output” AP) and STA 3 accesses the WM to send the message to STA 4 (the intended destination).

How the message is distributed within the DS is not specified by IEEE 802.11. All IEEE 802.11 is required to do is to provide the DS with enough information for the DS to be able to determine the “output” point that corresponds to the desired recipient. The necessary information is provided to the DS by the three association related services (association, reassociation, and disassociation).

The previous example was a case in which the AP that invoked the distribution service was different from the AP that received the distributed message. If the message had been intended for a station that was a member of the same BSS as the sending station, then the “input” and “output” APs for the message would have been the same.

In either example, the distribution service was logically invoked. Whether the message actually had to traverse the physical DSM or not is a DS implementation matter and is not specified by this standard.

While IEEE 802.11 does not specify DS implementations, it does recognize and support the use of the WM as the DSM. This is specifically supported by the IEEE 802.11 frame formats. (Refer to Clause 7 for details.)

5.4.1.2 Integration

If the distribution service determines that the intended recipient of a message is a member of an integrated LAN, the “output” point of the DS would be a portal instead of an AP.

Messages that are distributed to a portal cause the DS to invoke the Integration function (conceptually after the distribution service). The Integration function is responsible for accomplishing whatever is needed to deliver a message from the DSM to the integrated LAN media (including any required media or address space translations). Integration is a DSS.

Messages received from an integrated LAN (via a portal) by the DS for an IEEE 802.11 STA will invoke the Integration function before the message is distributed by the distribution service.

The details of an Integration function are dependent on a specific DS implementation and are outside the scope of this standard.

5.4.2 Services that support the distribution service

The primary purpose of a MAC sublayer is to transfer MSDUs between MAC sublayer entities. The information required for the distribution service to operate is provided by the association services. Before a data message can be handled by the distribution service, a STA shall be “associated.”

To understand the concept of association, it is necessary first to understand the concept of mobility.

5.4.2.1 Mobility types

The three transition types of significance to this standard that describe the mobility of stations within a network are as follows:

- a) **No-transition:** In this type, two subclasses that are usually indistinguishable are identified:
 - 1) Static—no motion.
 - 2) Local movement—movement within the PHY range of the communicating STAs [i.e., movement within a basic service area (BSA)].
- b) **BSS-transition:** This type is defined as a station movement from one BSS in one ESS to another BSS within the same ESS.
- c) **ESS-transition:** This type is defined as station movement from a BSS in one ESS to a BSS in a different ESS. This case is supported only in the sense that the STA may move. Maintenance of upper-layer connections cannot be guaranteed by IEEE 802.11; in fact, disruption of service is likely to occur.

The different association services support the different categories of mobility.

5.4.2.2 Association

To deliver a message within a DS, the distribution service needs to know which AP to access for the given IEEE 802.11 STA. This information is provided to the DS by the concept of association. Association is necessary, but not sufficient, to support BSS-transition mobility. Association is sufficient to support no-transition mobility. Association is a DSS.

Before a STA is allowed to send a data message via an AP, it shall first become associated with the AP. The act of becoming associated invokes the association service, which provides the STA to AP mapping to the

DS. The DS uses this information to accomplish its message distribution service. How the information provided by the association service is stored and managed within the DS is not specified by this standard.

At any given instant, a STA may be associated with no more than one AP. This ensures that the DS may determine a unique answer to the question, “Which AP is serving STA X?” Once an association is completed, a STA may make full use of a DS (via the AP) to communicate. Association is always initiated by the mobile STA, not the AP.

An AP may be associated with many STAs at one time.

A STA learns what APs are present and then requests to establish an association by invoking the association service. For details of how a station learns about what APs are present, see 11.1.3.

5.4.2.3 Reassociation

Association is sufficient for no-transition message delivery between IEEE 802.11 stations. Additional functionality is needed to support BSS-transition mobility. The additional required functionality is provided by the reassociation service. Reassociation is a DSS.

The reassociation service is invoked to “move” a current association from one AP to another. This keeps the DS informed of the current mapping between AP and STA as the station moves from BSS to BSS within an ESS. Reassociation also enables changing association attributes of an established association while the STA remains associated with the same AP. Reassociation is always initiated by the mobile STA.

5.4.2.4 Disassociation

The disassociation service is invoked whenever an existing association is to be terminated. Disassociation is a DSS.

In an ESS, this tells the DS to void existing association information. Attempts to send messages via the DS to a disassociated STA will be unsuccessful.

The disassociation service may be invoked by either party to an association (non-AP STA or AP). Disassociation is a notification, not a request. Disassociation cannot be refused by either party to the association.

APs may need to disassociate STAs to enable the AP to be removed from a network for service or for other reasons.

STAs shall attempt to disassociate whenever they leave a network. However, the MAC protocol does not depend on STAs invoking the disassociation service. (MAC management is designed to accommodate loss of an associated STA.)

5.4.3 Access and confidentiality control services

Two services are required for IEEE 802.11 to provide functionality equivalent to that which is inherent to wired LANs. The design of wired LANs assumes the physical attributes of wire. In particular, wired LAN design assumes the physically closed and controlled nature of wired media. The physically open medium nature of an IEEE 802.11 LAN violates those assumptions.

Two services are provided to bring the IEEE 802.11 functionality in line with wired LAN assumptions; authentication and privacy. Authentication is used instead of the wired media physical connection. Privacy is used to provide the confidential aspects of closed wired media.

5.4.3.1 Authentication

In wired LANs, physical security can be used to prevent unauthorized access. This is impractical in wireless LANs since they have a medium without precise bounds.

IEEE 802.11 provides the ability to control LAN access via the authentication service. This service is used by all stations to establish their identity to stations with which they will communicate. This is true for both ESS and IBSS networks. If a mutually acceptable level of authentication has not been established between two stations, an association shall not be established. Authentication is an SS.

IEEE 802.11 supports several authentication processes. The IEEE 802.11 authentication mechanism also allows expansion of the supported authentication schemes. IEEE 802.11 does not mandate the use of any particular authentication scheme.

IEEE 802.11 provides link-level authentication between IEEE 802.11 STAs. IEEE 802.11 does not provide either end-to-end (message origin to message destination) or user-to-user authentication. IEEE 802.11 authentication is used simply to bring the wireless link up to the assumed physical standards of a wired link. (This use of authentication is independent of any authentication process that may be used in higher levels of a network protocol stack.) If authentication other than that described here is desired, it is recommended that IEEE Std 802.10-1992 [B3]⁴ be implemented.

If desired, an IEEE 802.11 network may be operated using Open System authentication (see 8.1.1). This may violate implicit assumptions made by higher network layers. In an Open System, any station may become authenticated.

IEEE 802.11 also supports Shared Key authentication. Use of this authentication mechanism requires implementation of the wired equivalent privacy (WEP) option (see 8.2). In a Shared Key authentication system, identity is demonstrated by knowledge of a shared, secret, WEP encryption key.

Management information base (MIB) functions are provided to support the standardized authentication schemes.

IEEE 802.11 requires mutually acceptable, successful, authentication.

A STA may be authenticated with many other STAs at any given instant.

5.4.3.1.1 Preauthentication

Because the authentication process could be time-consuming (depending on the authentication protocol in use), the authentication service can be invoked independently of the association service.

Preauthentication is typically done by a STA while it is already associated with an AP (with which it previously authenticated). IEEE 802.11 does not require that STAs preauthenticate with APs. However, authentication is required before an association can be established.

If the authentication is left until reassociation time, this may impact the speed with which a STA can reassociate between APs, limiting BSS-transition mobility performance. The use of preauthentication takes the authentication service overhead out of the time-critical reassociation process.

⁴The numbers in brackets correspond to those of the bibliography in Annex E.

5.4.3.2 Deauthentication

The deauthentication service is invoked whenever an existing authentication is to be terminated. Deauthentication is an SS.

In an ESS, since authentication is a prerequisite for association, the act of deauthentication shall cause the station to be disassociated. The deauthentication service may be invoked by either authenticated party (non-AP STA or AP). Deauthentication is not a request; it is a notification. Deauthentication shall not be refused by either party. When an AP sends a deauthentication notice to an associated STA, the association shall also be terminated.

5.4.3.3 Privacy

In a wired LAN, only those stations physically connected to the wire may hear LAN traffic. With a wireless shared medium, this is not the case. Any IEEE 802.11-compliant STA may hear all like-PHY IEEE 802.11 traffic that is within range. Thus the connection of a single wireless link (without privacy) to an existing wired LAN may seriously degrade the security level of the wired LAN.

To bring the functionality of the wireless LAN up to the level implicit in wired LAN design, IEEE 802.11 provides the ability to encrypt the contents of messages. This functionality is provided by the privacy service. Privacy is an SS.

IEEE 802.11 specifies an optional privacy algorithm, WEP, that is designed to satisfy the goal of wired LAN “equivalent” privacy. The algorithm is not designed for ultimate security but rather to be “at least as secure as a wire.” See Clause 8 for more details.

IEEE 802.11 uses the WEP mechanism (see Clause 8) to perform the actual encryption of messages. MIB functions are provided to support WEP.

Note that privacy may only be invoked for data frames and some Authentication Management frames. All stations initially start “in the clear” in order to set up the authentication and privacy services.

The default privacy state for all IEEE 802.11 STAs is “in the clear.” If the privacy service is not invoked, all messages shall be sent unencrypted. If this default is not acceptable to one party or the other, data frames shall not be successfully communicated between the LLC entities. Unencrypted data frames received at a station configured for mandatory privacy, as well as encrypted data frames using a key not available at the receiving station, are discarded without an indication to LLC (or without indication to distribution services in the case of “To DS” frames received at an AP). These frames are acknowledged on the WM [if received without frame check sequence (FCS) error] to avoid wasting WM bandwidth on retries.

5.5 Relationships between services

A STA keeps two state variables for each STA with which direct communication via the WM is needed:

- *Authentication state*: The values are unauthenticated and authenticated.
- *Association state*: The values are unassociated and associated.

These two variables create three local states for each remote STA:

- *State 1*: Initial start state, unauthenticated, unassociated.
- *State 2*: Authenticated, not associated.
- *State 3*: Authenticated and associated.

The relationships between these station state variables and the services are given in Figure 8.

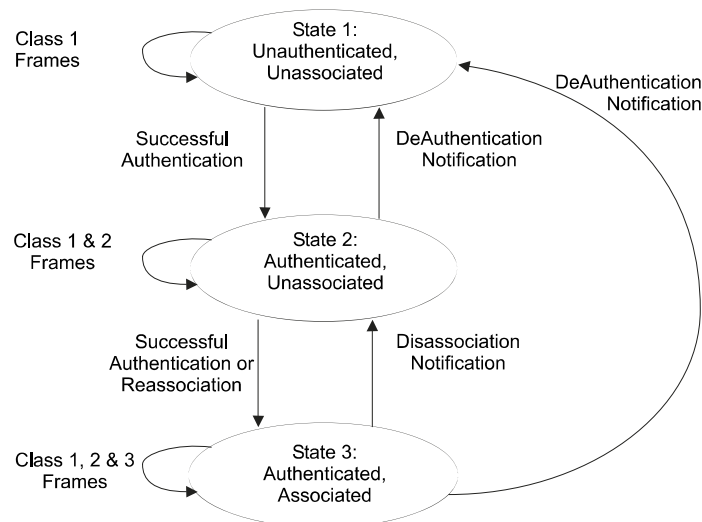


Figure 8—Relationship between state variables and services

The current state existing between the source and destination station determines the IEEE 802.11 frame types that may be exchanged between that pair of STAs (see Clause 7). The state of the sending STA given by Figure 8 is with respect to the intended receiving STA. The allowed frame types are grouped into classes and the classes correspond to the station state. In State 1, only Class 1 frames are allowed. In State 2, either Class 1 or Class 2 frames are allowed. In State 3, all frames are allowed (Classes 1, 2, and 3). The frame classes are defined as follows:

- a) Class 1 frames (permitted from within States 1, 2, and 3):
 - 1) Control frames
 - i) Request to send (RTS)
 - ii) Clear to send (CTS)
 - iii) Acknowledgment (ACK)
 - iv) Contention-Free (CF)-End+ACK
 - v) CF-End
 - 2) Management frames
 - i) Probe request/response
 - ii) Beacon
 - iii) Authentication: Successful authentication enables a station to exchange Class 2 frames. Unsuccessful authentication leaves the STA in State 1.
 - iv) Deauthentication: Deauthentication notification when in State 2 or State 3 changes the STA's state to State 1. The STA shall become authenticated again prior to sending Class 2 frames.
 - v) Announcement traffic indication message (ATIM)
 - 3) Data frames
 - i) Data: Data frames with frame control (FC) bits "To DS" and "From DS" both false.
- b) Class 2 frames (if and only if authenticated; allowed from within States 2 and 3 only):
 - 1) Management frames:
 - i) Association request/response
 - Successful association enables Class 3 frames.
 - Unsuccessful association leaves STA in State 2.
 - ii) Reassociation request/response
 - Successful reassociation enables Class 3 frames.

- Unsuccessful reassociation leaves the STA in State 2 (with respect to the STA that was sent the reassociation message). Reassociation frames shall only be sent if the sending STA is already associated in the same ESS.
- iii) Disassociation
 - Disassociation notification when in State 3 changes a Station's state to State 2. This station shall become associated again if it wishes to utilize the DS.

If STA A receives a Class 2 frame with a unicast address in the Address 1 field from STA B that is not authenticated with STA A, STA A shall send a deauthentication frame to STA B.

- c) Class 3 frames (if and only if associated; allowed only from within State 3):
 - 1) Data frames
 - Data subtypes: Data frames allowed. That is, either the "To DS" or "From DS" FC bits may be set to true to utilize DSSs.
 - 2) Management frames
 - Deauthentication: Deauthentication notification when in State 3 implies disassociation as well, changing the STA's state from 3 to 1. The station shall become authenticated again prior to another association.
 - 3) Control frames
 - PS-Poll

If STA A receives a Class 3 frame with a unicast address in the Address 1 field from STA B that is authenticated but not associated with STA A, STA A shall send a disassociation frame to STA B.

If STA A receives a Class 3 frame with a unicast address in the Address 1 field from STA B that is not authenticated with STA A, STA A shall send a deauthentication frame to STA B.

(The use of the word "receive" in this subclause refers to a frame that meets all of the filtering criteria specified in Clauses 8 and 9.)

5.6 Differences between ESS and IBSS LANs

In 5.2.1 the concept of the IBSS LAN was introduced. It was noted that an IBSS is often used to support an ad hoc network. In an IBSS network, a STA communicates directly with one or more other STAs.

Consider the full IEEE 802.11 architecture as shown in Figure 9.

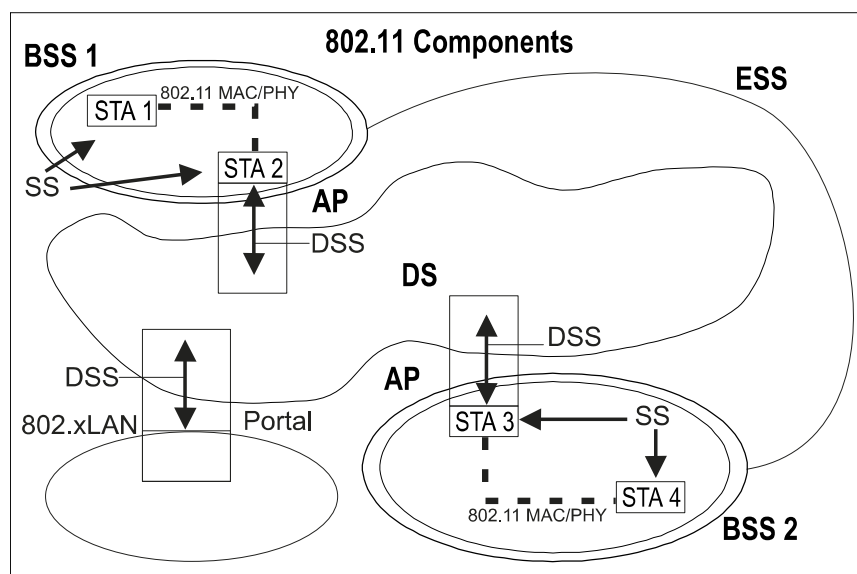


Figure 9—IEEE 802.11 architecture (again)

An IBSS consists of STAs that are directly connected. Thus there is (by definition) only one BSS. Further, since there is no physical DS, there cannot be a portal, an integrated wired LAN, or the DSSs. The logical picture reduces to Figure 10.

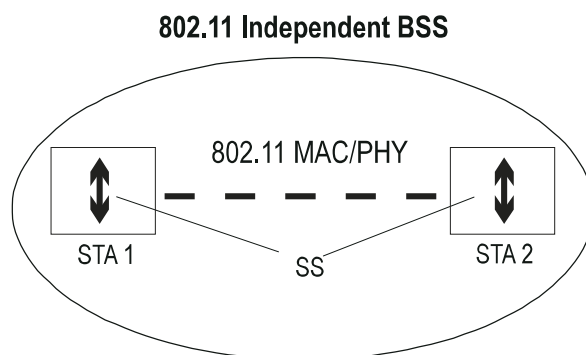


Figure 10—Logical architecture of an IBSS

Only the minimum two stations are shown in Figure 10. An IBSS may have an arbitrary number of members. In an IBSS, only Class 1 and Class 2 frames are allowed since there is no DS in an IBSS.

The services that apply to an IBSS are the SSs.

5.7 Message information contents that support the services

Each service is supported by one or more IEEE 802.11 messages. Information items are given by name; for corresponding values, see Clause 7.

5.7.1 Data

For a STA to send data to another STA, it sends a data message, as shown below:

Data messages

- Message type: Data
- Message subtype: Data
- Information items:
 - IEEE source address of message
 - IEEE destination address of message
 - BSS ID
- Direction of message: From STA to STA

5.7.2 Association

For a STA to associate, the association service causes the following messages to occur:

Association request

- Message type: Management
- Message subtype: Association request
- Information items:
 - IEEE address of the STA initiating the association
 - IEEE address of the AP with which the initiating station will associate
 - ESS ID
- Direction of message: From STA to AP

Association response

- Message type: Management
- Message subtype: Association response
- Information items:
 - Result of the requested association. This is an item with values “successful” and “unsuccessful.”
 - If the association is successful, the response shall include the association identifier (AID).
- Direction of message: From AP to STA

5.7.3 Reassociation

For a STA to reassociate, the reassociation service causes the following message to occur:

Reassociation request

- Message type: Management
- Message subtype: Reassociation request
- Information items:
 - IEEE address of the STA initiating the reassociation
 - IEEE address of the AP with which the initiating station will reassociate
 - IEEE address of the AP with which the initiating station is currently associated
 - ESS ID
- Direction of message:
 - From STA to AP (The AP with which the STA is requesting reassociation)

The address of the current AP is included for efficiency. The inclusion of the current AP address facilitates MAC reassociation to be independent of the DS implementation.

Reassociation response

- Message type: Management
- Message subtype: Reassociation response
- Information items:
 - Result of the requested reassociation. This is an item with values “successful” and “unsuccessful.”
 - If the reassociation is successful, the response shall include the AID.
- Direction of message: From AP to STA

5.7.4 Disassociation

For a STA to terminate an active association, the disassociation service causes the following message to occur:

Disassociation

- Message type: Management
- Message subtype: Disassociation
- Information items:
 - IEEE address of the station that is being disassociated. This shall be the broadcast address in the case of an AP disassociating with all associated stations.
 - IEEE address of the AP with which the station is currently associated.
- Direction of message: From STA to STA (e.g., STA to AP or AP to STA)

5.7.5 Privacy

For a STA to invoke the WEP privacy algorithm (as controlled by the related MIB attributes, see Clause 11), the privacy service causes MPDU encryption and sets the WEP frame header bit appropriately (see Clause 7).

5.7.6 Authentication

For a STA to authenticate with another STA, the authentication service causes one or more authentication management frames to be exchanged. The exact sequence of frames and their content is dependent on the authentication scheme invoked. For all authentication schemes, the authentication algorithm is identified within the management frame body.

In an IBSS environment, either station may be the initiating STA (STA 1). In an ESS environment, STA 1 is the mobile STA, and STA 2 is the AP.

Authentication (first frame of sequence)

- Message type: Management
- Message subtype: Authentication
- Information items:
 - Authentication algorithm identification
 - Station identity assertion
 - Authentication transaction sequence number
 - Authentication algorithm dependent information
- Direction of message: First frame in the transaction sequence is always from STA 1 to STA 2.

The first frame in an authentication sequence shall always be unencrypted.

Authentication (intermediate sequence frames)

- Message type: Management
- Message subtype: Authentication
- Information items:
 - Authentication algorithm identification
 - Authentication transaction sequence number
 - Authentication algorithm dependent information
- Direction of message:
 - Even transaction sequence numbers: From STA 2 to STA 1
 - Odd transaction sequence numbers: From STA 1 to STA 2

Authentication (final frame of sequence)

- Message type: Management
- Message subtype: Authentication
- Information items:
 - Authentication algorithm identification
 - Authentication transaction sequence number
 - Authentication algorithm dependent information
 - The result of the requested authentication. This is an item with values “successful” and “unsuccessful.”
- Direction of message: From STA 2 to STA 1

5.7.7 Deauthentication

For a STA to invalidate an active authentication, the following message is sent:

Deauthentication

- Message type: Management
- Message subtype: Deauthentication
- Information items:
 - IEEE address of the STA that is being deauthenticated
 - IEEE address of the STA with which the STA is currently authenticated
 - This shall be the broadcast address in the case of a STA deauthenticating all STAs currently authenticated.
- Direction of message: From STA to STA

5.8 Reference model

This standard presents the architectural view, emphasizing the separation of the system into two major parts: the MAC of the data link layer and the PHY. These layers are intended to correspond closely to the lowest

layers of the ISO/IEC basic reference model of Open Systems Interconnection (OSI) (ISO/IEC 7498-1: 1994⁵). The layers and sublayers described in this standard are shown in Figure 11.

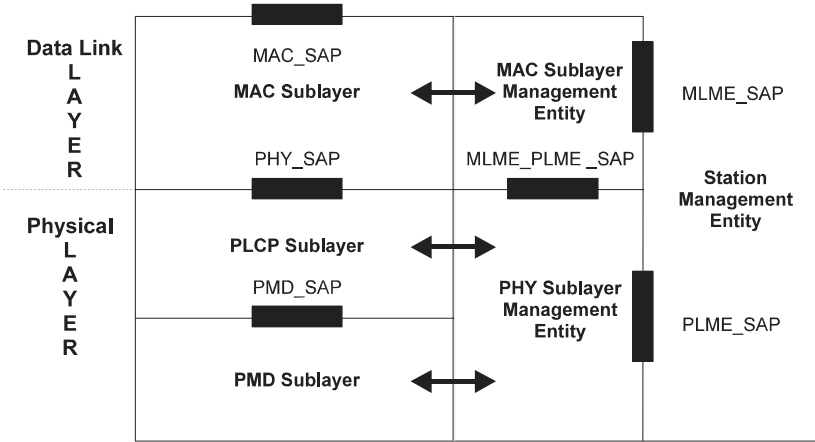


Figure 11—Portion of the ISO/IEC basic reference model covered in this standard

⁵Information on normative references can be found in Clause 2.

14. Frequency-Hopping spread spectrum (FHSS) PHY specification for the 2.4 GHz Industrial, Scientific, and Medical (ISM) band

14.1 Overview

14.1.1 Overview of FHSS PHY

The PHY services provided to the IEEE 802.11 wireless LAN MAC for the 2.4 GHz frequency-hopping spread spectrum (FHSS) system are described in this clause. The FHSS PHY consists of the following two protocol functions:

- a) A physical layer convergence function, which adapts the capabilities of the physical medium dependent (PMD) system to the PHY service. This function is supported by the physical layer convergence procedure (PLCP), which defines a method of mapping the IEEE 802.11 MAC sublayer protocol data units (MPDUs) into a framing format suitable for sending and receiving user data and management information between two or more STAs using the associated PMD system.
- b) A PMD system, whose function defines the characteristics of, and method of transmitting and receiving data through, a wireless medium (WM) between two or more STAs.

14.1.2 FHSS PHY functions

The 2.4 GHz FHSS PHY architecture is shown in Figure 11. The FHSS PHY contains three functional entities: the PMD function, the physical layer convergence function, and the physical layer management function. Each of these functions is described in detail in the following subclauses.

The FHSS PHY service is provided to the MAC entity at the STA through a PHY service access point (SAP) called the PHY-SAP, as shown in Figure 11. A set of primitives might also be defined that describe the interface between the physical layer convergence protocol sublayer and the PMD sublayer, called the PMD-SAP.

14.1.2.1 PLCP sublayer

To allow the IEEE 802.11 MAC to operate with minimum dependence on the PMD sublayer, a PHY convergence sublayer is defined. This function simplifies provision of a PHY service interface to the IEEE 802.11 MAC services.

14.1.2.2 Physical layer management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MAC management entity.

14.1.2.3 PMD sublayer

The PMD sublayer provides a transmission interface used to send and receive data between two or more STAs.

14.1.3 Service specification method and notation

The models represented by state diagrams in the following subclauses are intended as the primary specifications of the functions provided. It is important to distinguish, however, between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, while any realistic implementation may place heavier emphasis on efficiency and suitability to a particular implementation technology.

The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition of service is independent of any particular implementation.

14.2 FHSS PHY-specific service parameter lists

14.2.1 Overview

The architecture of the IEEE 802.11 MAC is intended to be PHY independent. Some PHY implementations require medium management state machines running in the MAC sublayer in order to meet certain PMD requirements. These PHY-dependent MAC state machines reside in a sublayer defined as the MAC sublayer management entity (MLME). The MLME in certain PMD implementations may need to interact with the physical layer management entity (PLME) as part of the normal PHY-SAP primitives. These interactions are defined by the PLME parameter list currently defined in the PHY Service Primitives as TXVECTOR and RXVECTOR. The list of these parameters and the values they may represent are defined in the specific PHY specifications for each PMD. This subclause addresses the TXVECTOR and RXVECTOR for the FHSS PHY.

All of the values included in the TXVECTOR or RXVECTOR described in this subclause are considered mandatory unless otherwise specified. The 1 Mbit/s and 2 Mbit/s data rates are the only rates currently supported. Other indicated data rates are for possible future use.

14.2.2 TXVECTOR parameters

The parameters in Table 28 are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request service primitive.

Table 28—TXVECTOR parameters

Parameter	Associate primitive	Value
LENGTH	PHY-TXSTART.request (TXVECTOR)	1–4095
DATARATE	PHY-TXSTART.request (TXVECTOR)	1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5

14.2.2.1 TXVECTOR LENGTH

The LENGTH parameter has the value of 1 to 4095. This parameter is used to indicate the number of octets in the MPDU that the MAC is currently requesting the PHY to transmit. This value is used by the PHY to determine the number of octet transfers that will occur between the MAC and the PHY after receiving a request to start a transmission.

14.2.2.2 TXVECTOR DATARATE

The DATARATE parameter describes the bit rate at which the PLCP should transmit the PSDU. Its value can be any of the rates as defined in Table 28, and supported by the conformant FH PHY.

14.2.3 RXVECTOR parameters

The parameters in Table 29 are defined as part of the RXVECTOR parameter list in the PHY-RXSTART.indicate service primitive.

Table 29—RXVECTOR parameters

Parameter	Associate primitive	Value
LENGTH	PHY-RXSTART.indicate (RXVECTOR)	1–4095
RSSI	PHY-RXSTART.indicate (RXVECTOR)	0–RSSI Max
DATARATE	PHY-RXSTART.request (RXVECTOR)	1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5

14.2.3.1 TRXVECTOR LENGTH

The LENGTH parameter has the value of 1 to 4095. This parameter is used to indicate the value contained in the LENGTH field that the PLCP has received in the PLCP Header. The MAC and PLCP will use this value to determine the number of octet transfers that will occur between the two sublayers during the transfer of the received PSDU.

14.2.3.2 RXVECTOR RSSI

The receive signal strength indicator (RSSI) is an optional parameter that has a value of 0 through RSSI Max. This parameter is a measure by the PHY sublayer of the energy observed at the antenna used to receive the current PPDU. RSSI shall be measured between the beginning of the start frame delimiter (SFD) and the end of the PLCP header error check (HEC). RSSI is intended to be used in a relative manner. Absolute accuracy of the RSSI reading is not specified.

14.3 FHSS PLCP sublayer

14.3.1 Overview

This subclause provides a convergence procedure to map MPDUs into a frame format designed for FHSS radio transceivers. The procedures for transmission, carrier sense, and reception are defined for single and multiple antenna diversity radios.

14.3.1.1 State diagram notation

The operation of the procedures can be described by state diagrams. Each diagram represents the domain and consists of a group of connected, mutually exclusive states. Only one state is active at any given time. Each state is represented by a rectangle as shown in Figure 69. These are divided into two parts by a horizontal line. In the upper part the state is identified by a name. The lower part contains the name of any signal that is generated. Actions described by short phrases are enclosed in brackets.

Each permissible transition between the states is represented graphically by an arrow from the initial to the terminal state. A transition that is global in nature (for example, an exit condition from all states to the IDLE or RESET state) is indicated by an open arrow. Labels on transitions are qualifiers that must be fulfilled before the transition will be taken. The label UCT designates an unconditional transition. Qualifiers described by short phrases are enclosed in parentheses.

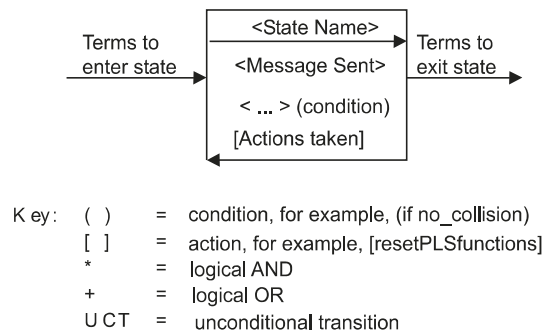


Figure 69—State diagram notation example

State transitions and sending and receiving of messages occur instantaneously. When a state is entered and the condition to leave that state is not immediately fulfilled, the state executes continuously, sending the messages and executing the actions contained in the state in a continuous manner.

Some devices described in this standard are allowed to have two or more ports. State diagrams capable of describing the operation of devices with an unspecified number of ports require qualifier notation that allows testing for conditions at multiple ports. The notation used is a term that includes a description in parentheses of which ports must meet the term for the qualifier to be satisfied (e.g., ANY and ALL). It is also necessary to provide for term-assignment statements that assign a name to a port that satisfies a qualifier. The following convention is used to describe a term-assignment statement that is associated with a transition:

- a) The character “:” (colon) is a delimiter used to denote that a term assignment statement follows.
- b) The character “<” (left arrow) denotes assignment of the value following the arrow to the term preceding the arrow.

The state diagrams contain the authoritative statement of the procedures they depict; when apparent conflicts between descriptive text and state diagrams arise, the state diagrams are to take precedence. This does not, however, override any explicit description in the text that has no parallel in the state diagrams.

The models presented by state diagrams are intended as the primary specifications to be provided. It is important to distinguish, however, between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, while any realistic implementation may place heavier emphasis on efficiency and suitability to a particular implementation technology. It is the functional behavior of any unit that must match the standard, not its internal structure. The internal details of the model are useful only to the extent that they specify the external behavior clearly and precisely.

14.3.2 PLCP frame format

The PLCP protocol data unit (PPDU) frame format provides for the asynchronous transfer of MAC sublayer MPDUs from any transmitting STA to all receiving STAs within the wireless LAN’s BSS. The PPDU illustrated in Figure 70 consists of three parts: a PLCP Preamble, a PLCP Header, and a PSDU. The PLCP Preamble provides a period of time for several receiver functions. These functions include antenna diversity, clock and data recovery, and field delineation of the PLCP Header and the PSDU. The PLCP Header is used to specify the length of the whitened PSDU field and support any PLCP management information. The PPDU contains the PLCP Preamble, the PLCP Header, and the PSDU modified by the PPDU data whitener.

PLCP Preamble		PLCP Header			Whitened PSDU
Sync	Start Frame Delimiter	PLW	PSF	Header Error Check	
80 bits	16 bits	12 bits	4 bits	16 bits	Variable number of octets

Figure 70—PLCP frame format

14.3.2.1 PLCP Preamble

The PLCP Preamble contains two separate subfields; the Preamble Synchronization (SYNC) field and the Start Frame Delimiter (SFD), to allow the PHY circuitry to reach steady-state demodulation and synchronization of bit clock and frame start.

14.3.2.1.1 Preamble SYNC field

The Preamble SYNC field is an 80-bit field containing an alternating zero-one pattern, transmitted starting with zero and ending with one, to be used by the PHY sublayer to detect a potentially receivable signal, select an antenna if diversity is utilized, and reach steady-state frequency offset correction and synchronization with the received packet timing.

14.3.2.1.2 Start Frame Delimiter (SFD)

The SFD consists of the 16-bit binary pattern 0000 1100 1011 1101 (transmitted leftmost bit first). The first bit of the SFD follows the last bit of the sync pattern. The SFD defines the frame timing.

14.3.2.2 PLCP Header field

The PLCP Header field contains three separate subfields: a 12-bit PSDU Length Word (PLW), a 4-bit PLCP Signaling field (PSF), and a 16-bit PLCP HEC field.

14.3.2.2.1 PSDU length word

The PSDU length word (PLW) is passed from the MAC as a parameter within the PHY-TXSTART.request primitive. The PLW specifies the number of octets contained in the PSDU. Its valid values are X'001'–X'FFF', representing counts of one to 4095 octets. The PLW is transmitted lsb first and msb last. The PLW is used by the receiving STA, in combination with the 32/33 coding algorithm specified in this clause, to determine the last bit in the packet.

14.3.2.2.2 PLCP Signaling field (PSF)

The 4-bit PSF is defined in Table 30. The PSF is transmitted bit 0 first and bit 3 last.

Table 30—PSF bit descriptions

Bit	Parameter name	Parameter values	Description																																				
0	Reserved	Default = 0	Reserved																																				
1:3	PLCP_BITRATE	<table> <tr> <td>b1</td><td>b2</td><td>b3</td><td>= Data Rate</td></tr> <tr> <td>0</td><td>0</td><td>0</td><td>= 1.0 Mbit/s,</td></tr> <tr> <td>0</td><td>0</td><td>1</td><td>= 1.5 Mbit/s,</td></tr> <tr> <td>0</td><td>1</td><td>0</td><td>= 2.0 Mbit/s,</td></tr> <tr> <td>0</td><td>1</td><td>1</td><td>= 2.5 Mbit/s,</td></tr> <tr> <td>1</td><td>0</td><td>0</td><td>= 3.0 Mbit/s,</td></tr> <tr> <td>1</td><td>0</td><td>1</td><td>= 3.5 Mbit/s,</td></tr> <tr> <td>1</td><td>1</td><td>0</td><td>= 4.0 Mbit/s,</td></tr> <tr> <td>1</td><td>1</td><td>1</td><td>= 4.5 Mbit/s</td></tr> </table>	b1	b2	b3	= Data Rate	0	0	0	= 1.0 Mbit/s,	0	0	1	= 1.5 Mbit/s,	0	1	0	= 2.0 Mbit/s,	0	1	1	= 2.5 Mbit/s,	1	0	0	= 3.0 Mbit/s,	1	0	1	= 3.5 Mbit/s,	1	1	0	= 4.0 Mbit/s,	1	1	1	= 4.5 Mbit/s	This field indicates the data rate of the whitened PSDU from 1 Mbit/s to 4.5 Mbit/s in 0.5 Mbit/s increments.
b1	b2	b3	= Data Rate																																				
0	0	0	= 1.0 Mbit/s,																																				
0	0	1	= 1.5 Mbit/s,																																				
0	1	0	= 2.0 Mbit/s,																																				
0	1	1	= 2.5 Mbit/s,																																				
1	0	0	= 3.0 Mbit/s,																																				
1	0	1	= 3.5 Mbit/s,																																				
1	1	0	= 4.0 Mbit/s,																																				
1	1	1	= 4.5 Mbit/s																																				

14.3.2.2.3 Header Error Check (HEC) field

The HEC field is a 16-bit CCITT CRC-16 error detection field. The HEC uses the CCITT CRC-16 generator polynomial $G(x)$ as follows:

$$G(x) = x^{16} + x^{12} + x^5 + 1$$

The HEC shall be the one's complement of the sum (modulo 2) of the following:

- The remainder of $x^k \times (x^{15} + x^{14} + \dots + x^2 + x^1 + 1)$ divided (modulo 2) by $G(x)$, where k is the number of bits in the PSF and PLW fields of the PLCP Header;
- The remainder after multiplication by x^{16} and then division (modulo 2) by $G(x)$ of the content (treated as a polynomial) of the PSF and PLW fields.

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

As a typical implementation, at the transmitter, the initial remainder of the division is preset to all ones and is then modified by division of the PSF and PLW fields by the generator polynomial, $G(x)$. The one's complement of this remainder is inserted in the HEC field with the msb transmitted first.

At the receiver, the initial remainder of the division is again preset to all ones. The division of the received PSF, PLW, and HEC fields by the generator polynomial, $G(x)$, results, in the absence of transmission errors, in a unique nonzero value, which is the following polynomial $R(x)$:

$$R(x) = x^{12} + x^{11} + x^{10} + x^8 + x^3 + x^2 + x^1 + 1$$

14.3.2.3 PLCP data whitener

The PLCP data whitener uses a length-127 frame-synchronous scrambler followed by a 32/33 bias-suppression encoding to randomize the data and to minimize the data dc bias and maximum run lengths. Data octets are placed in the transmit serial bit stream lsb first and msb last. The frame synchronous scrambler uses the generator polynomial $S(x)$ as follows:

$$S(x) = x^7 + x^4 + 1$$

and is illustrated in Figure 71. The 127-bit sequence generated repeatedly by the scrambler is (leftmost bit used first) 00001110 11110010 11001001 00000010 00100110 00101110 10110110 00001100 11010100 11100111 10110100 00101010 11111010 01010001 10111000 1111111. The same scrambler is used to scramble transmit data and to descramble receive data. The data whitening starts with the first bit of the PSDU, which follows the last bit of the PLCP Header. The specific bias suppression encoding and decoding method used is defined in Figure 75 and Figure 80. The format of the packet after data whitening is as shown in Figure 72.

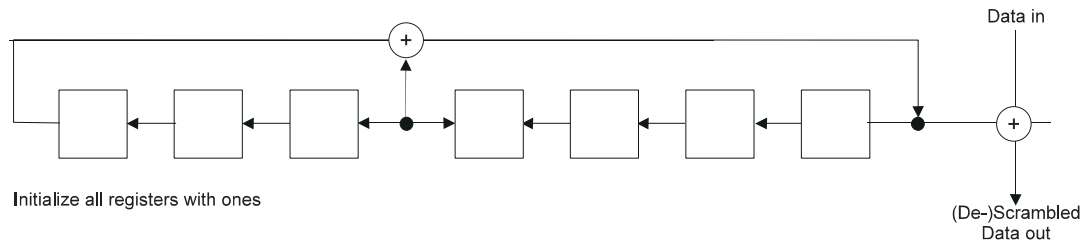


Figure 71—Frame synchronous scrambler/descrambler

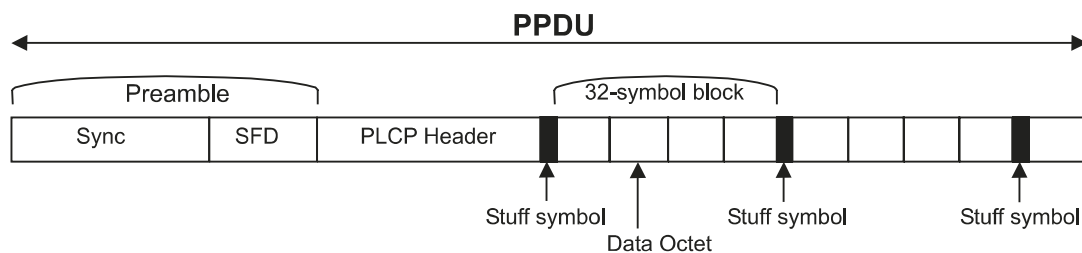


Figure 72—PLCP data whitener format

14.3.3 PLCP state machines

The PLCP consists of three state machines, as illustrated in the overview diagram of Figure 73: the transmit (TX), carrier sense/clear channel assessment (CS/CCA), and receive (RX) state machines. The three PLCP state machines are defined in the subclauses below; Figure 73 is not a state diagram itself. Execution of the PLCP state machines normally is initiated by the FH PLME state machine and begins at the CS/CCA state machine. The PLCP returns to the FH PLME state machine upon interrupt to service a PLME service request, such as PLME-SET, PLME-RESET, etc.

14.3.3.1 PLCP transmit procedure

The PLCP transmit procedure is invoked by the CS/CCA procedure immediately upon receiving a PHY-TXSTART.request(TXVECTOR) from the MAC sublayer. The CSMA/CA protocol is performed by the MAC with the PHY PLCP in the CS/CCA procedure prior to executing the transmit procedure.

14.3.3.1.1 Transmit state machine

The PLCP transmit state machine illustrated in Figure 74 includes functions that must be performed prior to, during, and after PPDU data transmission. Upon entering the transmit procedure in response to a PHY-TXSTART.request (TXVECTOR) from the MAC, the PLCP shall switch the PHY PMD circuitry from receive to transmit state; ramp on the transmit power amplifier in the manner prescribed in 14.6; and transmit the preamble sync pattern and SFD. The PLCP shall generate the PLCP Header as defined in 14.3.2.2 in

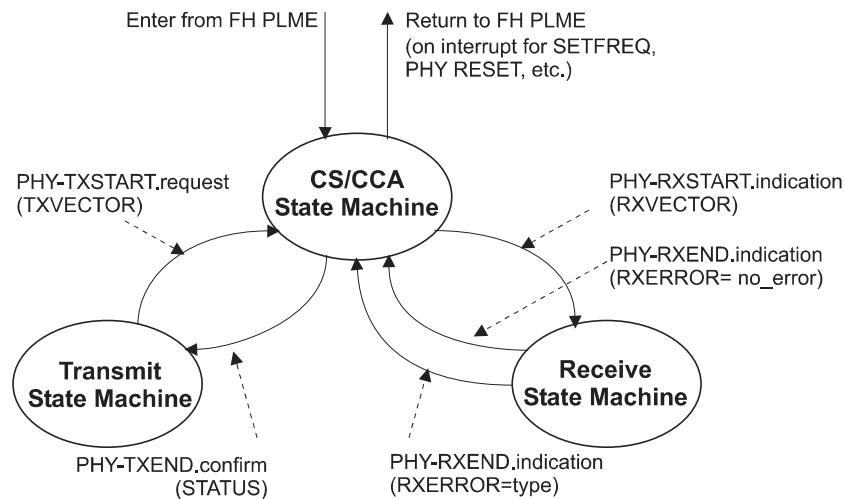


Figure 73—PLCP top-level state diagram

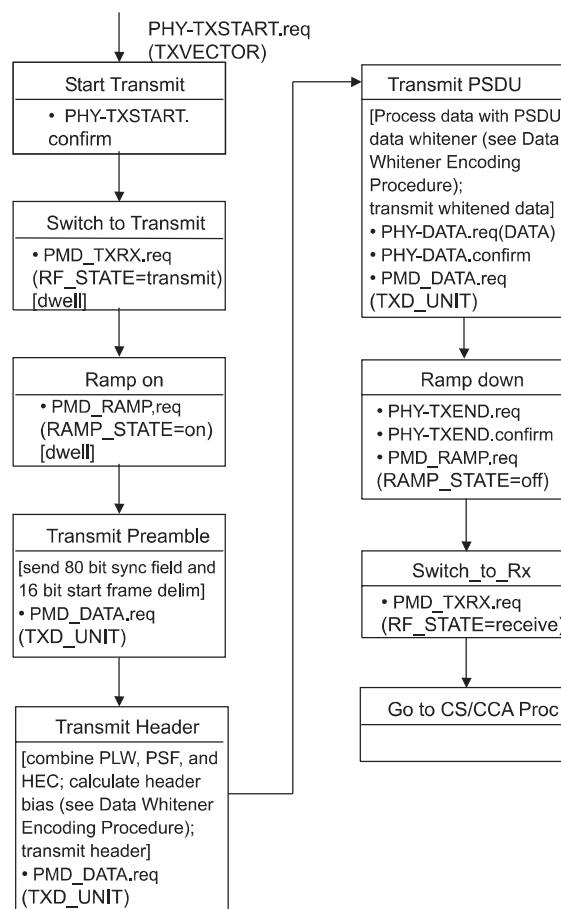


Figure 74—Transmit state machine

sufficient time to send the bits at their designated bit slot time. The PLCP shall add the PLCP Header to the start of the PSDU data.

Prior to transmitting the first PSDU data bit, the PLCP shall send a PHY-TXSTART.confirm message to the MAC indicating that the PLCP is ready to receive an MPDU data octet. The MAC will pass an MPDU data octet to the PHY with a PHY-DATA.request(DATA), which the PHY will respond to with a PHY-DATA.confirm. This sequence of PHY-DATA.request(DATA) and PHY-DATA.confirm shall be executed until the last data octet is passed to the PLCP. During transmission of the PSDU data, each bit of the PSDU shall be processed by the data whitener algorithm defined in Figure 75 and described in 14.3.2.3. Each PSDU data octet is processed and transmitted lsb first and msb last.

Data whitener encoding algorithm:

```

/*      If msb of stuff symbol = 1 then the next block is inverted; 0 = not inverted */
/*      Accumulate PLCP Header; begin stuffing on first bit of the PSDU */

/***** Calculate number of 32-symbol BSE blocks required to send PSDU;
        no padding is necessary when the number of symbols is not a multiple of 32 *****/
Input parameter: number_of_PSDU_octets, rate;          /* rate is 1 or 2 */
number_of_symbols = (number_of_PSDU_octets * 8) / rate;
number_of_blocks_in_packet = truncate((number_of_symbols + 31) / 32);

/***** Accumulate the bias in the header to use in calculating the inversion state of the first
        block of PSDU data *****/
Read in header {b(1),...,b(32)};          /* b(1) is first bit in */
header_bias = Sum{weight(b(1)),...,weight(b(32))};
/* calculate bias in header; weights are defined in Table 31 */
Transmit {b(1),...,b(32)};          /* no stuffing on header */
accum = header_bias;          /* initialize accum */
Initialize scrambler to all ones;

/***** Whiten the PSDU data with scrambler and BSE encoder *****/
For n = 1 to number_of_blocks_in_packet
{
    b(0) = 0 for 1 Mbit/s; b(0)=00 for 2 Mbit/s;          /* b(0) is the stuff symbol */
    N = min(32, number_of_symbols);          /* N= block size in symbols */
    Read in next symbol block {b(1),...,b(N)};          /* b(n) = {0,1} or {0,1,2,3};
    1 - 8 octets, use PHY-DATA.req(DATA), PHY-DATA.confirm for each octet */
    Scramble {b(1),...,b(N)};          /* see 14.3.2.3 */
    bias_next_block = Sum{weight(b(0)),...,weight(b(N))};          /* calculate bias with b(0)=0 */

    /**** if accum and bias of next block has the same sign, then invert block;
        if accum=0 or bias_next_block=0, don't invert ****/
    If {(accum * bias_next_block > 0)} then
    {
        Invert {b(0),...,b(N)};          /* Invert deviation, or, negate msb of symbol */
        bias_next_block = - bias_next_block;
    }

    accum = accum + bias_next_block;
    transmit {b(0),...,b(N)};          /* b(0) is first symbol out */
    number_of_symbols = number_of_symbols - N
}

```

Figure 75—Data whitener encoding procedure

After the last MPDU octet is passed to the PLCP, the MAC will indicate the end of the frame with a *PHY-TXEND.request*. After the last bit of the PSDU data has completed propagation through the radio and been transmitted on the air, the PLCP shall complete the transmit procedure by sending a *PHY-TXEND.confirm* to the MAC sublayer, ramp off the power amplifier in the manner prescribed in 14.6, and switch the PHY PMD circuitry from transmit to receive state. The execution shall then return to the CS/CCA procedure.

The weights assigned to each value of the symbols are defined in Table 31 for the 1 Mbit/s (2GFSK) and 2 Mbit/s (4GFSK) symbols.

Table 31—PLCP field bit descriptions

2GFSK	4GFSK	Weight
—	10	3
1	—	2
—	11	1
Center	Center	0
—	01	−1
0	—	−2
—	00	−3

14.3.3.1.2 Transmit state timing

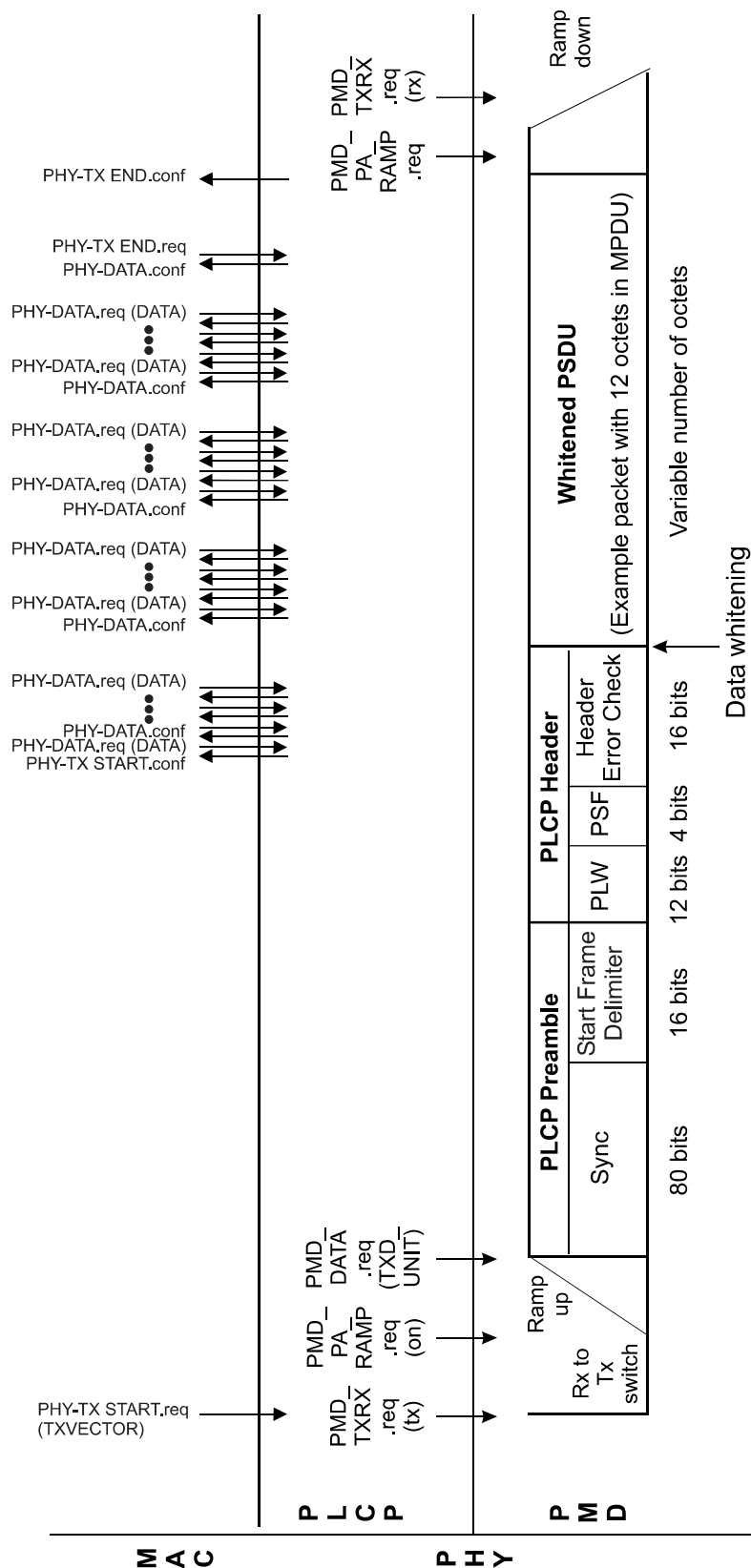
The transmit timing illustrated in Figure 76 is defined from the instant that the *PHY-TXSTART.request(TXVECTOR)* is received from the MAC sublayer. The PLCP shall switch the PMD circuitry from receive to transmit, turn on and settle the transmitter, and begin transmitting the first bit of the preamble at the antenna within a maximum of 20 μ s of receiving the *PHY-TXSTART.request(TXVECTOR)*. The PLCP Preamble shall be transmitted at 1 Mbit/s and be completed in 96 μ s. The PLCP Header shall be transmitted at 1 Mbit/s and be completed in 32 μ s. The variable length PSDU shall be transmitted at the selected data rate. After the last bit of the PSDU data has completed propagation through the radio and been transmitted on the air, the PLCP shall send the *PHY-TXEND.confirm* to the MAC sublayer. The PLCP shall turn off the transmitter, reducing the output energy to less than the specified off-mode transmit power within the time specified in 14.6. At the end of the power amplifier ramp down period, the PLCP shall switch the PMD circuitry from transmit to receive.

14.3.3.2 Carrier sense/clear channel assessment (CS/CCA) procedure

The PLCP CS/CCA procedure is executed while the receiver is turned on and the STA is not currently receiving or transmitting a packet. The CS/CCA procedure is used for two purposes: to detect the start of a network signal that can be received (CS) and to determine whether the channel is clear prior to transmitting a packet (CCA).

14.3.3.2.1 CS/CCA state machine

Timing for priority (PIFS, DIFS), contention backoff (slot times), and CS/CCA assessment windows is defined relative to the end of the last bit of the last packet on the air. The CS/CCA state machine is shown in Figure 77. The PLCP shall perform a CS/CCA assessment on a minimum of one antenna within a MAC contention back-off slot time of 50 μ s. The PLCP shall be capable of detecting within the slot time an FH PHY conformant signal that is received at the selected antenna up to 22 μ s after the start of the slot time with the synchronous detection performance specified in 14.6.15.3. Subclause 14.6.15.3 specifies detection performance with zero-one sync patterns and with random data patterns. If a start of a transmission is asynchronous with the BSS and arrives after the start of the slot but at least 16 μ s prior to the end of the slot, the PLCP shall indicate a busy channel prior to the end of the slot time with the asynchronous detection performance specified in 14.6.15.3.



The CCA indication immediately prior to transmission shall be performed on an antenna with essentially the same free space gain and gain pattern as the antenna to be used for transmission. The method of determining CS/CCA is unspecified except for the detection performance of a conformant method as specified in 14.6.15.3.

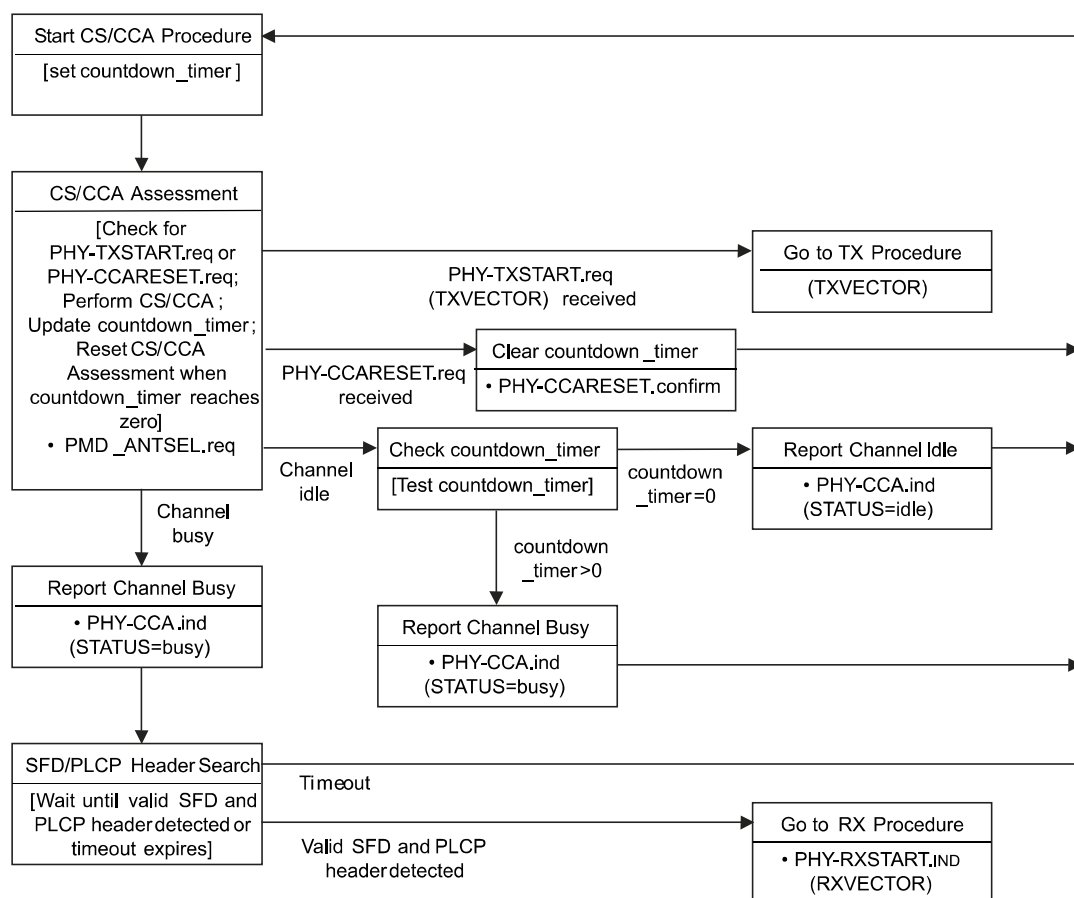


Figure 77—CS/CCA state machine

If a *PHY-TXSTART.request (TXVECTOR)* is received, the CS/CCA procedure shall exit to the transmit procedure within 1 μ s. If a *PHY-CCARESET.request* is received, the PLCP shall reset the CS/CCA state machine to the state appropriate for the end of a complete received frame. This service primitive is generated by the MAC at the end of a NAV period. The PHY shall indicate completion of the request by sending a *PHY-CCARESET.confirm* to the MAC.

If a CS/CCA assessment returns a channel idle result, the PHY shall send a *PHY-CCA.indicate(STATUS=idle)* to the MAC.

If a CS/CCA assessment returns a channel busy result, the PHY shall send a *PHY-CCA.indicate(STATUS=busy)* to the MAC. Upon a channel busy assessment, the PLCP shall stop any antenna switching prior to the earliest possible arrival time of the SFD and detect a valid SFD and PLCP Header if received. A valid PLCP Header is defined as containing valid PLCP Length Word and PHY Signaling field values and a valid HEC field. If a valid SFD/PLCP Header is detected, the CS/CCA procedure shall send a *PHY-RXSTART.indicate(RXVECTOR)* message to the MAC sublayer and exit to the receive procedure. The PLCP shall dwell and search for the SFD/PLCP Header for a minimum period longer than the latest possible arrival time of the SFD/PLCP Header. Indication of a busy channel does not necessarily lead to the successful reception of a frame.

The octet/bit count remaining may be a nonzero value when returning from the receive procedure if a signal in the process of being received was lost prior to the end as determined from the Length field of a valid PLCP Header. The countdown timer shall be set to the octet/bit count and used to force the CS/CCA indication to remain in the BUSY state until the predicted end of the frame regardless of actual CS/CCA indications.

However, if the CS/CCA procedure indicates the start of a new frame within the countdown timer period, it is possible to transition to the receive procedure prior to the end of the countdown timer period. If the PHY transitions to receive under these conditions, the countdown timer shall be reset to the longer of (1) the remaining time of the current frame or (2) the length of the new frame.

When a nonzero countdown timer reaches zero, the PLCP shall reset the CS/CCA state machine to the state appropriate for the end of a complete received frame and the CS/CCA indication shall reflect the state of the channel.

If the receive procedure encountered an unsupported rate error, the PLCP shall keep the CS/CCA state at Busy for the duration of the frame by setting the countdown timer to the value corresponding to the calculated time based on the information in the PLCP Header and the 33/32 expansion factor.

14.3.3.2.2 CS/CCA state timing

Timing for priority (PIFS, DIFS), contention backoff (slot times), and CS/CCA assessment windows is defined relative to the end of the last bit of the last packet on the air. The PLCP shall perform a CS/CCA assessment on a minimum of one antenna within a slot time. The appropriate CS/CCA indication shall be available prior to the end of each 50 μ s slot time with the performance specified in 14.6. See Figure 78.

If a STA has not successfully received the previous packet, the perceived packet end time and slot boundary times will have a higher uncertainty for that STA.

14.3.3.3 PLCP receive procedure

The PLCP receive procedure is invoked by the PLCP CS/CCA procedure upon detecting a portion of the preamble sync pattern followed by a valid SFD and PLCP Header.

14.3.3.3.1 Receive state machine

The PLCP receive procedure shown in Figure 79 includes functions that must be performed while the PPDU is being received. The PLCP receive procedure begins upon detection of a valid SFD and PLCP Header in the CS/CCA procedure. The PLCP shall set a PPDU octet/bit counter to indicate the last bit of the packet, receive the PPDU bits, and perform the data whitening decoding procedure shown in Figure 80 on each PPDU bit. The PLCP shall pass correctly received data octets to the MAC with a series of *PHY-DATA.indicate(DATA)*. After the last PPDU bit is received and the last octet is passed to the MAC, the PLCP shall send a *PHY-RXEND.indicate(RXERROR=no_error)* to the MAC sublayer. Upon error-free completion of a packet reception, the PLCP shall exit the receive procedure and return to the PLCP CS/CCA procedure with the octet/bit count set to 0.

If the PLCP Header was decoded without a CRC error but encountered an unsupported rate, then the PLCP shall immediately complete the receive procedure with a *PHY-RXEND.indicate(RXERROR=unsupported_rate)* to the MAC, and return to the CS/CCA procedure with the octet/bit count remaining and the data rate value contained in the PLCP Header.

If an error was detected during the reception of the PPDU, the PLCP shall immediately complete the receive procedure with a *PHY-RXEND.indicate(RXERROR=carrier_lost)* to the MAC, and return to the CS/CCA procedure with the octet/bit count remaining and the data rate value contained in the PLCP Header.

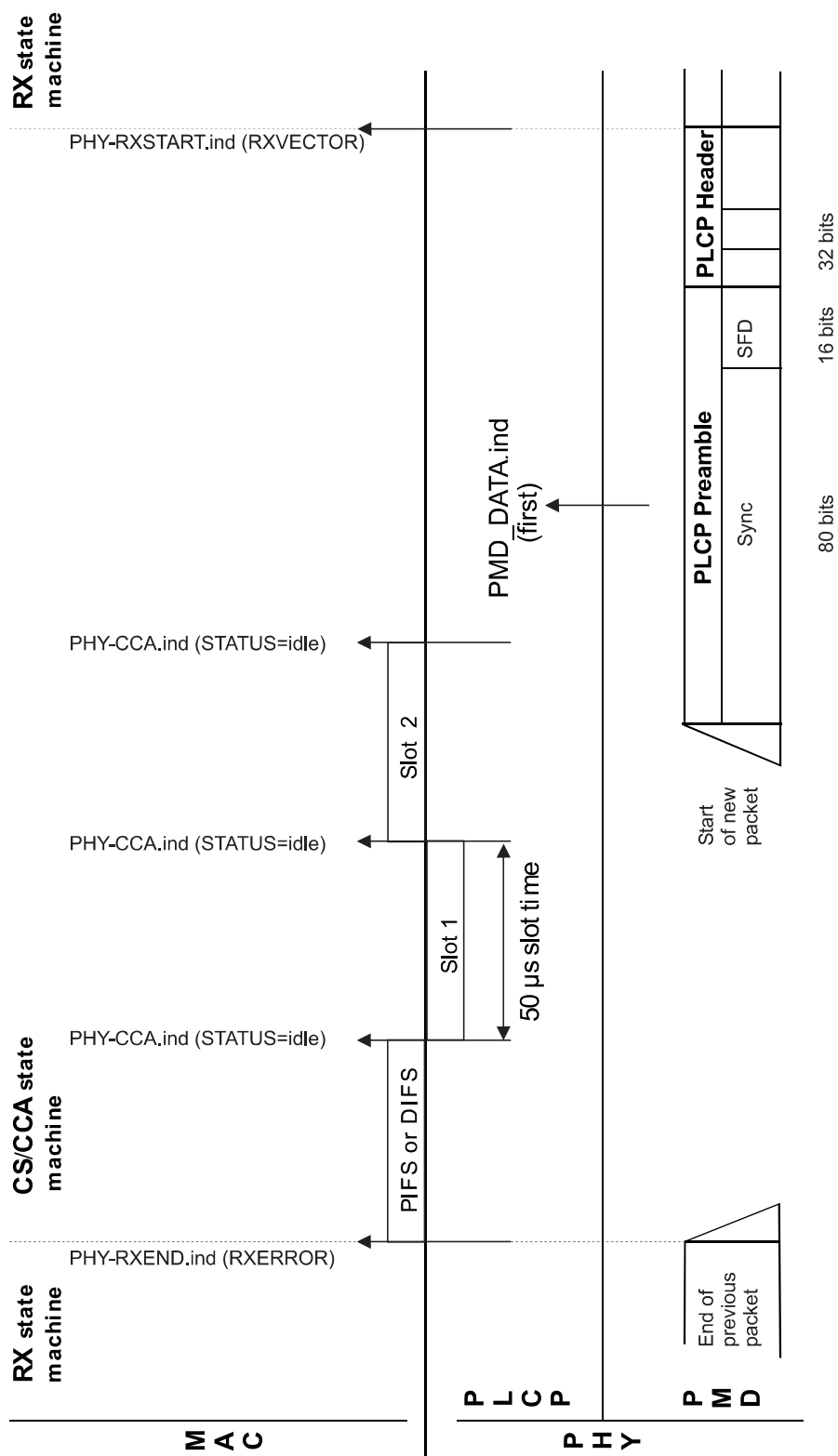


Figure 78—CS/CCA state timing

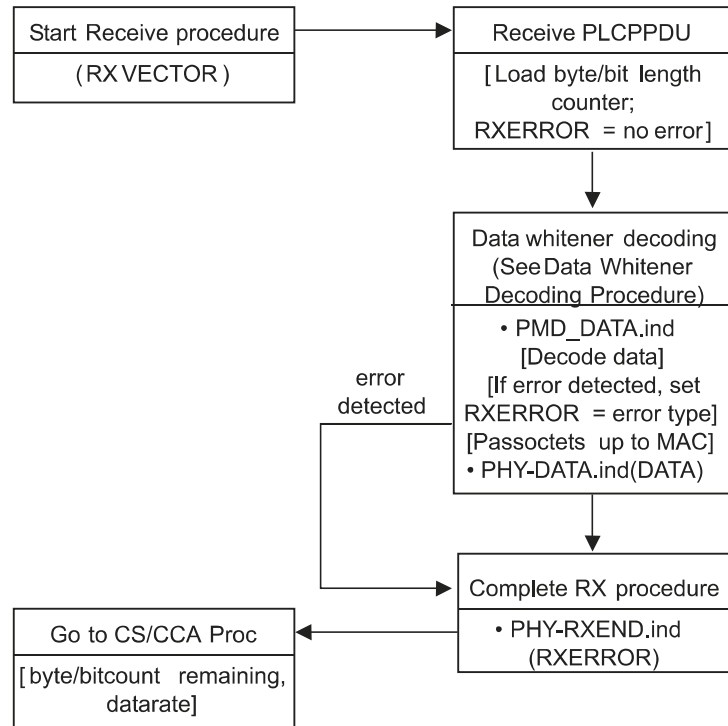


Figure 79—Receive state machine

Data whitener decoding algorithm:

```

/*      If msb of stuff symbol = 1 then the next block is inverted; 0 = not inverted */
/*      Stuffing begins on first symbol of PLCP Header following the SFD */
/*      Algorithm begins after verifying validity of header with HEC */

/***** Read header *****/
Read in header {b(1),...,b(32)};          /* b(1) is first bit in */

Get number_of_PSDU_octets, rate from header;          /* rate is 1 or 2 */
number_of_symbols = (number_of_PSDU_octets*8)/rate
number_of_blocks_in_packet = truncate((number_of_symbols + 31) / 32);
Initialize scrambler to all ones;

/***** De-whiten the PPDU data with BSE decoder and de-scrambler *****/
For n = 1 to number_of_blocks_in_packet
{
    N = min(32, # of symbols remaining);          /* N= block size in symbols */
    Read in next block {b(0),...,b(N)};          /* b(n) = {0,1} or {0,1,2,3} */

    If {[msb of b(0)=1] then Invert {b(1),...,b(N)};          /* if invert bit=true */
    Descramble {b(1),...,b(N)};          /* see 14.3.2.3 */
    Send {b(1),...,b(N)} to MAC          /* 1 - 8 octets; use PHY-DATA.ind(DATA) for each octet. */
}
  
```

Figure 80—Data whitener decoding procedure

14.3.3.3.2 Receive state timing

The receive state timing shown in Figure 81 is defined to begin upon detection of a valid SFD and PLCP Header in the CS/CCA procedure. The PLCP shall begin receiving the variable length whitened PSDU immediately after the end of the last bit of the PLCP Header. The PLCP shall send a *PHY-RXEND.indicate(RXERROR)* after receiving the last PPDU data bit.

If any error was detected during the reception of the PPDU, the PLCP may send a *PHY-RXEND.indicate(RXERROR)* and terminate the receive procedure before the last bit arrives.

14.4 PLME SAP layer management

14.4.1 Overview

This subclause describes the services provided by the FHSS PLME to the upper layer management entities. The PLME/PMD services are defined in terms of service primitives. These primitives are abstract representations of the services and are not intended to restrict implementations.

14.4.2 FH PHY specific MAC sublayer management entity (MLME) procedures

14.4.2.1 Overview

The specific MAC sublayer management entity (MLME) procedures required for operating the FHSS PHY are specified in this portion of the subclause. The relationship between the MLME and FH PLME procedures is also described.

14.4.2.2 FH synchronization

The MLME of a compliant FH PHY STA shall perform the FH time synchronization procedure as defined in 11.1.5. This procedure provides for synchronized frequency hopping for all compliant FH PHY STAs within a single BSS or ad hoc network. The FH PLME accepts *PLME-SET.request* commands from the MLME to change the tune frequency at the time determined by the MLME. The tune frequency is changed by updating any combination of the Set, Pattern, and Index PHY MIB parameters.

14.4.3 FH PHY layer management entity state machines

14.4.3.1 Overview

This portion of this subclause describes the FH PHY layer management state machines to turn the PMD on/off, reset the PLCP state machine, and change the frequency hop channel.

14.4.3.2 PLME state machine

The PLME state machine in Figure 82 begins with a *PLME-SET.request (dot11CurrentPowerState= ON)*, which turns on the PHY circuitry, resets the PLME and PLCP state machines, and sends a *PLME-SET.confirm*. The MAC then sends a series of three *PLME-SET.request* primitives to update the *dot11CurrentSet*, *dot11CurrentPattern*, and *dot11CurrentIndex* PHY MIB parameters, which together tune the PMD to the selected channel. The PLME then transfers execution to the PLCP state machine as defined in 14.3.3.

Upon receiving a PLME request from a higher-level LME, the PLCP shall return execution to the PLME state machine and process the request. A *PLME-RESET.request* shall cause a reset to the PLME and PLCP state machines. A *PLME-SET.request* updating the *dot11CurrentIndex* or a combination of the *dot11CurrentSet*, *dot11CurrentPattern*, and *dot11CurrentIndex* shall cause the PLCP to terminate a receive

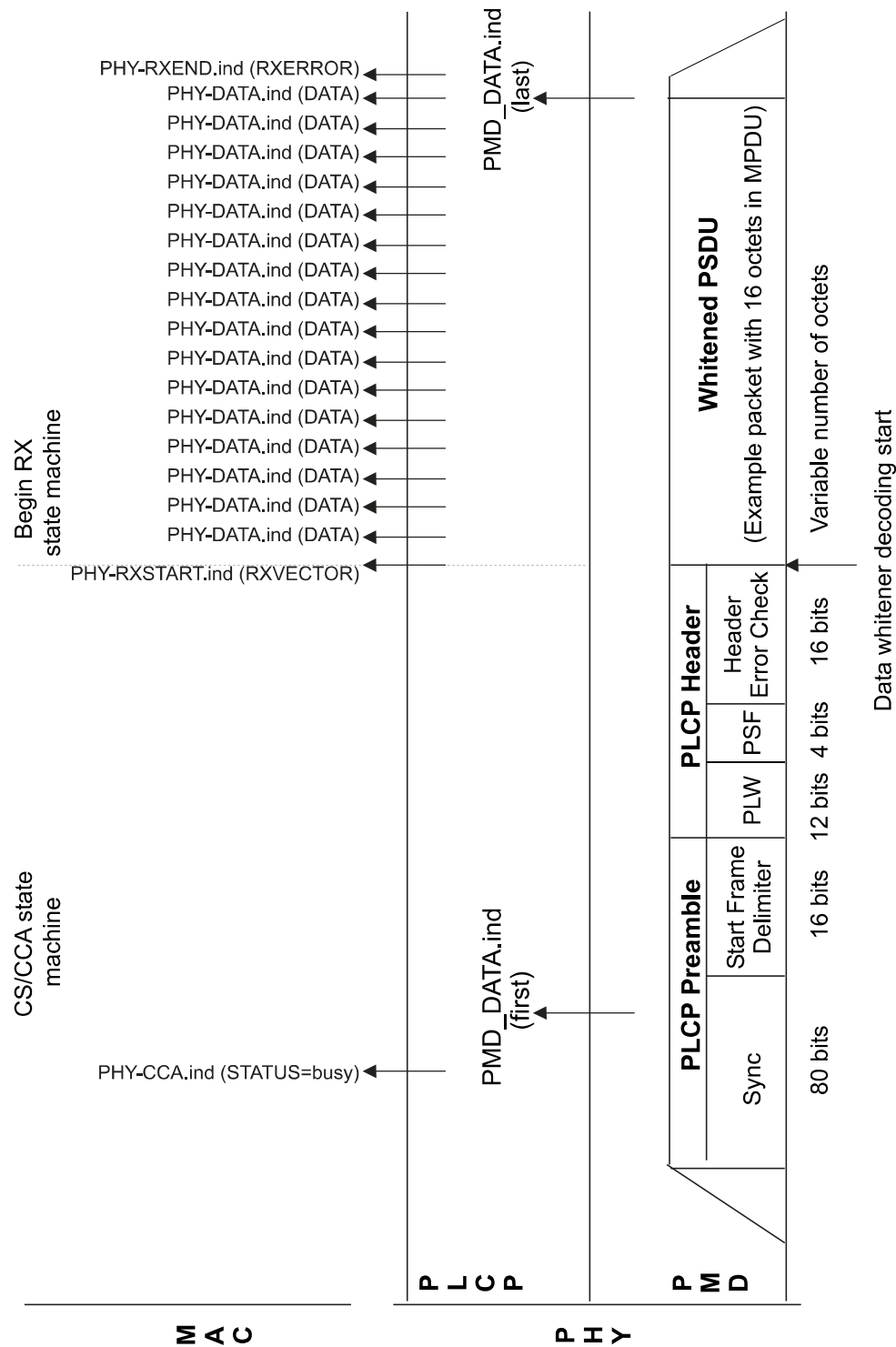


Figure 81—Receive timing

or CS/CCA process and change frequency before returning to the PLCP state machine. A *PLME-SET.request(dot11CurrentPowerState=OFF)* shall cause the PLCP to terminate a receive or CS/CCA process, power down the PMD circuitry, and return the PLME state machine to the idle state. *PLME-SET.requests* to any parameter other than the ones identified within this paragraph shall be executed and control shall be returned to the PLCP state machine. The MAC should not send a PLME request while the PLCP is in the transmit state.

All *PLME-GET.requests* shall be processed in parallel and with no interruption to the execution of any state machine in process.

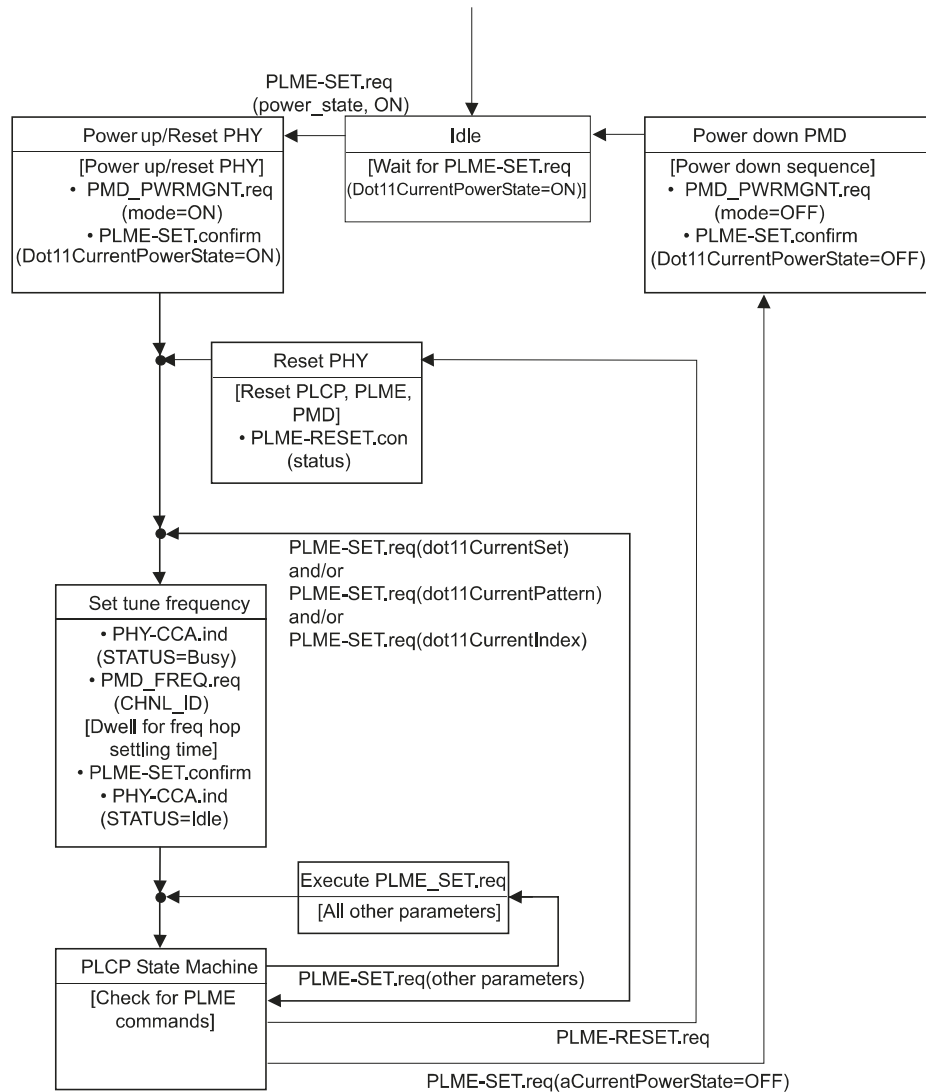


Figure 82—PLME state machine

14.4.3.3 PLME management primitives

The FH PLME uses the generic management primitives defined in 10.2 to manage all FH PHY parameters.

14.5 FHSS PMD sublayer services

14.5.1 Scope and field of application

The PMD services provided to the PLCP for the FHSS PHY are described in this subclause. Also defined in this subclause are the functional, electrical, and RF characteristics required for interoperability of implementations conforming to this specification. The relationship of this specification to the entire FHSS PHY is shown in Figure 83.

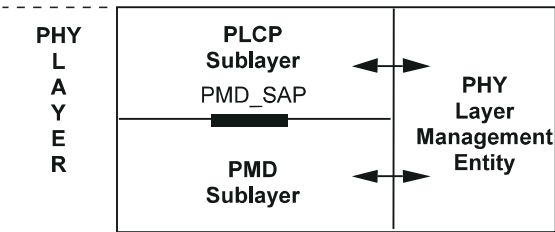


Figure 83—PMD layer reference model

14.5.2 Overview of services

In general, the FHSS PMD sublayer accepts PLCP sublayer service primitives and provides the actual means by which the signals required by these primitives are imposed onto the medium. In the FHSS PMD sublayer at the receiver the process is reversed. The combined function of the transmitting and receiving FHSS PMD sublayers results in a data stream, timing information, and receive parameter information being delivered to the receiving PLCP sublayer.

14.5.3 Overview of interactions

The primitives associated with the IEEE 802.11 PLCP sublayer to the FHSS PMD sublayer fall into the following two basic categories:

- a) Service primitives that support PLCP peer-to-peer interactions;
- b) Service primitives that have local significance and support sublayer-to-sublayer interactions.

14.5.4 Basic service and options

All of the service primitives described in this subclause are considered mandatory unless otherwise specified.

14.5.4.1 PMD_SAP peer-to-peer service primitives

Table 32 indicates the primitives for peer-to-peer interactions.

Table 32—PMD-SAP peer-to-peer service primitives

Primitive	Request	Indicate	Confirm	Response
PMD_DATA	X	X	—	—

14.5.4.2 PMD_SAP sublayer-to-sublayer service primitives

Table 33 indicates the primitives for sublayer-to-sublayer interactions.

Table 33—PMD_SAP sublayer-to-sublayer service primitives

Primitive	Request	Indicate	Confirm	Response
PMD_TXRX	X	—	—	—
PMD_PA_RAMP	X	—	—	—
PMD_ANTSEL	X	—	—	—
PMD_TXPWRLVL	X	—	—	—
PMD_FREQ	X	—	—	—
PMD_RSSI	—	X	—	—
PMD_PWRMGMT	X	—	—	—

14.5.4.3 PMD_SAP service primitives parameters

Table 34 shows the parameters used by one or more of the PMD_SAP service primitives.

Table 34—List of parameters for PMD primitives

Parameter	Associate primitive	Value
TXD_UNIT	PMD_DATA.request	1 Mbit/s: 0, 1 2 Mbit/s: 0, 1, 2, 3
RXD_UNIT	PMD_DATA.indicate	1 Mbit/s: 0, 1 2 Mbit/s: 0, 1, 2, 3
RF_STATE	PMD_TXRX.request	TRANSMIT, RECEIVE
RAMP_STATE	PMD_PA_RAMP.request	ON, OFF
ANTENNA_STATE	PMD_ANTSEL.request	1 to 255
TXPWR_LEVEL	PMD_TXPWRLVL.request	LEVEL1, LEVEL2, LEVEL3, LEVEL4
CHNL_ID	PMD_FREQ.request	2–80 inclusive
STRENGTH	PMD_RSSI.indicate	0 to RSSI Max
MODE	PMD_PWRMGMT.request	ON, OFF

14.5.5 PMD_SAP detailed service specification

This subclause describes the services provided by each PMD primitive.

14.5.5.1 PMD_DATA.request

14.5.5.1.1 Function

This primitive defines the transfer of data from the PLCP sublayer to the PMD entity.

14.5.5.1.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_DATA.request (TXD_UNIT)

The TXD_UNIT parameter can take on one of two values: one or zero. This parameter represents a single data bit. The effect of this parameter is that the PMD will properly modulate the medium to represent ones or zeros as defined in the FHSS PMD modulation specifications for a given data rate.

14.5.5.1.3 When generated

This primitive is generated by the PLCP sublayer to request the transmission of a single data bit on the PMD sublayer. The bit clock is assumed to be resident or part of the PLCP and this primitive is issued at every clock edge once the PLCP has begun transmitting data.

14.5.5.1.4 Effect of receipt

The receipt of this primitive will cause the PMD entity to encode and transmit a single data bit.

14.5.5.2 PMD_DATA.indicate

14.5.5.2.1 Function

This primitive defines the transfer of data from the PMD entity to the PLCP sublayer.

14.5.5.2.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_DATA.indicate (RXD_UNIT)

The RXD_UNIT parameter can take on one of two values: one or zero. This parameter represents the current state of the medium as determined by the FHSS PMD modulation specifications for a given data rate.

14.5.5.2.3 When generated

The PMD_DATA.indicate is generated to all receiving PLCP entities in the network after a PMD_DATA.request is issued.

14.5.5.2.4 Effect of receipt

The effect of receipt of this primitive by the PLCP is unspecified in this standard.

14.5.5.3 PMD_TXRX.request

14.5.5.3.1 Function

This primitive is used to place the PMD entity into the transmit or receive function.

14.5.5.3.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_TXRX.request (RF_STATE)

The RF_STATE parameter can take on one of two values: TRANSMIT or RECEIVE. When the value of the primitive is TRANSMIT, the RF state of the radio is transmit. If the value of the primitive is RECEIVE, the RF state of the radio is receive.

14.5.5.3.3 When generated

This primitive is generated whenever the mode of the radio needs to be set or when changing from transmit to receive or receive to transmit.

14.5.5.3.4 Effect of receipt

The receipt of this primitive by the PMD entity will cause the mode of the radio to be in either transmit or receive.

14.5.5.4 PMD_PA_RAMP.request

14.5.5.4.1 Function

This primitive defines the start of the ramp up or ramp down of the radio transmitter's power amplifier.

14.5.5.4.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_PA_RAMP.request (RAMP_STATE)

The RAMP_STATE parameter can take on one of two values: ON or OFF. When the value of the primitive is ON, the state of the transmit power amplifier is "on." If the value of the primitive is OFF, the state of the transmit power amplifier is "off."

14.5.5.4.3 When generated

This primitive is issued only during transmit and to establish the initial state. It is generated by the PLCP at the start of the transmit function to turn the transmitter's power amplifier "on." A power amplifier ramp-up period follows the change of state from "off" to "on." After the PLCP has transferred all required data to the PMD entity, this primitive again will be issued by the PLCP to place the transmit power amplifier back into the "off" state. A power amplifier ramp-down period follows the change of state from "on" to "off."

14.5.5.4.4 Effect of receipt

The receipt of this primitive by the PMD entity will cause the transmit power amplifier to turn on or off.

14.5.5.5 PMD_ANTSEL.request

14.5.5.5.1 Function

This primitive is used to select which antenna the PMD entity will use to transmit or receive data.

14.5.5.5.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_ANTSEL.request (ANTENNA_STATE)

The ANTENNA_STATE parameter can take on values from one to N (where N is the number of antennas supported). When the value of the primitive is a ONE, the PMD will switch to antenna 1 for receive or transmit; if the value of the primitive is TWO, the PMD entity will switch to antenna 2 for receive or transmit, etc.

14.5.5.5.3 When generated

This primitive is generated at various times by the PLCP entity to select an antenna. During receive, this primitive can be used to manage antenna diversity. During transmit, this primitive can be used to select a transmit antenna. This primitive will also be used during CCA.

14.5.5.5.4 Effect of receipt

The receipt of this primitive by the PMD entity will cause the radio to select the antenna specified.

14.5.5.6 PMD_TXPWRLVL.request

14.5.5.6.1 Function

This primitive defines the power level the PMD entity will use to transmit data.

14.5.5.6.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_TXPWRLVL.request (TXPOWER_LEVEL)

The TXPOWER_LEVEL parameter can be one of the values listed in Table 35.

Table 35—Transmit power levels

TXPWR_LEVEL	Level description
LEVEL1	Defined as TxPowerLevel1 in MIB
LEVEL2	Defined as TxPowerLevel2 in MIB
LEVEL3	Defined as TxPowerLevel3 in MIB
LEVEL4	Defined as TxPowerLevel4 in MIB
LEVEL5	Defined as TxPowerLevel5 in MIB
LEVEL6	Defined as TxPowerLevel6 in MIB
LEVEL7	Defined as TxPowerLevel7 in MIB
LEVEL8	Defined as TxPowerLevel8 in MIB

14.5.5.6.3 When generated

This primitive is generated as part of the transmit sequence.

14.5.5.6.4 Effect of receipt

The receipt of this primitive by the PMD entity will cause the transmit power level to be modify.

14.5.5.7 PMD_FREQ.request

14.5.5.7.1 Function

This primitive defines the frequency the PMD entity will use to receive or transmit data. Since changing the radio frequency is not an immediate function, this primitive serves also as an indication of the start of this process. The completion of this process is dictated by other PMD specifications.

14.5.5.7.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_FREQ.request (CHANNEL_ID)

The CHANNEL_ID parameter can be one of the values listed in Table 38, Table 39, Table 40, or Table 41.

14.5.5.7.3 When generated

This primitive is generated by the PLCP whenever a change to a new frequency is required.

14.5.5.7.4 Effect of receipt

The receipt of this primitive by the PMD entity will cause the radio to change to a new frequency defined by the value of the CHNL_ID.

14.5.5.8 PMD_RSSI.indicate

14.5.5.8.1 Function

This primitive transfers a receiver signal strength indication of the physical medium from the PMD sublayer to the PLCP sublayer. This value will be used by the PLCP to perform any diversity or clear channel assessment functions required by the PLCP or other sublayers.

14.5.5.8.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_RSSI.indicate (STRENGTH)

The STRENGTH parameter can be a value from 0 to 15. This parameter is an indication by the PMD sublayer of the magnitude of the energy observed at the selected antenna. This reported value is used to generate the RSSI term in the PHY-RXSTART.ind(RXVECTOR) primitive and might also be used by any diversity function. Since RSSI is only used in a relative manner by the MAC sublayer, this parameter is defined to have no more than 16 values, ranging from 0 through RSSI_Max. The value zero is the weakest signal strength, while RSSI_Max is the strongest signal strength.

14.5.5.8.3 When generated

This primitive is generated continually by the PMD entity to transfer a receive signal strength indication to the PLCP.

14.5.5.8.4 Effect of receipt

The effect of receipt of this primitive by the PLCP is unspecified in this standard.

14.5.5.9 PMD_PWRMGMT.request

14.5.5.9.1 Function

This primitive is used by the higher-layer entities to manage or control the power consumption of the PMD when not in use. This allows higher-layer entities to put the radio into a sleep or standby mode when receipt or sending of any data is not expected.

14.5.5.9.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_PWRMGMT.request (MODE)

The MODE parameter can have one of two values: ON or OFF. When the value of the parameter is ON, the PMD entity will enter into a fully functional mode that allows it to send or receive data. When the value of the parameter is OFF, the PMD entity will place itself in a standby or power-saving mode. In the low-power mode, the PMD entity is not expected to be able to perform any request by the PLCP, nor is it expected to indicate any change in PMD state or status.

14.5.5.9.3 When generated

This primitive is delivered by the PLCP but actually is generated by a higher-layer management entity.

14.5.5.9.4 Effect of receipt

Upon receipt of this primitive, the PMD entity will enter a fully functional or low power consumption state depending on the value of the primitive's parameter.

14.6 FHSS PMD sublayer, 1.0 Mbit/s

14.6.1 1 Mbit/s PMD operating specifications, general

In general, the PMD accepts convergence layer service primitives and provides the actual means by which the signals required by these primitives are imposed on the medium. In the PMD sublayer at the receiver, the process is reversed. The combined function of the transmitting and receiving PMD sublayers results in a data stream, timing information, and receive parameter information being delivered to the receiving convergence sublayer.

14.6.2 Regulatory requirements

Wireless LANs implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PMD specification establishes minimum technical requirements for interoperability, based upon established regulations for Europe, Japan, and North America at the time this standard was issued. These regulations are subject to revision, or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PMD specification. Regulatory requirements that do not affect interoperability are not addressed within this standard. Implementors are referred to the following regulatory sources for further information.

Operation in countries within Europe, or other regions outside Japan or North America, may be subject to additional or alternative national regulations.

The documents listed below specify the current regulatory requirements for various geographic areas at the time this standard was developed. They are provided for information only, and are subject to change or revision at any time.

Geographic area	Approval standards	Documents	Approval authority
Europe	European Telecommunications Standards Institute (ETSI)	ETS 300-328, ETS 300-339	National type approval authorities
France	Règle technique applicable aux équipements radioélectriques de transmission de données à large bande fonctionnant dans la bande de fréquences à 2,4 GHz et utilisant la technique de l'étalement de spectre (Édition février 1995)	SP/DGPT/ATAS/23, ETS 300-328, ETS 300-339	Direction Générale des Postes et Télécommunications (DGPT)
Japan	Association of Radio Industries and Businesses (ARIB)	RCR STD-33A	Ministry of Telecommunications (MKK)
North America Canada USA	Industry Canada (IC) Federal Communications Commission (FCC)	GL36 CFR47, Part 15, Sections 15.205, 15.209, 15.247	IC FCC
Spain	Suplemento Del Numero 164 Del Boletín Oficial Del Estado (Published 10 July 1991, Revised 25 June 1993)	ETS 300-328, ETS 300-339	Cuadro Nacional De Atribución De Frecuencias

14.6.3 Operating frequency range

A conformant PMD implementation shall be able to select the carrier frequency (F_c) from the full geographic-specific set of available carrier frequencies. Table 36 summarizes these frequencies for a number of geographic locations.

Table 36—Operating frequency range

Lower Limit	Upper limit	Regulatory range	Geography
2.402 GHz	2.480 GHz	2.400–2.4835 GHz	North America
2.402 GHz	2.480 GHz	2.400–2.4835 GHz	Europe ^a
2.473 GHz	2.495 GHz	2.471–2.497 GHz	Japan
2.447 GHz	2.473 GHz	2.445–2.475 GHz	Spain
2.448 GHz	2.482 GHz	2.4465–2.4835 GHz	France
NOTE—The frequency ranges in this table are subject to the geographic-specific regulatory authorities.			

^aExcluding Spain and France.

14.6.4 Number of operating channels

The number of transmit and receive frequency channels used for operating the PMD entity is 79 for the USA and Europe, and 23 for Japan. Table 37 summarizes these frequencies for a number of geographic locations. This is more fully defined in Table 38 through Table 41.

Table 37—Number of operating channels

Minimum	Hopping set	Geography
75	79	North America
20	79	Europe ^a
Not applicable	23	Japan
20	27	Spain
20	35	France
NOTE—The number of required hopping channels is subject to the geographic-specific regulatory authorities.		

^aExcluding Spain and France.

14.6.5 Operating channel center frequency

The channel center frequency is defined in sequential 1.0 MHz steps beginning with the first channel, channel 2.402 GHz for the USA and Europe excluding Spain and France, as listed in Table 38. The channel centers for Japan, starting at 2.473 GHz with 1 MHz increments, are listed in Table 39. The channel centers for Spain and France are listed in Table 40 and Table 41, respectively.

**Table 38—Requirements in North America and Europe
(excluding Spain and France; values specified in GHz)**

Channel #	Value	Channel #	Value	Channel #	Value
2	2.402	28	2.428	54	2.454
3	2.403	29	2.429	55	2.455
4	2.404	30	2.430	56	2.456
5	2.405	31	2.431	57	2.457
6	2.406	32	2.432	58	2.458
7	2.407	33	2.433	59	2.459
8	2.408	34	2.434	60	2.460
9	2.409	35	2.435	61	2.461
10	2.410	36	2.436	62	2.462
11	2.411	37	2.437	63	2.463
12	2.412	38	2.438	64	2.464

**Table 38—Requirements in North America and Europe
(excluding Spain and France; values specified in GHz) (continued)**

Channel #	Value	Channel #	Value	Channel #	Value
13	2.413	39	2.439	65	2.465
14	2.414	40	2.440	66	2.466
15	2.415	41	2.441	67	2.467
16	2.416	42	2.442	68	2.468
17	2.417	43	2.443	69	2.469
18	2.418	44	2.444	70	2.470
19	2.419	45	2.445	71	2.471
20	2.420	46	2.446	72	2.472
21	2.421	47	2.447	73	2.473
22	2.422	48	2.448	74	2.474
23	2.423	49	2.449	75	2.475
24	2.424	50	2.450	76	2.476
25	2.425	51	2.451	77	2.477
26	2.426	52	2.452	78	2.478
27	2.427	53	2.453	79	2.479
—	—	—	—	80	2.480

**Table 39—Requirements in Japan
(values specified in GHz)**

Channel #	Value	Channel #	Value	Channel #	Value
73	2.473	81	2.481	89	2.489
74	2.474	82	2.482	90	2.490
75	2.475	83	2.483	91	2.491
76	2.476	84	2.484	92	2.492
77	2.477	85	2.485	93	2.493
78	2.478	86	2.486	94	2.494
79	2.479	87	2.487	95	2.495
80	2.480	88	2.488	—	—

**Table 40—Requirements in Spain
(values specified in GHz)**

Channel #	Value	Channel #	Value	Channel #	Value
47	2.447	56	2.456	65	2.465
48	2.448	57	2.457	66	2.466
49	2.449	58	2.458	67	2.467
50	2.450	59	2.459	68	2.468
51	2.451	60	2.460	69	2.469
52	2.452	61	2.461	70	2.470
53	2.453	62	2.462	71	2.471
54	2.454	63	2.463	72	2.472
55	2.455	64	2.464	73	2.473

**Table 41—Requirements in France
(values specified in GHz)**

Channel #	Value	Channel #	Value	Channel #	Value
48	2.448	60	2.460	72	2.472
49	2.449	61	2.461	73	2.473
50	2.450	62	2.462	74	2.474
51	2.451	63	2.463	75	2.475
52	2.452	64	2.464	76	2.476
53	2.453	65	2.465	77	2.477
54	2.454	66	2.466	78	2.478
55	2.455	67	2.467	79	2.479
56	2.456	68	2.468	80	2.480
57	2.457	69	2.469	81	2.481
58	2.458	70	2.470	82	2.482
59	2.459	71	2.471	—	—

14.6.6 Occupied channel bandwidth

Occupied channel bandwidth shall meet all applicable local geographic regulations for 1 MHz channel spacing. The rate at which the PMD entity will hop is governed by the MAC. The hop rate is an attribute with a maximum dwell time subject to local geographic regulations.

14.6.7 Minimum hop rate

The minimum hop rate shall be governed by the regulatory authorities.

14.6.8 Hop sequences

The hopping sequence of an individual PMD entity is used to create a pseudorandom hopping pattern utilizing uniformly the designated frequency band. Sets of hopping sequences are used to co-locate multiple PMD entities in similar networks in the same geographic area and to enhance the overall efficiency and throughput capacity of each individual network.

An FH pattern, F_x , consists of a permutation of all frequency channels defined in Table 38 and Table 39. For a given pattern number, x , the hopping sequence can be written as follows:

$$F_x = \{f_x(1), f_x(2), \dots, f_x(p)\} \quad (1)$$

where

$f_x(i)$ is the channel number (as defined in 14.6.4) for i^{th} frequency in x^{th} hopping pattern;
 p is the number of frequency channels in hopping pattern (79 for North America and most of Europe, 23 for Japan, 35 for France, 27 for Spain).

Given the hopping pattern number, x , and the index for the next frequency, i (in the range 1 to p), the channel number shall be defined to be as follows:

$f_x(i) = [b(i) + x] \bmod (79) + 2$ in North America and most of Europe, with $b(i)$ defined in Table 42.
 $= [(i - 1) \times x] \bmod (23) + 73$ in Japan.
 $= [b(i) + x] \bmod (27) + 47$ in Spain with $b(i)$ defined in Table 43.
 $= [b(i) + x] \bmod (35) + 48$ in France with $b(i)$ defined in Table 44.

Table 42—Base-Hopping sequence $b(i)$ for North America and most of Europe

i	$b(i)$	i	$b(i)$	i	$b(i)$	i	$b(i)$	i	$b(i)$	i	$b(i)$	i	$b(i)$	i	$b(i)$
1	0	11	76	21	18	31	34	41	14	51	20	61	48	71	55
2	23	12	29	22	11	32	66	42	57	52	73	62	15	72	35
3	62	13	59	23	36	33	7	43	41	53	64	63	5	73	53
4	8	14	22	24	71	34	68	44	74	54	39	64	17	74	24
5	43	15	52	25	54	35	75	45	32	55	13	65	6	75	44
6	16	16	63	26	69	36	4	46	70	56	33	66	67	76	51
7	71	17	26	27	21	37	60	47	9	57	65	67	49	77	38
8	47	18	77	28	3	38	27	48	58	58	50	68	40	78	30
9	19	19	31	29	37	39	12	49	78	59	56	69	1	79	46
10	61	20	2	30	10	40	25	50	45	60	42	70	28	—	—

Table 43—Base-Hopping sequence $b(i)$ for Spain

i	$b(i)$	i	$b(i)$	i	$b(i)$
1	13	10	19	19	14
2	4	11	8	20	1
3	24	12	23	21	20
4	18	13	15	22	7
5	5	14	22	23	16
6	12	15	9	24	2
7	3	16	21	25	11
8	10	17	0	26	17
9	25	18	6	27	26

Table 44—Base-Hopping sequence $b(i)$ for France

i	$b(i)$	i	$b(i)$	i	$b(i)$
1	17	13	31	25	15
2	5	14	20	26	3
3	18	15	29	27	11
4	32	16	22	28	30
5	23	17	12	29	24
6	7	18	6	30	9
7	16	19	28	31	27
8	4	20	14	32	19
9	13	21	25	33	2
10	33	22	0	34	21
11	26	23	8	35	34
12	10	24	1	—	—

The sequences are designed to ensure some minimum distance in frequency between contiguous hops. The minimum hop size is 6 MHz for North America and Europe, including Spain and France, and 5 MHz for Japan.

The hopping pattern numbers x are divided into three sets. The sets are designed to avoid prolonged collision periods between different hopping sequences in a set. Hopping sequence sets contain 26 sequences for North America and Europe, and 4 sequences per set for Japan:

For North America and most of Europe:

$x = \{0,3,6,9,12,15,18,21,24,27,30,33,36,39,42,45,48,51,54,57,60,63,66,69,72,75\}$	Set 1
$x = \{1,4,7,10,13,16,19,22,25,28,31,34,37,40,43,46,49,52,55,58,61,64,67,70,73,76\}$	Set 2
$x = \{2,5,8,11,14,17,20,23,26,29,32,35,38,41,44,47,50,53,56,59,62,65,68,71,74,77\}$	Set 3

For Japan:

$x = \{6,9,12,15\}$ Set 1
 $x = \{7,10,13,16\}$ Set 2
 $x = \{8,11,14,17\}$ Set 3

For Spain:

$x = \{0,3,6,9,12,15,18,21,24\}$ Set 1
 $x = \{1,4,7,10,13,16,19,22,25\}$ Set 2
 $x = \{2,5,8,11,14,17,20,23,26\}$ Set 3

For France:

$x = \{0,3,6,9,12,15,18,21,24,27,30\}$ Set 1
 $x = \{1,4,7,10,13,16,19,22,25,28,31\}$ Set 2
 $x = \{2,5,8,11,14,17,20,23,26,29,32\}$ Set 3

The three sets of hopping sequences for North America and most of Europe, of 26 patterns each, are listed in Tables B.1, B.2, and B.3 in Annex B. Similarly, there are three sets for Japan of four patterns each. The three sets for Spain have nine patterns each. The three sets for France have 11 patterns each. The channel numbers listed under each pattern refer to the actual frequency values listed in Table 38 and Table 39.

14.6.9 Unwanted emissions

Conformant PMD implementations shall limit the emissions that fall outside of the operating frequency range, defined in Table 36, to the geographically applicable limits.

14.6.10 Modulation

The minimum set of requirements for a PMD to be compliant with the IEEE 802.11 FHSS PHY shall be as follows.

The PMD shall be capable of operating using two-level Gaussian frequency shift key (GFSK) modulation with a nominal bandwidth bit-period (BT)=0.5. The PMD shall accept symbols from the set $\{\{1\},\{0\}\}$ from the PLCP. The symbol $\{1\}$ shall be encoded with a peak deviation of $(+f_d)$, giving a peak transmit frequency of $(F_c + f_d)$, which is greater than the carrier center frequency (F_c). The symbol $\{0\}$ shall be encoded with a peak frequency deviation of $(-f_d)$, giving a peak transmit frequency of $(F_c - f_d)$.

An incoming bit stream at 1 Mbit/s will be converted to symbols at $F_{clk} = 1 \text{ Msymbols/s}$, as shown in Table 45.

Table 45—Symbol encoding into carrier deviation (1 Mbit/s, 2-GFSK)

Symbol	Carrier deviation
1	$1/2 \times h_2 \times F_{clk}$
0	$-1/2 \times h_2 \times F_{clk}$
NOTE—These deviation values are measured using the center symbol of 7 consecutive symbols of the same value. The instantaneous deviation will vary due to Gaussian pulse shaping.	

The deviation factor h_2 for 2GFSK (measured as difference between frequencies measured in the middle of 0000 and 1111 patterns encountered in the SFD, divided by 1 MHz) will nominally be 0.32.

The minimum frequency deviation, as shown in Figure 84, shall be greater than 110 kHz relative to the nominal center frequency F_c . F_d is the average center frequency of the last 8 bits of the Preamble Sync field, measured as the deviation at the midsymbol. Midsymbol is defined as the point that is midway between the zero crossings derived from a best fit to the last 8 bits of the Sync field. Maximum deviation is not specified, but modulation is subject to the occupied bandwidth limits of 14.6.5.

The zero crossing error shall be less than $\pm 1/8$ of a symbol period. The zero crossing error is the time difference between the ideal symbol periods and measured crossings of F_c . This is illustrated in Figure 84.

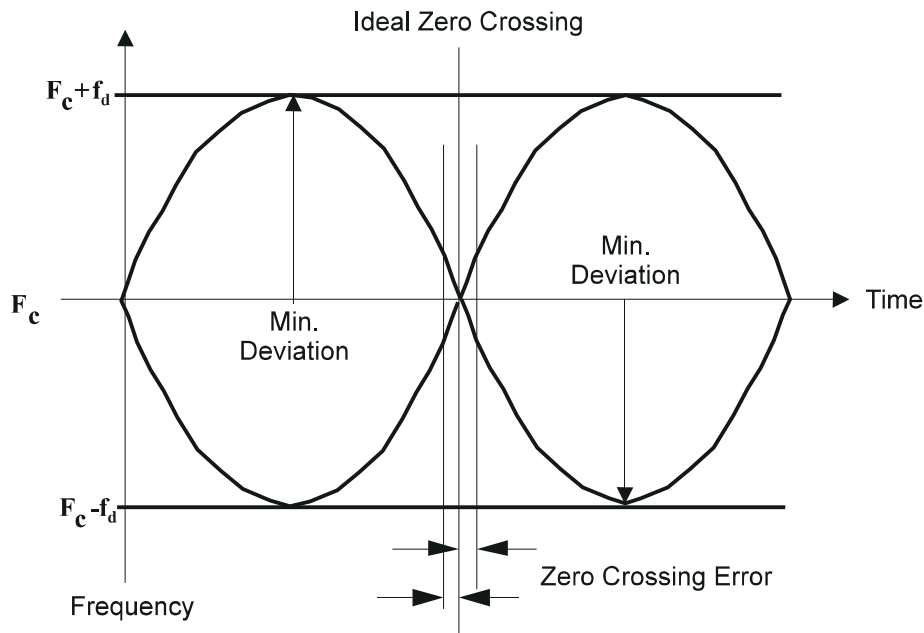


Figure 84—Transmit modulation mask

14.6.11 Channel data rate

A compliant IEEE 802.11 FHSS PMD shall be capable of transmitting and receiving at a nominal data rate of 1.0 Mbit/s $\pm$ 50 parts per million (ppm).

14.6.12 Channel switching/settling time

The time to change from one operating channel frequency, as specified in 14.6.3, is defined as 224 μ s. A conformant PMD meets this switching time specification when the operating channel center frequency has settled to within ± 60 kHz of the nominal channel center frequency as outlined in 14.6.3.

14.6.13 Receive to transmit switch time

The maximum time for a conformant PMD to switch the radio from the receive state to the transmit state and place the start of the first bit on the air shall be 19 μ s. At the end of this 19 μ s, the RF carrier shall be within the nominal transmit power level range, and within the described modulation specifications.

14.6.14 PMD transmit specifications

The following portion of this subclause describes the transmit functions and parameters associated with the PMD sublayer. In general, these are specified by primitives from the PLCP, and the transmit PMD entity provides the actual means by which the signals required by the PLCP primitives are imposed onto the medium.

14.6.14.1 Nominal transmit power

The nominal transmit power of a frame is defined as the power averaged between the start of the first symbol in the PLCP Header to the end of the last symbol in the PLCP Header. When in the transmit state, the transmit power shall be within 2 dB of the nominal transmit power from the start of the Preamble SYNC field to the last symbol at the end of the frame.

14.6.14.2 Transmit power levels

Unless governed by more stringent local geographic regulations, the radiated emissions from compliant devices shall meet IEEE Std C95.1-1991 limits for controlled or uncontrolled environments, in accordance with their intended usage. In addition, all conformant PMD implementations shall support at least one power level with a minimum equivalent isotropically radiated power (EIRP) of 10 mW.

14.6.14.3 Transmit power level control

If a conformant PMD implementation has the ability to transmit in a manner that results in the EIRP of the transmit signal exceeding the level of 100 mW, at least one level of transmit power control shall be implemented. This transmit power control shall be such that the level of the emission is reduced to a level at or below 100 mW under the influence of said power control.

14.6.14.4 Transmit spectrum shape

Within the operational frequency band the transmitter shall pass a spectrum mask test. The duty cycle between Tx and Rx is nominally 50% and the transmit frame length is nominally 400 μ s. The adjacent channel power is defined as the sum of the power measured in a 1 MHz band. For a pseudorandom data pattern, the adjacent channel power shall be a function of the offset between channel number N and the assigned transmitter channel M , where M is the actual transmitted center frequency and N is a channel separated from it by an integer number of megahertz.

Channel offset:

$|N-M|=2$ -20 dBm or -40 dBc, whichever is the lower power.

$|N-M|\geq 3$ -40 dBm or -60 dBc, whichever is the lower power.

The levels given in dBc are measured relative to the transmitter power measured in a 1 MHz channel centered on the transmitter center frequency. The adjacent channel power and the transmitter power for this subclause of the specification shall be measured with a resolution bandwidth of 100 kHz, a video bandwidth of 300 kHz, and a peak detector, and with the measurement device set to maximum hold.

For any transmit center frequency M , two exceptions to the spectrum mask requirements are permitted within the operational frequency band, provided the exceptions are less than -50 dBc, where each offset channel exceeded counts as a separate exception. An exception occurs when the total energy within a given 1 MHz channel as defined in 14.6.5 exceeds the levels specified above.

14.6.14.5 Transmit center frequency tolerance

The PMD transmit center frequency shall be within ± 60 kHz of the nominal center frequency as specified in 14.6.5.

14.6.14.6 Transmitter ramp periods

The transmitter shall go from off to within 2 dB of the nominal transmit power in 8 μ s or less. The transmitter shall go from within 2 dB of the nominal transmit power to off (less than -50 dBm) in 8 μ s or less.

14.6.15 PMD receiver specifications

The following portion of this subclause describes the receive functions and parameters associated with the PMD sublayer. In general, these are specified by primitives from the PLCP. The Receive PMD entity provides the actual means by which the signals required by the PLCP primitives are recovered from the medium. The PMD sublayer monitors signals on the medium and will return symbols from the set $\{\{1\}, \{0\}\}$ to the PLCP sublayer.

14.6.15.1 Input signal range

The PMD shall be capable of recovering a conformant PMD signal from the medium, as described in related subclauses, with a frame error ratio (FER) $\leq 3\%$ for PSDUs of 400 octets generated with pseudorandom data, for receiver input signal levels in the range from -20 dBm to the receiver sensitivity (as specified in 14.6.15.4), across the frequency band of operation.

14.6.15.2 Receive center frequency acceptance range

An IEEE 802.11 FHSS compliant PMD shall meet all specifications with an input signal having a center frequency range of ± 60 kHz from nominal.

14.6.15.3 CCA power threshold

In the presence of any IEEE 802.11 compliant 1 Mbit/s FH PMD signal above -85 dBm that starts synchronously with respect to slot times as specified in 14.3.3.2.1, the PHY shall signal busy, with a 90% probability of detection, during the preamble within the CCA assessment window. In the presence of any IEEE 802.11 compliant 1 Mbit/s FH PMD signal above -85 dBm that starts asynchronously with respect to slot times as specified in 14.3.3.2.1, the PHY shall signal busy, with a 70% probability of detection, during the preamble within the CCA window. In the presence of any IEEE 802.11 compliant 1 Mbit/s FH PMD signal above -65 dBm, the PHY shall signal busy, with a 70% probability of detection, during random data within the CCA window. This specification applies to a PMD operating with a nominal EIRP of < 100 mW. A compliant PMD operating at a nominal output power greater than 100 mW shall use the following equation to define the CCA threshold, where P_t represents transmit power.

$$\text{CCA threshold (preamble)} = -85 \text{ dBm} - \left[5 \times \log_{10} \left(\frac{P_t}{100 \text{ mW}} \right) \right] \text{ dBm}$$

$$\text{CCA threshold (random data)} = \text{CCA threshold (preamble)} + 20 \text{ dB}$$

14.6.15.4 Receiver sensitivity

The sensitivity is defined as the minimum signal level required for an FER of 3% for PSDUs of 400 octets generated with pseudorandom data. The sensitivity shall be less than or equal to -80 dBm. The reference sensitivity is defined as -80 dBm for the 1 Mbit/s FH PHY specifications.

14.6.15.5 Intermodulation

Intermodulation protection (IMp) is defined as the ratio of the minimum amplitude of one of two equal interfering signals to the desired signal amplitude, where the interfering signals are spaced 4 MHz and 8 MHz removed from the center frequency of the desired signal, both on the same side of center frequency. The IMp protection ratio is established at the interfering signal level that causes the FER of the receiver to be increased to 3% for PSDUs of 400 octets generated with pseudorandom data, when the desired signal is -77 dBm. Each interfering signal is modulated with the FH PMD modulation uncorrelated in time to each other or the desired signal. The PMD shall have the IMp for the interfering signal at 4 MHz and 8 MHz be ≥30 dB.

14.6.15.6 Desensitization

Desensitization (Dp) is defined as the ratio to measured sensitivity of the minimum amplitude of an interfering signal that causes the FER at the output of the receiver to be increased to 3% for PSDUs of 400 octets generated with pseudorandom data, when the desired signal is -77 dBm. The interfering signal shall be modulated with the FHSS PMD modulation uncorrelated in time to the desired signal. The minimum Dp shall be as given in Table 46. The spectral purity of the interferer shall be sufficient to ensure that the measurement is limited by the receiver performance.

Table 46—1 Mbit/s Dp

Interferer frequency ^a	Dp minimum
$M = N \pm 2$	30 dB
$M = N \pm 3$ or more	40 dB

^aWhere *M* is the interferer frequency and *N* is the desired channel frequency.

14.6.15.7 Receiver radiation

The signal leakage when receiving shall not exceed -50 dBm EIRP in the operating frequency range. The FHSS PHY shall conform with out-of-band spurious emissions by regulatory bodies.

14.6.16 Operating temperature range

Two temperature ranges for full operation compliance to the FH PHY are specified. Type 1 is defined as 0 °C to 40 °C and is designated for office environments. Type 2 is defined as -30 °C to +70 °C and is designated for industrial environments.

14.7 FHSS PMD sublayer, 2.0 Mbit/s

14.7.1 Overview

This subclause details the RF specification differences of the optional 2 Mbit/s operation from the baseline 1 Mbit/s PMD as contained in 14.6. Unless otherwise specified in this subclause, the compliant PMD shall also meet all requirements of 14.6 when transmitting at 2 Mbit/s. When implementing the 2 Mbit/s option, the preamble and PHY Header shall be transmitted at 1 Mbit/s. STAs implementing the 2 Mbit/s option shall also be capable of transmitting and receiving PPDU's at 1 Mbit/s.

14.7.2 Four-Level GFSK modulation

For an FHSS 2 Mbit/s PMD, the modulation scheme shall be four-level Gaussian frequency shift keying (4GFSK), with a nominal symbol-period bandwidth product (BT) of 0.5. The four-level deviation factor, defined as the frequency separation of adjacent symbols divided by symbol rate, h_4 , shall be related to the deviation factor of the 2GFSK modulation, h_2 , by the following equation:

$$h_4/h_2 = 0.45 \pm 0.01$$

An incoming bit stream at 2 Mbit/s will be converted to 2-bit words or symbols, with a rate of $F_{clk} = 1$ Msymbol/s. The first received bit will be encoded as the LMB of the symbol in Table 47. The bits will be encoded into symbols as shown in Table 47.

Table 47—Symbol encoding into carrier deviation

1 Mbit/s, 2GFSK	
Symbol	Carrier deviation
1	$1/2 \times h_2 \times F_{clk}$
0	$-1/2 \times h_2 \times F_{clk}$
2 Mbit/s, 4GFSK	
Symbol	Carrier deviation
10	$3/2 \times h_4 \times F_{clk}$
11	$1/2 \times h_4 \times F_{clk}$
01	$-1/2 \times h_4 \times F_{clk}$
00	$-3/2 \times h_4 \times F_{clk}$
NOTE—These deviation values are measured using the center symbol of 7 consecutive symbols of the same value. The instantaneous deviation will vary due to Gaussian pulse shaping.	

The deviation factor h_2 for 2GFSK (measured as the difference between frequencies measured in the middle of 0000 and 1111 patterns encountered in the SFD, divided by 1 MHz) will nominally be 0.32. The deviation factor h_2 will be no less than 0.30 (with maximum dictated by regulatory bandwidth requirement). Accordingly, h_4 (measured as a difference between the outermost frequencies, divided by 3, divided by 1 MHz) is nominally $0.45 \times 0.32 = 0.144$, and it will be no less than $0.45 \times 0.3 = 0.135$.

The modulation error shall be less than ± 15 kHz at the midsymbol time for 4GFSK, from the frequency deviations specified above, for a symbol surrounded by identical symbols, and less than ± 25 kHz for any symbol. The deviation is relative to the actual center frequency of the RF carrier. For definition purposes, the actual center frequency is the midfrequency between symbols 11 and 01. The actual center frequency shall be within ± 60 kHz of the nominal channel center frequency defined in 14.6.5 and shall not vary by more than ± 10 kHz/ms, from the start to end of the PPDU. The peak-to-peak variation of the actual center frequency over the PPDU shall not exceed 15 kHz. Symbols and terms used within this subclause are illustrated in Figure 85.

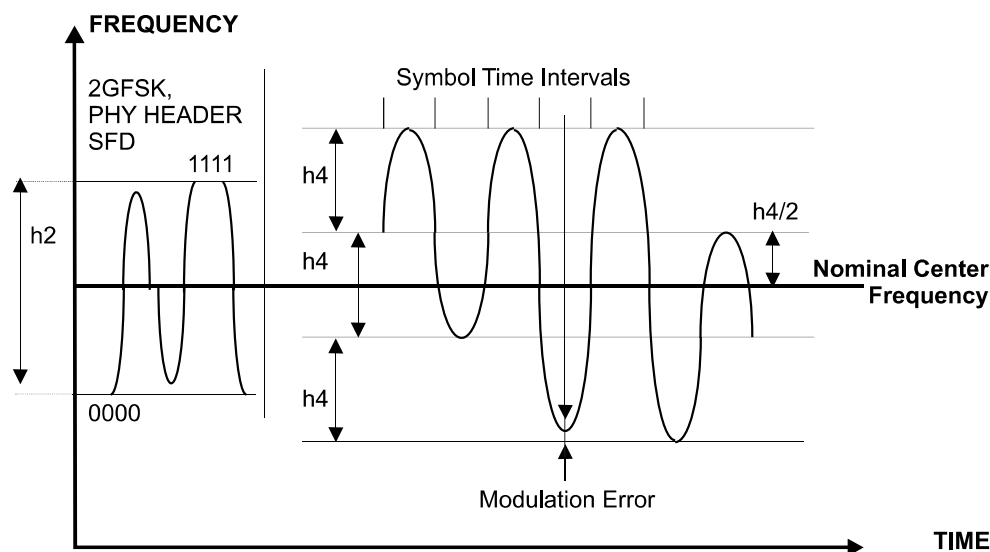


Figure 85—Four-Level GFSK transmit modulation

14.7.2.1 Frame structure for HS FHSS PHY

The high rate FHSS PPDU consists of PLCP Preamble, PLCP Header, and whitened PSDU. The PLCP Preamble and PLCP Header format are identical to the 1 Mbit/s PHY, as described in 14.3.2. The whitened PSDU is transmitted in 2GFSK, 4GFSK, or potentially a higher-rate format, according to the rate chosen. The rate is indicated in a 3-bit field in a PLCP Header, having a value of 1 or 2 bits/symbol (or Mbit/second).

The PPDU is transmitted as four-level symbols, with the amount determined by $\text{number_of_symbols} = (\text{number_of_PSDU_octets} \times 8) / \text{rate}$.

The input bits are scrambled according to the method in 14.3.2.3.

The scrambled bit stream is divided into groups of rate (1 or 2) consecutive bits. The bits are mapped into symbols according to Table 47.

A bias suppression algorithm is applied to the resulting symbol stream. The bias suppression algorithm is defined in 14.3.2.3, Figure 72, and Figure 75. A polarity control symbol is inserted prior to each block of 32 symbols (or less for the last block). The polarity control signals are 4GFSK symbols 10 or 00. The algorithm is equivalent to the case of 2GFSK, with the polarity symbol 2GFSK “1” replaced with 4GFSK symbol “10,” and the 2GFSK polarity symbol “0” replaced with a 4GFSK symbol “00.”

14.7.3 Channel data rate

The data rate for the whitened PSDU at the optional rate shall be 2.0 Mbit/s $\pm$ 50 ppm.

14.7.3.1 Input dynamic range

The PMD shall be capable of recovering a conformant PMD signal from the medium, as described in related subclauses, with an FER $\leq$ 3% for PSDUs of 400 octets generated with pseudorandom data, for receiver input signal levels in the range from -20 dBm to the receiver sensitivity (as specified in 14.7.3.2), across the frequency band of operation.

14.7.3.2 Receiver sensitivity

The sensitivity is defined as the minimum signal level required for an FER of 3% for PSDUs of 400 octets generated with pseudorandom data. The sensitivity shall be less than or equal to -75 dBm. The reference sensitivity is defined as -75 dBm for the 2 Mbit/s FH PHY specifications.

14.7.3.3 IMp

IMp is defined as the ratio to -77 dBm of the minimum amplitude of one of the two equal-level interfering signals at 4 MHz and 8 MHz removed from center frequency, both on the same side of center frequency, that cause the FER of the receiver to be increased to 3% for PSDUs of 400 octets generated with pseudorandom data, when the desired signal is -72 dBm (3 dB above the specified sensitivity specified in 14.7.3.2). Each interfering signal is modulated with the FH 1 Mbit/s PMD modulation uncorrelated in time to each other or the desired signal. The FHSS optional 2 Mbit/s rate IMp shall be ≥ 25 dB.

14.7.3.4 Dp

Dp is defined as the ratio to measured sensitivity of the minimum amplitude of an interfering signal that causes the FER of the receiver to be increased to 3% for PSDUs of 400 octets generated with pseudorandom data, when the desired signal is -72 dB (3 dB above sensitivity specified in 14.7.3.2). The interfering signal shall be modulated with the FHSS PMD modulation uncorrelated in time to the desired signal. The minimum Dp shall be as given in Table 48.

Table 48—2 Mbit/s Dp

Interferer frequency ^a	DP minimum
$M = N \pm 2$	20 dB
$M = N \pm 3$ or more	30 dB

^aWhere M is the interferer frequency and N is the desired channel frequency.

14.8 FHSS PHY management information base (MIB)

14.8.1 Overview

The following is the MIB for the FHSS PHY.

14.8.2 FH PHY attributes

This subclause defines the attributes for the FHSS MIB. Table 49 lists these attributes and the default values. Following the table is a description of each attribute.

Table 49—FHSS PHY attributes

Attribute	Default value	Operational semantics	Operational behavior
dot11PHYType	FHSS = X'01'	Static	Identical for all FH PHYs
dot11RegDomainsSupported	FCC = X'10' IC = X'20' ETSI = X'30' Spain = X'31' France = X'32' MKK = X'40'	Static	Implementation dependent
dot11CurrentRegDomain	X'00'	Dynamic LME	Implementation dependent
dot11TempType	Type 1 = X'01' Type 2 = X'02' Type 3 = X'03'	Static	Implementation dependent
dot11SupportedDataRatesTX	1 Mbit/s = X'02' mandatory 2 Mbit/s = X'04' optional	Static	Identical for all FH PHYs
dot11SupportedDataRatesRX	1 Mbit/s = X'02' mandatory 2 Mbit/s = X'04' optional	Static	Identical for all FH PHYs
dot11SupportedTxAntennas	Ant 1 = X'01' Ant 2 = X'02' Ant 3 = X'03' Ant n = n	Static	Implementation dependent
dot11CurrentTxAntenna	Ant 1 = default	Dynamic LME	Implementation dependent
dot11SupportedRxAntennas	Ant 1 = X'01' Ant 2 = X'02' Ant 3 = X'03' Ant n = n	Static	Implementation dependent
dot11DiversitySupport	Available = X'01' Not avail. = X'02' Control avail. = X'03'	Static	Implementation dependent
dot11DiversitySelectionRx	Ant 1 = X'01' Ant 2 = X'02' Ant 3 = X'03' Ant 4 = X'04' Ant 5 = X'05' Ant 6 = X'06' Ant 7 = X'07' Ant 8 = X'08'	Dynamic LME	Implementation dependent
dot11NumberSupportedPowerLevels	Lvl1 = X'01' Lvl2 = X'02' Lvl3 = X'03' Lvl4 = X'04' Lvl5 = X'05' Lvl6 = X'06' Lvl7 = X'07' Lvl8 = X'08'	Static	Implementation dependent
dot11TxPowerLevel1	Factory default	Static	Implementation dependent
dot11TxPowerLevel2	Factory default	Static	Implementation dependent
dot11TxPowerLevel3	Factory default	Static	Implementation dependent

Table 49—FHSS PHY attributes (continued)

Attribute	Default value	Operational semantics	Operational behavior
dot11TxPowerLevel4	Factory def.	Static	Implementation dependent
dot11TxPowerLevel5	Factory def.	Static	Implementation dependent
dot11TxPowerLevel6	Factory def.	Static	Implementation dependent
dot11TxPowerLevel7	Factory def.	Static	Implementation dependent
dot11TxPowerLevel8	Factory def.	Static	Implementation dependent
dot11CurrentTxPowerLevel	TxPowerLevel1	Dynamic LME	Implementation dependent
dot11HopTime	224 μ s	Static	Identical for all FH PHYs
dot11CurrentChannelNumber	X'00'	Dynamic PLME	
dot11MaxDwellTime	390 TU	Static	Regulatory domain dependent
dot11CurrentSet	X'00'	Dynamic PLME	
dot11CurrentPattern	X'00'	Dynamic PLME	
dot11CurrentIndex	X'00'	Dynamic PLME	
dot11CurrentPowerState	X'01' off X'02' on	Dynamic LME	
NOTE—The column titled “Operational semantics” contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. MIB attributes defined as dynamic can be modified by some management entity. Whenever an attribute is defined as dynamic, the column also shows which entity has control over the attribute. LME refers to the MAC sublayer management entity (MLME), while PHY refers to the physical layer management entity (PLME).			

14.8.2.1 FH PHY attribute definitions

14.8.2.1.1 dot11PHYType

The dot11PHYType is FHSS. The LME uses this attribute to determine what PLCP and PMD are providing services to the MAC. It also is used by the MAC to determine what MAC sublayer management state machines must be invoked to support the PHY. The value of this attribute is defined as the integer 01 to indicate the FHSS PHY.

14.8.2.1.2 dot11RegDomainsSupported

Operational requirements for FHSS PHY are defined by agencies representing certain geographical regulatory domains. These regulatory agencies may define limits on various parameters that differ from region to region. This parameters may include dot11TxPowerLevels, and dot11MaxDwellTime, as well as the total number of frequencies in the hopping pattern. The values shown in Table 50 indicate regulatory agencies supported by this document.

Since a PLCP and PMD might be designed to support operation in more than one regulatory domain, this attribute can actually represent a list of agencies. This list can be one or more of the above agencies and must be terminated using the null terminator. Upon activation of the PLCP and PMD, the information in this list must be used to set the value of the dot11CurrentRegDomain attribute.

14.8.2.1.3 dot11CurrentRegDomain

The dot11CurrentRegDomain attribute for the FHSS PHY is defined as the regulatory domain under which the PMD is currently operating. This value must be one of the values listed in the dot11RegDomainsSupported list. This MIB attribute is managed by the LME.

Table 50—Regulatory domain codes

Code point	Regulatory agency	Region
X'10'	FCC	United States
X'20'	IC	Canada
X'30'	ETSI	Most of Europe
X'31'	Spain	Spain
X'32'	France	France
X'40'	MKK	Japan

14.8.2.1.4 dot11TempType

The parameter dot11TempType defines the temperature range supported by the PHY. Type 1 equipment (X'01') supports a temperature range of 0 °C to 40 °C. Type 2 equipment (X'02') supports a temperature range of –20 °C to +55 °C. Type 3 equipment (X'03') supports a temperature range of –30 °C to +70 °C.

14.8.2.1.5 dot11CurrentPowerState

The dot11CurrentPowerState attribute for the FHSS PHY allows the MAC sublayer management entity to control the power state of the PHY. This attribute can be updated using the PLMESET.request. The permissible values are ON and OFF.

14.8.2.1.6 dot11SupportedDataRatesTX

The dot11SupportedDataRatesTX attribute for the FHSS PHY is defined as a null terminated list of supported data rates in the transmit mode for this implementation. Table 51 shows the possible values appearing in the list.

Table 51—Supported data rate codes (dot11SupportedDataRatesTX)

Code point	Data rate
X'02'	1 Mbit/s
X'04'	2 Mbit/s
X'00'	Null terminator

14.8.2.1.7 dot11SupportedDataRatesRX

The dot11SupportedDataRatesRX attribute for the FHSS PHY is defined as a null terminated list of supported data rates in the receive mode for this implementation. Table 52 shows the possible values appearing in the list.

14.8.2.1.8 aMPDUMaxLength

The aMPDUMaximumLength attribute for the FHSS PHY is defined as the maximum PSDU, in octets, that the PHY shall ever be capable of accepting. This value for the FHSS PHY is set at 4095 octets. The recommended value for maximum PSDU length in an FHSS PHY system is 400 octets at 1 Mbit/s and 800 octets at 2 Mbit/s, which corresponds to a frame duration less than 3.5 ms. These values are optimized to achieve

Table 52—Supported data rate codes (dot11SupportedDataRatesRX)

Code point	Data rate
X'02'	1 Mbit/s
X'04'	2 Mbit/s
X'00'	Null terminator

high performance in a variety of RF channel conditions, particularly with respect to indoor multipath, channel stability for moving STAs, and interference in the 2.4 GHz band.

14.8.2.1.9 dot11SupportedTxAntennas

The dot11SupportedTxAntennas attribute for the FHSS PHY is defined as a null terminated list of antennas that this implementation can use to transmit data. Table 53 shows the possible values appearing in the list, where $N \leq 255$.

Table 53—Number of transmit antennas

Code point	Antenna number
X'01'	Tx Antenna 1
X'02'	Tx Antenna 2
X'03'	Tx Antenna 3
...	...
N	Tx Antenna N
X'00'	Null terminator

14.8.2.1.10 dot11CurrentTxAntenna

The dot11CurrentTxAntenna attribute for the FHSS PHY is used to describe the current antenna the implementation is using for transmission. This value should represent one of the antennas appearing in the dot11SupportedTxAntennas list.

14.8.2.1.11 dot11SupportedRxAntenna

The dot11SupportedRxAntennas attribute for the FHSS PHY is defined as a null terminated list of antennas that this implementation can use to receive data. In the FHSS PHY primitives, one of these values is passed as part of the PHY-RXSTART.indicate to the MAC sublayer for every received packet. Table 54 shows the possible values appearing in the list, where $N \leq 255$.

Table 54—Number of receive antennas

Code point	Antenna number
X'01'	Rx Antenna 1
X'02'	Rx Antenna 2
X'03'	Rx Antenna 3
...	...
<i>N</i>	Rx Antenna <i>N</i>
X'00'	Null terminator

14.8.2.1.12 dot11DiversitySupport

The dot11DiversitySupport attribute for the FHSS PHY is used to describe the implementation's diversity support. Table 55 shows the possible values appearing in the list.

Table 55—Diversity support codes

Code point	Diversity support
X'01'	Diversity available
X'02'	No diversity
X'03'	Control available

The value X'01' indicates that this implementation uses two or more antennas for diversity. The value X'02' indicates that the implementation has no diversity support. The value X'03' indicates that the choice of antennas used during diversity is programmable. (See 14.8.2.1.13.)

14.8.2.1.13 dot11DiversitySelectionRx

The dot11DiversitySelectionRx attribute for the FHSS PHY is a null terminated list describing the receive antenna or antennas currently in use during diversity and packet reception. Table 56 shows the possible values appearing in the list, where $N \leq 255$.

Table 56—Diversity select antenna codes

Code point	Antenna number
X'01'	Rx Antenna 1
X'02'	Rx Antenna 2
X'03'	Rx Antenna 3
...	...
<i>N</i>	Rx Antenna <i>N</i>
X'00'	Null terminator

The null terminated list can consist of one or more of the receive antennas listed in the dot11SupportedRxAntennas attribute. This attribute can be changed dynamically by the LME.

14.8.2.1.14 dot11NumberSupportedPowerLevels

The dot11NumberSupportedPowerLevels attribute for the FHSS PHY describes the number of power levels this implementation supports. This attribute can be an integer of value 1 through 8, inclusive.

14.8.2.1.15 dot11TxPowerLevel1-8

Some implementations may provide up to eight different transmit power levels. The dot11TxPowerLevels attribute for the FHSS PHY is a list of up to eight power levels supported. Table 57 describes the list.

Table 57—Transmit power levels

Attribute	Power level
TxPowerLevel1	Default setting
TxPowerLevel2	Level 2
TxPowerLevel3	Level 3
TxPowerLevel4	Level 4
TxPowerLevel5	Level 5
TxPowerLevel6	Level 6
TxPowerLevel7	Level 7
TxPowerLevel8	Level 8

14.8.2.1.16 dot11CurrentTxPowerLevel

The dot11CurrentTxPowerLevel attribute for the FHSS PHY is defined as the current transmit output power level. This level shall be one of the levels implemented in the list of attributes called dot11TxPowerLevel N (where N is 1–8). This MIB attribute is also used to define the sensitivity of the CCA mechanism when the output power exceeds 100 mW. This MIB attribute is managed by the LME.

14.8.2.1.17 dot11HopTime

The dot11HopTime attribute for the FHSS PHY describes the time allocated for the PHY to change to a new frequency. For the FHSS PHY, this time period is 224 μ s.

14.8.2.1.18 dot11CurrentChannelNumber

The dot11CurrentChannelNumber attribute for the FHSS PHY is defined as the current operating channel number of the PMD. The values of this attribute correspond to the values shown in Table 38. This MIB attribute is managed by the PLME and is updated as the result of a PLMESET.request to dot11CurrentSet, dot11CurrentPattern, or dot11CurrentIndex.

14.8.2.1.19 dot11MaxDwellTime

The dot11MaxDwellTime attribute for the FHSS PHY is defined as the maximum time the PMD can dwell on a channel and meet the requirements of the current regulatory domain. For the FCC regulatory domain, this number is 390 TU (FCC = 400 ms). The recommended dwell time for the FHSS PHY is 19 TU.

14.8.2.1.20 dot11CurrentSet

The FHSS PHY contains three sets of hopping patterns. The dot11CurrentSet attribute for the FHSS PHY defines what set the STA is using to determine the hopping pattern. Its value can be 1, 2, or 3. This attribute is managed by the PLME.

14.8.2.1.21 dot11CurrentPattern

There are up to 78 patterns in each hopping set used by the FHSS PHY. The dot11CurrentPattern attribute for the FHSS PHY defines the x value used in Equation (1) in 14.6.8 to calculate the current channel number. Its value has various ranges, always within the overall range of 0 to 77, depending on the dot11CurrentRegDomain. This attribute is managed by the PLME.

14.8.2.1.22 dot11CurrentIndex

The FHSS PHY addresses each channel in the selected hopping pattern through an index. The dot11CurrentIndex attribute for the FHSS PHY defines the i value used in the equation for $f_x(i)$ in 14.6.8 to calculate the current channel number. Its value has various ranges, always within the overall range of 1 to 79, depending on the dot11CurrentRegDomain. This attribute is managed by the PLME.

14.8.2.1.23 dot11CurrentPowerState

The parameter dot11CurrentPowerState defines the operational state of the FHSS PHY. When this attribute has a value of X'01', the PHY is "OFF." When this attribute has a value of X'02', the PHY is "ON." This attribute is managed by the PLME.

14.9 FH PHY characteristics

Following are the static FH PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive. The definitions of these characteristics are in 10.4.3.

Table 57a—FH PHY characteristics

Characteristic	Value	Notes
aSlotTime	50 μ s	—
aSIFSTime	28 μ s	In order to account for variations between implementations, this value has a tolerance as specified in 9.2.3.1.
aCCATime	27 μ s	This period includes the aRxRFDelay and the aRxPLCPDelay.
aRxTxTurnaroundTime	20 μ s	—
aTxPLCPDelay	1 μ s	Implementors may choose to increase or decrease this delay as long as the requirements of aRxTxTurnaroundTime are met.
aRxPLCPDelay	2 μ s	Implementors may choose to increase or decrease this delay as long as the requirements of aSIFSTime and aCCATime are met.
aRxTxSwitchTime	10 μ s	Implementors may choose to increase or decrease this delay as long as the requirements of aRxTxTurnaroundTime are met.
aTxRampOnTime	8 μ s	Implementors may choose to increase or decrease this delay as long as the requirements of aRxTxTurnaroundTime are met.
aTxRampOffTime	8 μ s	—
aTxRFDelay	1 μ s	Implementors may choose to increase or decrease this delay as long as the requirements of aRxTxTurnaroundTime are met.
aRxRFDelay	4 μ s	Implementors may choose to increase or decrease this delay as long as the requirements of aSIFSTime and aCCATime are met.
aAirPropagationTime	1 μ s	Variations in the actual propagation time are accounted for in the allowable range of aSIFSTime.
aMACProcessingDelay	2 μ s	Implementors may choose to increase or decrease this delay as long as the requirements of aSIFSTime are met.
aPreambleLength	96 μ s	—
aPLCPHeaderLength	32 μ s	—
aMPDUDurationFactor	31250000	This factor is calculated as $[(33/32) - 1] \times 10^9$ to account for the expansion due to the data whitener encoding algorithm.
aMPDUMaxLength	4095	The recommended value for maximum PSDU length in an FHSS PHY system is 400 octets at 1 Mbit/s and 800 octets at 2 Mbit/s, which corresponds to a frame duration less than 3.5 ms. These values are optimized to achieve high performance in a variety of RF channel conditions, particularly with respect to indoor multipath, channel stability for moving STAs, and interference in the 2.4 GHz band.
aCWmin	15	—
aCWmax	1023	—