

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

# **Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications Amendment 10: Mesh Networking**

IEEE Computer Society

Sponsored by the  
LAN/MAN Standards Committee

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10 September 2011

## **IEEE Std 802.11s™-2011**

(Amendment to IEEE Std 802.11™-2007  
as amended by IEEE Std 802.11k™-2008,  
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IEEE Std 802.11v™-2011, and IEEE Std 802.11u™-2011)



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

**Amendment 10: Mesh Networking**

Sponsor

**LAN/MAN Standards Committee**  
of the  
**IEEE Computer Society**

Approved 10 September 2011  
**IEEE-SA Standards Board**

**Abstract:** This amendment describes protocols for IEEE 802.11 stations to form self-configuring multi-hop networks that support both broadcast/multicast and unicast data delivery.

**Keywords:** forwarding, IEEE 802.11s, medium access control, mesh, multi-hop, path selection, wireless LAN, zero-knowledge proof

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This introduction is not part of IEEE Std 802.11s-2011, IEEE Standard for Information Technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 11: Wireless Medium Access Control (MAC) and physical layer (PHY) specifications—Amendment 10: Mesh Networking.

This amendment specifies enhancements to support mesh networking. The networks described in this amendment make use of layer-2 mesh path selection and forwarding (that is, a wireless mesh network that performs routing at the link layer). Wireless mesh networks have advantageous properties in terms of robustness, range extension and density, but also have potential challenges such as power consumption and security. This amendment is specifically designed to address these challenges.

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

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

### Amendment 10: Mesh Networking

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(This amendment specifies enhancements to IEEE Std 802.11™. It is based on IEEE Std 802.11™-2007, as amended by IEEE Std 802.11k™-2008, IEEE Std 802.11r™-2008, IEEE Std 802.11y™-2008, IEEE Std 802.11w™-2009, IEEE Std 802.11n™-2009, IEEE Std 802.11p™-2010, IEEE Std 802.11z™-2010, IEEE Std 802.11v™-2011, and IEEE Std 802.11u™-2011.)

NOTE—The editing instructions are shown in ***bold italic***. Four editing instructions are used: change, delete, insert, and replace. ***Change*** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~striktthrough~~ (to remove old material) and underscore (to add new material). ***Delete*** removes existing material. ***Insert*** adds new material without disturbing the existing material. Insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. ***Replace*** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editing instructions, change markings, and this NOTE will not be carried over into future editions because the changes will be incorporated into the base standard.<sup>1</sup>

<sup>1</sup>Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

## 1. Overview

### 1.2 Purpose

*Insert the following dash list item to the end of 1.2:*

- Defines the MAC procedures that are necessary for wireless multi-hop communication to support wireless LAN mesh topologies.

## 2. Normative references

*Insert the following new normative references:*

IETF RFC 5297, Synthetic Initialization Vector (SIV) Authenticated Encryption Using the Advanced Encryption Standard (AES), D. Harkins, October 2008 (status: informational).

IETF RFC 2409, The Internet Key Exchange (IKE), D. Harkins, D. Carrel, November 1998 (status: Standards Track).

## 3. Definitions

*Insert the following new subclause title:*

### 3.1 General definitions

*Change the definition for basic service set (BSS) as follows:*

**basic service set (BSS):** A set of stations (STAs) that have successfully synchronized using the JOIN service primitives and one STA that has used the START primitive. Alternatively, a set of STAs that have used the START primitive specifying matching mesh profiles where the match of the mesh profiles has been verified via the scanning procedure. Membership in a BSS does not imply that wireless communication with all other members of the BSS is possible.

*Change the definition for distribution system service (DSS) as follows:*

**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 (STAs) 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, transport of MSDUs between mesh gates in the same or different mesh basic service sets (MBSSs), transport of MSDUs between mesh gates and APs, transport of MSDUs between mesh gates and portals, and transport of MSDUs between STAs in the same BSS in cases where the MSDU has a group destination address or where the destination is an individual address and the STA is associated with an AP.

NOTE—DSSs are provided between pairs of IEEE 802.11 MACs.

*Change the definition for distribution system medium (DSM) as follows:*

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

*Change the definition for wireless distribution system (WDS) as follows:*

**wireless distribution system (WDS):** ~~A mechanism for wireless communication using a four address frame format specified in this standard. This standard describes such a frame format, but does not describe how such a mechanism or frame format would be used. Often used as a vernacular term for a mechanism for wireless communication among non-mesh stations (STAs) using a four address frame format.~~

NOTE—This standard specifies such a frame format and its use only for a mesh basic service set (MBSS). Because of this, the term WDS is obsolete and subject to removal in a subsequent revision of this standard.

*Insert the following new definitions in alphabetical order:*

**active mode:** A mesh power mode in which the mesh station (STA) operates in the Awake state towards a neighbor mesh STA.

**candidate peer mesh station (STA):** A neighbor mesh STA to which a mesh peering has not been established but meets eligibility requirements to become a peer mesh STA.

**deep sleep mode:** A mesh power mode in which the mesh station (STA) operates either in the Awake state or in the Doze state towards a neighbor mesh STA, and is not expected to receive beacons from this neighbor mesh STA.

**destination mesh station (STA):** A mesh STA that is the final destination of a MAC service data unit (MSDU). This mesh STA might reside in a proxy mesh gate that might forward the MSDU to a STA outside of the MBSS. A destination mesh STA might be an end station as defined in IEEE Std 802.1.

**forwarding information:** The information maintained by a mesh station (STA) that allows the mesh STA to perform its path selection and forwarding functions.

**light sleep mode:** A mesh power mode in which the mesh station (STA) operates either in the Awake state or in the Doze state towards a neighbor mesh STA, and is expected to receive beacons from this neighbor peer mesh STA.

**link metric:** A criterion used to characterize the performance, quality, and eligibility of a link.

**mesh basic service set (MBSS):** A basic service set (BSS) that forms a self-contained network of mesh stations (STAs). An MBSS contains zero or more mesh gates.

**mesh facility:** The set of enhanced functions, channel access rules, frame formats, mutual authentication methods, and managed objects used to provide data transfer among autonomously operating stations (STAs) that may not be in direct communication with each other over a single instance of the wireless medium.

**mesh gate:** Any entity that has mesh station (STA) functionality and provides access to one or more distribution systems, via the wireless medium (WM) for the mesh basic service set (MBSS).

**mesh link:** A link from one mesh station (STA) to a neighbor mesh STA that have a mesh peering with each other.

**mesh neighborhood:** The set of all neighbor mesh stations (STAs) relative to a particular mesh STA.

**mesh path:** A concatenated set of mesh links from a source mesh station (STA) to a destination mesh STA.

**mesh path selection:** The process of selecting a mesh path.

**mesh peer service period (MPSP):** A contiguous period of time during which one or more individually addressed frames are transmitted between two peer mesh stations (STAs) with at least one of those mesh STAs operating in light sleep or deep sleep mode. A mesh peer service period is directional and may contain one or more TXOPs. A mesh STA may have multiple mesh peer service periods ongoing in parallel. No more than one mesh peer service period may be set up in each direction with each peer mesh STA.

**mesh peer service period (MPSP) owner:** A mesh STA that obtains TXOPs, transmits individually addressed frames to the recipient mesh STA in the mesh peer service period, and terminates the mesh peer service period.

**mesh peering:** A logical relationship between two mesh stations (STAs) that is required for direct communication over a single instance of the wireless medium (WM). A mesh peering is established with a mesh peering protocol.

**mesh peering management:** A group of protocols to facilitate the mesh peering establishment and closure of the mesh peerings.

**mesh power mode:** The activity level identifier of a mesh station (STA) set per mesh peering or for non-peer neighbor STAs. A lower activity level enables a mesh STA to reduce its power consumption.

**mesh power mode tracking:** Operation to observe the peering-specific mesh power modes from the peer mesh STAs and to maintain the peering-specific mesh power modes for each peer mesh STA.

**mesh profile:** A set of values of parameters that identifies the attributes of the mesh basic service set (MBSS) and that is used in a single mesh BSS. The mesh profile consists of the identifiers that are the values for the parameters: mesh ID, active path selection protocol, active path selection metric, congestion control mode, synchronization method, and authentication protocol.

**mesh services:** The set of services that enable the creation and operation of a mesh basic service set (MBSS).

**mesh station (STA):** A quality-of-service (QoS) STA that implements the mesh facility.

**neighbor station (STA):** A STA that is in direct communication range over a single instance of the wireless medium.

**next-hop mesh station (STA):** The next peer mesh STA on the mesh path to the destination mesh STA.

**non-peer mesh power mode:** The activity level identifier of a mesh station (STA) towards non-peer neighbor mesh STAs. Two non-peer mesh power modes are defined: active mode and deep sleep mode.

**password:** A shared, secret, and potentially low-entropy word, phrase, code, or key used as a credential for authentication purposes.

NOTE—The method of distribution of a password to the units in the system is outside the scope of this standard.

**path metric:** An aggregate multi-hop criterion used to characterize the performance, quality, and eligibility of a mesh path.

**peer mesh station (STA):** A mesh STA to which a mesh peering has been established.

**peer-specific mesh power mode:** The activity level identifier of a mesh station (STA) set per mesh peering. Three peer-specific mesh power modes are defined: active mode, light sleep mode, and deep sleep mode.

**peer trigger frame:** A Mesh Data or quality-of-service (QoS) Null frame that initiates a mesh peer service period.

**precursor mesh station (STA):** A neighbor peer mesh STA on the mesh path to the destination mesh STA, that identifies the mesh STA as the next-hop mesh STA.

**protocol instance:** An execution of a particular protocol that consists of the state of the communicating parties as well as the messages exchanged.

**proxy mesh gate:** A mesh gate acting as an intermediary for IEEE 802 stations (STAs) outside the mesh basic service set (MBSS).

**source mesh station (STA):** A mesh STA from which a MAC service data unit (MSDU) enters the mesh basic service set (MBSS). A source mesh STA may be a mesh STA that is the source of an MSDU or a proxy mesh gate that receives an MSDU from a STA outside of the MBSS and forwards the MSDU on a mesh path.

**unreachable destination:** A destination mesh station (STA) for which the link to the next hop of the mesh path to this destination mesh STA is no longer usable.

*Insert the following new subclause and new definitions:*

### 3.2 Definitions specific to IEEE Std 802.11

**delivery traffic indication message (DTIM) interval:** The interval between the consecutive TBTTs of beacons containing a DTIM. The value, expressed in time units, is equal to the product of the value in the Beacon Interval field and the value in the DTIM Period subfield in the TIM element in Beacon frames.

**mesh awake window:** A period of time during which the mesh station (STA) operates in awake state after its Beacon or Probe Response frame transmission that contained the Mesh Awake Window element.

**mesh coordination function (MCF):** A coordination function that combines aspects of the contention-based and scheduled access methods. The MCF includes the functionality provided by both enhanced distributed channel access (EDCA) and MCF controlled channel access (MCCA).

**mesh coordination function (MCF) controlled channel access (MCCA):** A coordination function for the mesh basic service set (MBSS).

**mesh coordination function (MCF) controlled channel access opportunity (MCCAOP):** A period of time scheduled for frame transmissions between mesh stations (STAs) using MCF controlled channel access (MCCA).

**Mesh Data frame:** A unicast Data frame with both the FromDS and ToDS bits set to 1 and that is transmitted from a mesh station (STA) to a peer mesh STA, or a group addressed Data frame that has FromDS set to 1 and ToDS set to 0 that is transmitted by a mesh STA.

**Self-protected Action frame:** An Action frame that is not eligible for protection by the Robust Management frame service. The protection on each Self-protected Action frame is provided by the protocol that uses the frame.

## 4. Abbreviations and acronyms

*Insert the following new acronym in alphabetical order:*

|        |                                           |
|--------|-------------------------------------------|
| AMPE   | authenticated mesh peering exchange       |
| FSM    | finite state machine                      |
| GANN   | gate announcement                         |
| HWMP   | hybrid wireless mesh protocol             |
| MAF    | MCCA access fraction                      |
| MBCA   | mesh beacon collision avoidance           |
| MBSS   | mesh basic service set                    |
| MCCA   | MCF controlled channel access             |
| MCCAOP | MCF controlled channel access opportunity |
| MCF    | mesh coordination function                |
| MGTK   | mesh group temporal key                   |
| MICE   | MIC element                               |
| MPM    | mesh peering management                   |
| MPSP   | mesh peer service period                  |
| MTK    | mesh temporal key                         |
| PERR   | path error                                |
| PREP   | path reply                                |
| PREQ   | path request                              |
| PXU    | proxy update                              |
| PXUC   | proxy update confirm                      |
| RANN   | root announcement                         |
| RAV    | resource allocation vector                |
| RSPI   | receiver service period initiated         |
| SAE    | simultaneous authentication of equals     |
| TTL    | time to live                              |

## 5. General description

### 5.2 Components of the IEEE 802.11 architecture

#### 5.2.2 STA membership in a BSS is dynamic

*Change the first paragraph in 5.2.2 as follows:*

A STA's membership in 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 or an IBSS, a STA joins the BSS using the synchronization procedure described in 11.1.3.4. To start a new mesh BSS or to become a member of a mesh BSS, a STA starts beaconing and the synchronization maintenance procedure described in 11C.12. To access all the services of an infrastructure BSS, a STA becomes "associated." These associations are dynamic and involve the use of the distribution system service (DSS), which is described in 5.3.2. A mesh STA does not become associated as there is no central entity in a mesh BSS (MBSS). Instead, a mesh STA peers with other mesh STAs and thereby they form the MBSS.

#### 5.2.3 Distribution system (DS) concepts

##### 5.2.3.1 Extended service set (ESS): The large coverage network

*Change the first paragraph in 5.2.3.1 as follows:*

The DS and BSSs allow IEEE Std 802.11 to create a wireless network of arbitrary size and complexity. IEEE Std 802.11 refers to this type of network as the ESS network. An ESS is the union of the infrastructure BSSs with the same SSID connected by a DS. The ESS does not include the DS.

*Insert the following paragraph after the second paragraph in 5.2.3.1:*

Owing to its distributed nature, a mesh BSS (MBSS) has no central entity like the AP of an infrastructure BSS. Instead, an MBSS forms a single set of independent mesh STAs. This set is undivided and cannot be further unified. Therefore, the ESS concept does not apply to the MBSS.

#### 5.2.6 QoS BSS: The QoS network

*Change the first paragraph in 5.2.6 as follows:*

The IEEE 802.11 QoS facility provides MAC enhancements to support LAN applications with QoS requirements. The QoS enhancements are available to QoS STAs associated with a QoS access point in a QoS BSS. A subset of the QoS enhancements is available for use between STAs that are members of the same QoS IBSS. Similarly, a subset of the QoS enhancements is available for use between neighbor peer mesh STAs. A mesh BSS is one type of QoS BSS and it is described in 5.2.14. Because a non-mesh QoS STA implements a superset of STA functionality, as defined in this standard, the STA might may associate with a non-QoS access point in a non-QoS BSS, to provide non-QoS MAC data service when there is no QoS BSS with which to associate. As a mesh STA does not implement the necessary service, the mesh STA does not associate with any access point.

*Change the third paragraph in 5.2.6 as follows:*

For infrastructure BSS and IBSS, tThis standard provides two mechanisms for the support of applications with QoS requirements.

### 5.2.9 High-throughput (HT) station (STA)

*Insert the following text to the end of the first paragraph in 5.2.9:*

Similarly, a subset of the HT features is available for use between two HT STAs that have established mesh peering (see 7.3.2.56 for details).

*Insert the following new subclause after 5.2.13:*

### 5.2.14 Mesh BSS: IEEE 802.11 wireless mesh network

#### 5.2.14.1 General

The IEEE 802.11 mesh facility provides MAC enhancements to support wireless LAN mesh topologies. The mesh facilities are available to mesh STAs that belong to a mesh BSS (MBSS). For a mesh STA that has not become a member of an MBSS, only the mesh discovery service is available. The enhancements that distinguish mesh STAs from non-mesh STAs are collectively termed the “mesh facility”. The mesh-specific mechanisms vary among implementations.

#### 5.2.14.2 Overview of the mesh BSS

A mesh BSS is an IEEE 802.11 LAN consisting of autonomous STAs. Inside the mesh BSS, all STAs establish peer-to-peer wireless links and transfer messages mutually. Further, using the multi-hop capability, messages can be transferred between STAs that are not in direct communication with each other over a single instance of the wireless medium. From the data delivery point of view, it appears as if all STAs in a mesh BSS are directly connected at the MAC layer even if the STAs are not within range of each other. The multi-hop capability enhances the range of the STAs and benefits wireless LAN deployments.

STAs in a mesh BSS might be sources, sinks, or propagators of traffic; some mesh STAs might only propagate traffic for other STAs. As described in 5.2.14.4, a mesh BSS might have interfaces to external networks and can be utilized as a backhaul for infrastructure BSSs.

Within a mesh BSS, STAs utilize the mesh coordination function (MCF) to access the channel. MCF is based on the core QoS facilities specified in 5.2.6, and a mesh BSS is categorized as one type of QoS BSS. MCF is described in 9.9a.

#### 5.2.14.3 Mesh STA

A STA that belongs to a mesh BSS is termed a “mesh station” (mesh STA). Mesh STAs are QoS STAs that support mesh services, i.e., they participate in formation and operation of a mesh basic service set (MBSS). A mesh STA implements a subset of the QoS functionality:

- Use of QoS frame format
- EDCA (as a part of MCF)
- Block Acknowledgement (optional)
- No Acknowledgement (optional)

A mesh BSS does not incorporate the full hybrid coordinator (HC) and BSS QoS functionality. MBSSs do not incorporate the following:

- HCCA
- Traffic specifications (TSPECs)
- Traffic stream (TS) management
- Admission control

- Automatic power save delivery (APSD)
- Direct-link setup (DLS)
- Tunneled direct-link setup (TDLS)

#### 5.2.14.4 IEEE 802.11 components and mesh BSS

Example mesh and infrastructure BSSs are illustrated in Figure 5-6b. Only mesh STAs participate in mesh functionalities such as formation of the mesh BSS, path selection, and forwarding. Accordingly, a mesh STA is not a member of an IBSS or an infrastructure BSS. Consequently, mesh STAs do not communicate with non-mesh STAs.

However instead of existing independently, an MBSS might also access the distribution system (DS). The MBSS interconnects with other BSSs through the DS. Then, mesh STAs can communicate with non-mesh STAs. Therefore, a logical architectural component is introduced in order to integrate the MBSS with the DS—the mesh gate. Data move between an MBSS and the DS via one or more mesh gates. Thus, the mesh gate is the logical point at which MSDUs from an MBSS enter the IEEE 802.11 DS. Once an MBSS contains a mesh gate that connects it to the IEEE 802.11 DS, the MBSS can be integrated with other infrastructure BSSs too, given that their APs connect to the same DS. Several mesh gates are shown in Figure 5-6b connecting different MBSSs to the DS.

When an MBSS accesses the IEEE 802.11 DS through its mesh gate, the MBSS can be integrated with a non-IEEE-802.11 LAN. To integrate the IEEE 802.11 DS to which this MBSS connects, the DS needs to contain a portal. See 5.2.5. Consequently, mesh gate and portal are different entities. The portal integrates the IEEE 802.11 architecture with a non-IEEE-802.11 LAN (e.g., a traditional wired LAN), whereas the mesh gate integrates the MBSS with the IEEE 802.11 DS.

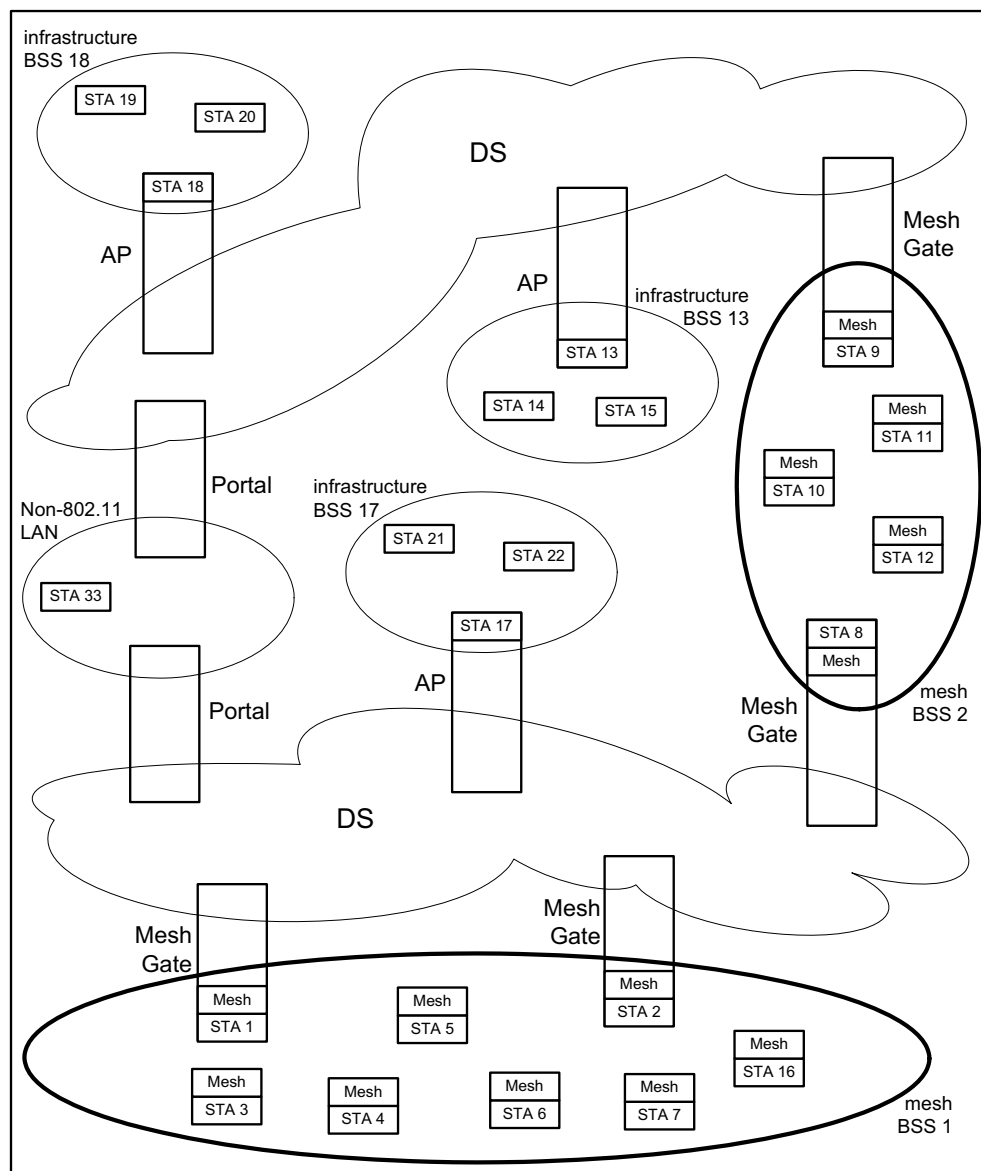


**Figure 5-6b—Example MBSS containing mesh STAs, mesh gates, APs, and portals**

It is possible for one device to offer any combination of the functions of an AP, a portal, and a mesh gate, see 11C.10.5. An example device combining the functions of an AP and a mesh gate is shown in Figure 5-6c. The implementation of such collocated entities is beyond the scope of this standard. The configuration of a mesh gate that is collocated with an access point allows the utilization of the mesh BSS as a distribution system medium. In this case, two different entities (mesh STA and access point) exist in the collocated device and the mesh BSS is hidden to STAs that associate to the access point. The mesh STA collocation is outlined in 11C.10.5, which states that the usage of a distinct MAC address for each collocated STA avoids ambiguities.

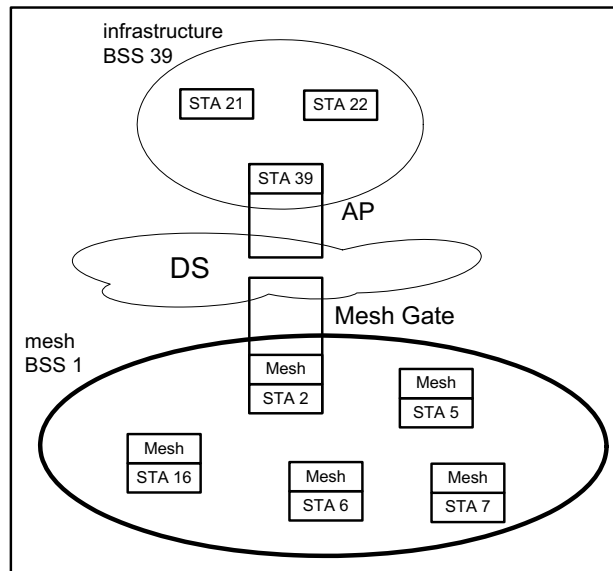


**Figure 5-6c—Example device consisting of mesh STA and AP STA to connect an MBSS and an infrastructure BSS**

#### 5.2.14.5 Introduction to mesh functions

A mesh BSS is formed and operated by the set of services called mesh services. Mesh services are provided by the following major mesh facilities:

- Mesh discovery
- Mesh peering management
- Mesh security
- Mesh beaconing and synchronization
- Mesh coordination function
- Mesh power management
- Mesh channel switching
- Three address, four address, and extended address frame formats
- Mesh path selection and forwarding
- Interworking with external networks
- Intra-mesh congestion control
- Emergency service support in mesh BSS

##### 5.2.14.5.1 Mesh discovery

A mesh STA performs either active scanning or passive scanning to discover an operating mesh BSS. Each mesh STA transmits Beacon frames periodically, and responds with Probe Response frames when a Probe Request frame is received, so that neighbor mesh STAs can perform mesh discovery appropriately. The identification of the mesh BSS is given by the Mesh ID element contained in the Beacon and the Probe Response frames. The details for the mesh discovery facility are described in 11C.2.

#### 5.2.14.5.2 Mesh peering management (MPM)

Within a mesh BSS, direct communication between neighbor mesh STAs is allowed only when they are peer mesh STAs. After mesh discovery, two neighbor mesh STAs agree to establish a mesh peering to each other, and, after successfully establishing the mesh peering, they become peer mesh STAs. A mesh STA can establish a mesh peering with multiple neighbor mesh STAs. The mesh peering management (MPM) facilitates the mesh peering establishment and closure of the mesh peerings. The details of MPM are described in 11C.3.

#### 5.2.14.5.3 Mesh security

In an MBSS, mesh link security protocols are used to authenticate a pair of mesh STAs and to establish session keys between them. Mesh authentication protocols establish a shared, common pairwise master key (PMK), and authenticate a peer mesh STA. The authenticated mesh peering exchange protocol relies on the existence of the PMK between the two mesh STAs to establish an authenticated peering and derive session keys. The details of mesh security are described in 8.2a, 11C.3.3, 11C.5, and 11C.6.

#### 5.2.14.5.4 Mesh beaconing and synchronization

In order to assist mesh discovery, mesh power management, and synchronization in a mesh BSS, all mesh STAs periodically transmit Beacon frames. Synchronization in a mesh BSS is maintained by an active synchronization method. The default synchronization method is the neighbor offset synchronization method. Mesh beacon collision avoidance (MBCA) mitigates collisions of Beacon frames among hidden nodes. The details of mesh beaconing and synchronization are described in 11C.12.

#### 5.2.14.5.5 Mesh coordination function (MCF)

A mesh STA uses the mesh coordination function (MCF) for channel access. MCF consists of EDCA (contention-based channel access defined in 9.9a.2) and MCCA (controlled channel access defined in 9.9a.3). MCCA is a reservation based channel access method and aims to optimize the efficiency of frame exchanges in a mesh BSS.

#### 5.2.14.5.6 Mesh power management

A mesh STA can manage the activity level of its links per mesh peering. A mesh STA sets the activity level of each of its mesh peerings to either active mode, light sleep mode, or deep sleep mode. The mesh STA performs mesh power mode tracking for each of its neighbor peer mesh STAs, and delivers the frames based on the rules defined in 11C.13.

#### 5.2.14.5.7 Mesh channel switching

When a mesh STA switches the operating channel, it uses the channel switch protocol defined in 11.9.7 and 11.9a.3. The channel switch protocol enables the propagation of channel switching messages throughout the mesh BSS, prior to the channel switch execution.

#### 5.2.14.5.8 Frame addressing in an MBSS

Three address, four address, and extended address frame formats enable the distribution of messages over multiple instances of the wireless medium within a mesh BSS and integration to the ESS. Frame format details are described in Clause 7 and 9.22.3.

### 5.2.14.5.9 Mesh path selection and forwarding

Mesh path selection enables path discovery over multiple instances of the wireless medium within a mesh BSS. The overview of the mesh path selection framework is described in 11C.7. The hybrid wireless mesh protocol (HWMP) is defined as the default path selection protocol for the mesh BSS. HWMP provides both proactive path selection and reactive path selection. The details of HWMP are described in 11C.9. The path selection protocol uses link metrics in the assessment of a mesh path to the destination. The airtime link metric is the default link metric. It is defined in 11C.8.

Once the mesh path of a particular pair of the source mesh STA and the destination mesh STA is found through the mesh path selection function, mesh STAs propagate the data by the forwarding function. The details of the forwarding function are described in 9.22.

As a result of the mesh path selection and forwarding, MSDUs are transmitted among all the mesh STAs in a mesh BSS, even if the mesh STAs are not neighbor STAs of each other. Figure 5-6d depicts the MSDU transfer within a mesh BSS.

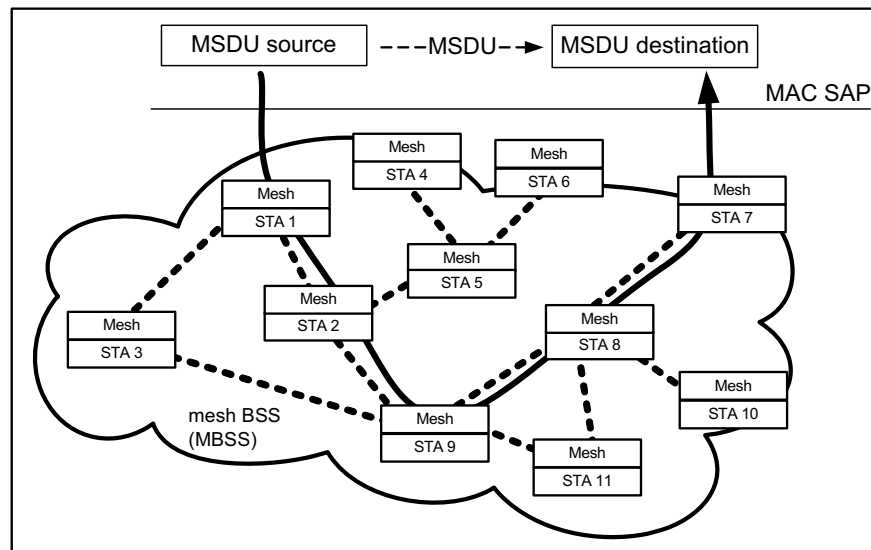


Figure 5-6d—MAC data transport over an MBSS

### 5.2.14.5.10 Interworking with the DS

A mesh BSS might contain one or more mesh gates that connect to one or more distribution systems. A mesh gate can announce its presence in the mesh BSS by sending Gate Announcement frames. Alternatively a mesh gate can announce its presence in the mesh BSS by sending HWMP Path Selection frames with the Root Announcement element or the Path Request element indicating mesh gate announcement, when it is configured as a root mesh STA. Typically a mesh gate announces its presence when it is collocated with a portal or it has access to a portal. Gate announcements allow mesh STAs to select the appropriate mesh gate and build a path towards it. It should be noted that, when multiple mesh gates that have access to the same DS are present in the mesh BSS, proper configuration is necessary.

When a mesh gate has access to IEEE 802 STAs outside the mesh BSS, the mesh gate acts as a proxy for the IEEE 802 STAs outside the MBSS. Such a mesh gate is called a proxy mesh gate. The details of the proxy functionality are described in 11C.10.3.

The details of the mesh BSS interworking are described in 11C.10.

#### 5.2.14.5.11 Intra-mesh congestion control

Intra-mesh congestion control is used to provide flow control over the multi-hop communication. Intra-mesh congestion control is useful to mitigate wasteful wireless medium utilization caused by buffer overflow at mesh STAs. Intra-mesh congestion control consists of three main mechanisms: local congestion monitoring and congestion detection, congestion control signaling, and local rate control. The details of the intra-mesh congestion control are described in 11C.11.

#### 5.2.14.5.12 Emergency service support in mesh BSS

Depending on regulations, emergency services support might be mandated over the mesh network. In this case the Beacon and Probe Response frames inform whether a mesh STA supports emergency services, advertising to other mesh STAs that mesh peering for emergency services is possible. If a mesh STA subsequently requires emergency services, an emergency indication is then set within the Mesh Peering Open frame. Mesh STAs that support emergency services, accept peering from other mesh STAs requiring emergency services, transferring frames to an emergency server (such as a PSAP).

### 5.3 Logical service interfaces

#### 5.3.2 DSS

*Change the second and the third paragraphs 5.3.2 as follows:*

This service is represented in the IEEE 802.11 architecture by arrows within ~~the~~ APs and mesh gates, indicating that the service is used to cross media and possibly address space logical boundaries. An AP and a mesh gate ~~are is a logical entities entity~~, and the functions described may be shared by one or more physical entities.

The services that comprise the DSS are as follows:

- a) Association (not mesh facility)
- b) Disassociation (not mesh facility)
- c) Distribution
- d) Integration
- e) Reassociation (not mesh facility)
- f) QoS traffic scheduling (QoS facility only)
- g) Interworking with the DS (mesh facility only)

### 5.4 Overview of the services

#### 5.4.1 Distribution of messages within a DS

##### 5.4.1.1 Distribution

*Change the sixth paragraph in 5.4.1.1 as follows:*

While IEEE Std 802.11 does not specify DS implementations, it does recognize and support the use of the WM as ~~the one possible~~ DSM. This is specifically supported by the IEEE 802.11 frame formats. (Refer to Clause 7 for details.) A mesh BSS might form an entire DS or a part of a DS using the WM, as shown in

Figure 5-6b. Mesh services are used to form a mesh BSS and distribute messages. Clause 11C defines how mesh BSSs are formed and how messages are distributed through a mesh BSS.

### 5.4.3 Access control and data confidentiality services

#### 5.4.3.1 Authentication

*Change the third and fourth paragraph in 5.4.3.1 as follows:*

IEEE Std 802.11 defines ~~three~~ four authentication methods: Open System authentication, Shared Key authentication, ~~and FT authentication, and simultaneous authentication of equals (SAE).~~ Open System authentication admits any STA to the DS. Shared Key authentication relies on WEP to demonstrate knowledge of a WEP encryption key. FT authentication relies on keys derived during the initial mobility domain association to authenticate the stations as defined in Clause 11A. SAE authentication uses finite field cryptography to prove knowledge of a shared password. The IEEE 802.11 authentication mechanism also allows definition of new authentication methods.

An RSNA might support SAE authentication. An RSNA also supports authentication based on IEEE Std 802.1X-2004, or preshared keys (PSKs) after Open System authentication. IEEE 802.1X authentication utilizes the EAP to authenticate STAs and the AS with one another. This standard does not specify an EAP method that is mandatory to implement. See 8.4.4 (RSNA policy selection in an IBSS and for DLS) for a description of the IEEE 802.1X authentication and PSK usage within an IEEE 802.11 IBSS.

*Change the sixth paragraph in 5.4.3.1 as follows:*

Either SAE authentication or ~~the~~ Open System authentication algorithm is used in RSNs based on infrastructure BSS and IBSS, although Open System authentication is optional in an RSN based on an IBSS. SAE authentication is used in an MBSS. RSNA disallows the use of Shared Key authentication.

*Change the eighth and ninth paragraph in 5.4.3.1 as follows:*

Because the IEEE 802.1X authentication process could be time-consuming (depending on the authentication protocol in use), the authentication service can be invoked independently of the association service.

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

*Insert the following paragraph to the end of 5.4.3.1:*

SAE authentication is performed prior to association and a STA can take advantage of the fact that it can be IEEE 802.11 authenticated to many APs simultaneously by completing the SAE protocol with any number of APs while still being associated to another AP. RSNA security can be established after association using the resulting shared key.

#### 5.4.3.2 Deauthentication

*Change the first paragraph in 5.4.3.2 as follows:*

The deauthentication service is invoked when an existing Open System ~~or~~, Shared Key, or SAE authentication is to be terminated. Deauthentication is an SS.

*Insert the following paragraph after the first paragraph in 5.4.3.2:*

When the deauthentication service is terminating SAE authentication any PTKSA, GTKSA, mesh TKSA, or mesh GTKSA related to this SAE authentication is destroyed. If PMK caching is not enabled, deauthentication also destroys any PMKSA created as a result of this successful SAE authentication.

#### 5.4.3.3 Data confidentiality

*Insert the following paragraph after the fourth paragraph in 5.4.3.3:*

IEEE Std 802.11 provides one security protocol, Counter mode with Cipher-block chaining Message authentication code Protocol (CCMP), for protection of individually addressed and group addressed data frames between mesh STAs.

*Insert the following new subclause after 5.6:*

### 5.6a Differences between ESS and MBSS LANs

In 5.2.14, the concept of the MBSS LAN was introduced. It was noted that using the multi-hop capability it appears as if all mesh STAs are directly connected at the MAC layer even if the STAs are not within range of each other. This is different from an IBSS network, where STAs cannot communicate if they are not within range of each other.

Unlike the IBSS, an MBSS might have access to the DS. An MBSS connects through one or more mesh gates to the DS. Since in an MBSS it appears as if all mesh STAs are directly connected at the MAC layer, the MBSS can be used as a DSM. APs, portals, and mesh gates might use the MBSS as a DSM to provide the DSS. Thus, different infrastructure BSSs can unite over the MBSS to form an ESS for example.

An AP identifies the infrastructure BSS that it forms. This is different from the MBSS where no such central entity exists. Whereas infrastructure BSSs need the ESS and thus the DS to unite, the MBSS network appears the same to an LLC layer without the need for access to a DS. However, if an MBSS has one or more mesh gates providing access to the DS, the MBSS might exist in disjointed areas and yet form a single network.

## 5.8 IEEE Std 802.11 and IEEE Std 802.1X-2004

### 5.8.2 Infrastructure functional model overview

*Change the first paragraph in 5.8.2 as follows:*

This subclause summarizes the system setup and operation of an RSN, in ~~three~~ two cases: when a password or PSK is used during IEEE 802.11 authentication, when an IEEE 802.1X AS is used after Open System authentication, and when a PSK is used after Open System authentication. For an ESS, the AP includes an Authenticator, and each associated STA includes a Supplicant.

*Insert the following new subclause after 5.8.2.1:*

#### 5.8.2.1a AKM Operations with a Password or PSK

The following AKM operations are carried out when authentication is accomplished using a Password or PSK:

- A STA discovers the AP's security policy through passively monitoring the Beacon frames or through active probing. After discovery the STA performs SAE authentication using IEEE 802.11 Authentication frames with the AP (see Figure 5-14a).

- Upon the successful conclusion of SAE, both the STA and AP generate a PMK. The STA then associates to an AP and negotiate security policy. The AKM confirmed in the Association Request and Response is the AKM of SAE or Fast BSS Transition.
- The PMK generated by SAE is used in a 4-Way Handshake using EAPOL-Key frames, just as with IEEE 802.1X authentication when an AS is present. See Figure 5-13.
- The GTK and GTK sequence number are sent from the Authenticator to the Supplicant just as in the AS case. See Figure 5-13 and Figure 5-14.

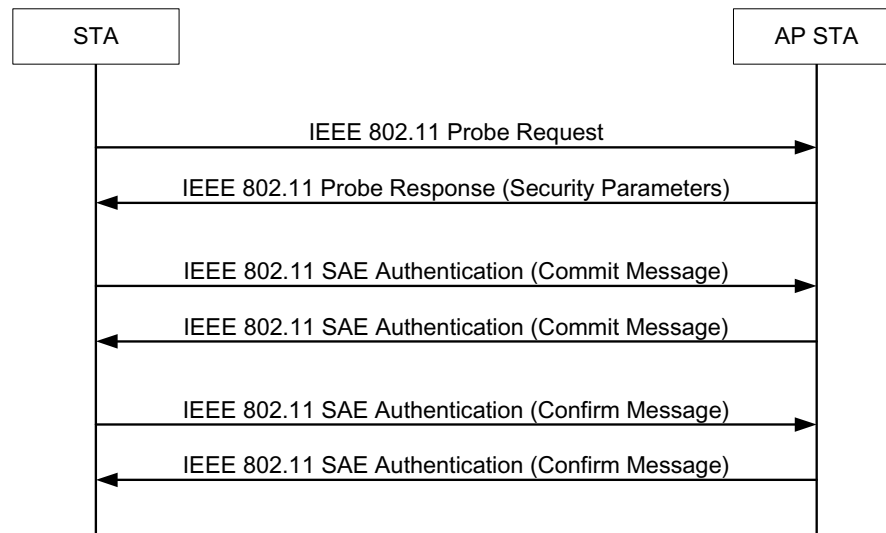


Figure 5-14a—Example using SAE Authentication

*Change the title of 5.8.2.2 as follows:*

### 5.8.2.2 Alternate Operations with PSK

*Change the first paragraph in 5.8.2.2 as follows:*

The following AKM operations ~~are~~ represent an alternate operation of using a PSK. This operation has security vulnerabilities when used with a low-entropy key and is recommended to be used only after taking that into account. When this operation is carried out, when the PMK is a PSK.

## 5.8.3 IBSS functional model description

### 5.8.3.2 Sample IBSS 4-Way Handshake

*Change the ninth paragraph in 5.8.3.2 as follows:*

If a fourth STA comes within range and its SME decides to initiate a security association with the three peers, its Authenticator initiates 4-Way Handshakes with each of the other three Supplicants. Similarly, the original three STA Authenticators in the IBSS need to initiate 4-Way Handshakes to the fourth STA Supplicant. A STA learns that a peer STA is RSNA-enabled and the peer's security policy [e.g., whether the Authentication and Key Management Protocol (AKMP) is SAE, PSK, or IEEE 802.1X authentication] from the Beacon or Probe Response frame. The initiation ~~might~~ may start for a number of reasons:

6. MAC service definition

6.1 Overview of MAC services

6.1.2 Security services

Insert the following paragraph to the end of 6.1.2:

A mesh STA with dot11MeshSecurityActivated equal to true shall not use the pairwise cipher suite selectors WEP-40, WEP-104, and TKIP.

6.1.5 MAC data service architecture

Replace Figure 6-1 with the following figure:

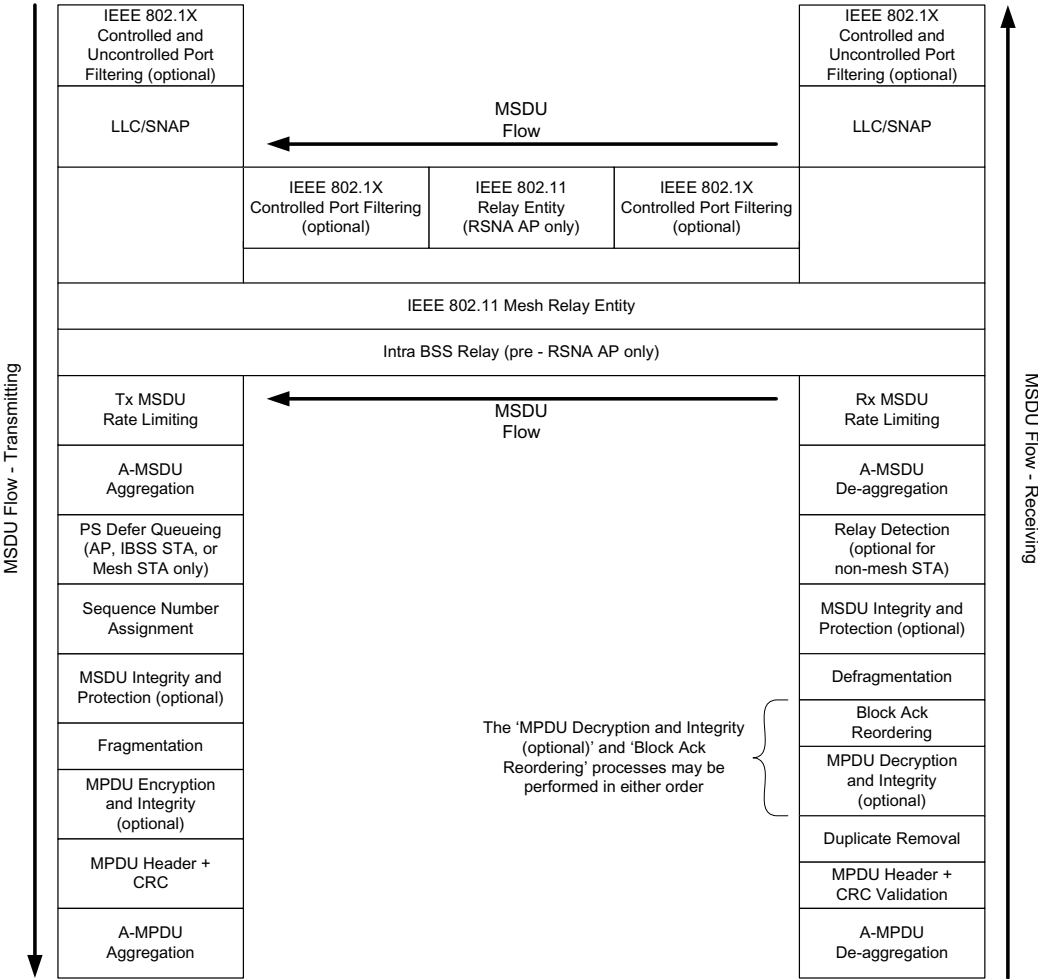


Figure 6-1—MAC data plane architecture

## 7. Frame formats

### 7.1 MAC frame formats

#### 7.1.1 Conventions

*Insert the following paragraph after the seventh paragraph in 7.1.1:*

A QoS Data frame that is transmitted by a mesh STA is referred to as a Mesh Data frame.

#### 7.1.2 General frame format

*Change the second paragraph in 7.1.2 as follows:*

The Frame Body field is of variable size. The maximum frame body size is determined by the maximum MSDU size (2304 octets) plus the length of the Mesh Control field (6, 12, or 18 octets) if present, or the maximum A-MSDU size (3839 or 7935 octets, depending upon the STA's capability), plus any overhead from security encapsulation.

#### 7.1.3 Frame fields

##### 7.1.3.1 Frame Control field

##### 7.1.3.1.3 To DS and From DS fields

*Change third and fourth row of Table 7-2 as follows:*

**Table 7-2—To/From DS combinations in data frames**

| To DS and From DS values | Meaning                                                                                                                                                                                             |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| To DS = 0<br>From DS = 1 | A data frame exiting the DS or being sent by the Port Access Entity in an AP, <u>or a group addressed Mesh Data frame with Mesh Control field present using the three-address MAC header format</u> |
| To DS = 1<br>From DS = 1 | A data frame using the four-address <u>MAC header</u> format. This standard <del>does not</del> defines procedures for using this combination of field values <u>only in a mesh BSS</u>             |

##### 7.1.3.1.6 Power Management field

*Change 7.1.3.1.6 as follows:*

The Power Management field is 1 bit in length and is used to indicate the power management mode of a STA. The value of this field remains constant in each frame from a particular STA within a frame exchange sequence (see Annex S). The value indicates the mode in which the station will be after the successful completion of the frame exchange sequence.

In an infrastructure BSS or in an IBSS the following applies:

A value of 1 indicates that the STA will be in PS mode. A value of 0 indicates that the STA will be in active mode. This field is always set to 0 in frames transmitted by an AP.

In an MBSS the following applies:

A value of 0 in group addressed frames, in management frames transmitted to non-peer STAs, and in Probe Response frames indicates that the mesh STA will be in active mode towards all neighbor mesh STAs. A value of 1 in group addressed frames, in management frames transmitted to non-peer STAs, and in Probe Response frames indicates that the mesh STA will be in deep sleep mode towards all non-peer mesh power STAs.

A value of 0 in individually addressed frames transmitted to a peer mesh STA indicates that the mesh STA will be in active mode towards this peer mesh STA. A value of 1 in individually addressed frames transmitted to a peer mesh STA, except Probe Response frames, indicates that the mesh STA will be in either light sleep mode or deep sleep mode towards this peer mesh STA. When the QoS Control field is present in the frame, the Mesh Power Save Level subfield in the QoS Control field indicates whether the mesh STA will be in light sleep mode or in deep sleep mode for the recipient mesh STA as specified in 7.1.3.5.10.

The mesh power mode transition rules are described in 11C.13.3.

#### **7.1.3.1.7 More Data field**

*Insert the following paragraph after the third paragraph (starting with “For a STA with TDLS peer PSM enabled”, which is added by IEEE 802.11z) of 7.1.3.1.7:*

The More Data field is 1 in individually addressed frames transmitted by a mesh STA to a peer mesh STA that is either in light sleep mode or in deep sleep mode for the corresponding mesh peering, when additional BUs remain to be transmitted to this peer mesh STA.

*Insert the following paragraph to the end of 7.1.3.1.7:*

The More Data field is 1 in group addressed frames transmitted by a mesh STA when additional group addressed BUs remain to be transmitted. The More Data field is 0 in group addressed frames transmitted by a mesh STA when no more group addressed BUs remain to be transmitted.

#### **7.1.3.5 QoS Control field**

*Change the first paragraph of 7.1.3.5 as follows:*

The QoS Control field is a 16-bit field that identifies the TC or TS to which the frame belongs ~~and as well as~~ various other QoS-related, A-MSDU related, and mesh-related information about the frame that varies by frame type, ~~and subtype, and type of transmitting STA~~. The QoS Control field is present in all data frames in which the QoS subfield of the Subtype field is set to 1 (see 7.1.3.1.2). Each QoS Control field comprises five or eight subfields, as defined for the particular sender (HC, or non-AP STA, or mesh STA) and frame type and subtype. The usage of these subfields and the various possible layouts of the QoS Control field are described in 7.1.3.5.1 to ~~7.1.3.5.8~~ 7.1.3.5.11 and illustrated in Table 7-4.

*Change Table 7-4 as follows:*

**Table 7-4—QoS Control field**

| Applicable frame (sub) types                                                                                                    | Bits 0–3   | Bit 4       | Bits 5–6          | Bit 7                 | Bit 8                       | Bit 9                        | Bit 10      | Bits 11–15      |
|---------------------------------------------------------------------------------------------------------------------------------|------------|-------------|-------------------|-----------------------|-----------------------------|------------------------------|-------------|-----------------|
| QoS CF-Poll and QoS CF-Ack+CF-Poll frames sent by HC                                                                            | TID        | EOSP        | Ack Policy        | Reserved              | TXOP Limit                  |                              |             |                 |
| QoS Data+CF-Poll and QoS Data+CF-Ack+CF-Poll frames sent by HC                                                                  | TID        | EOSP        | Ack Policy        | A-MSDU Present        | TXOP Limit                  |                              |             |                 |
| QoS Data and QoS Data+CF-Ack frames sent by HC                                                                                  | TID        | EOSP        | Ack Policy        | A-MSDU Present        | AP PS Buffer State          |                              |             |                 |
| QoS Null frames sent by HC                                                                                                      | TID        | EOSP        | Ack Policy        | Reserved              | AP PS Buffer State          |                              |             |                 |
| QoS Data and QoS Data+CF-Ack frames sent by non-AP STAs that are not a PU buffer STA or a PU sleep STA <u>in a non-mesh BSS</u> | TID        | 0           | Ack Policy        | A-MSDU Present        | TXOP duration requested     |                              |             |                 |
|                                                                                                                                 | TID        | 1           | Ack Policy        | A-MSDU Present        | Queue size                  |                              |             |                 |
| QoS Null frames sent by non-AP STAs that are not a PU buffer STA or a PU sleep STA <u>in a non-mesh BSS</u>                     | TID        | 0           | Ack Policy        | Reserved              | TXOP duration requested     |                              |             |                 |
|                                                                                                                                 | TID        | 1           | Ack Policy        | Reserved              | Queue Size                  |                              |             |                 |
| QoS Data and QoS Data+CF-Ack frames sent by PU buffer STAs <u>in a non-mesh BSS</u>                                             | TID        | EOSP        | Ack Policy        | A-MSDU Present        | Reserved                    |                              |             |                 |
| QoS Null frames sent by PU buffer STAs <u>in a non-mesh BSS</u>                                                                 | TID        | EOSP        | Ack Policy        | Reserved              | Reserved                    |                              |             |                 |
| QoS Data and QoS Data+CF-Ack frames sent by PU sleep STAs <u>in a non-mesh BSS</u>                                              | TID        | Reserved    | Ack Policy        | A-MSDU Present        | Reserved                    |                              |             |                 |
| QoS Null frames sent by PU sleep STAs <u>in a non-mesh BSS</u>                                                                  | TID        | Reserved    | Ack Policy        | Reserved              | Reserved                    |                              |             |                 |
| <u>All frames sent by mesh STAs in a mesh BSS</u>                                                                               | <u>TID</u> | <u>EOSP</u> | <u>Ack Policy</u> | <u>A-MSDU Present</u> | <u>Mesh Control Present</u> | <u>Mesh Power Save Level</u> | <u>RSPI</u> | <u>Reserved</u> |

#### 7.1.3.5.2 EOSP (end of service period) subfield

*Insert the following paragraph to the end of 7.1.3.5.2:*

The mesh STA uses the EOSP subfield to indicate the end of the current mesh peer service period (MPSP) in which it operates as the owner. The mesh STA sets the EOSP subfield to 1 in its transmission and retransmissions of the MPSP's final frame to end an MPSP, and sets it to 0 otherwise. See 11C.13.9.4 for details.

### 7.1.3.5.3 Ack Policy subfield

*Change the first (Bit5:0, Bit6:0) and the second (Bit5:1, Bit6:0) row of the Table 7-6 as follows:*

**Table 7-6—Ack Policy subfield in QoS Control field of QoS data frames**

| Bits in QoS Control field |       | Meaning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|---------------------------|-------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Bit 5                     | Bit 6 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 0                         | 0     | <p>Normal Ack or Implicit Block Ack Request.</p> <p>In a frame that is a non-A-MPDU frame: The addressed recipient returns an ACK or QoS +CF-Ack frame after a short interframe space (SIFS) period, according to the procedures defined in 9.2.0b.9 and 9.9.2.3. <u>If dot11MCCAActivated is false, For QoS Null (no data) frames, this is the only permissible value for the Ack Policy subfield for QoS Null (no data) frames.</u></p> <p>In a frame that is part of an A-MPDU: The addressed recipient returns a Block-Ack MPDU, either individually or as part of an A-MPDU starting a SIFS after the PPDU carrying the frame, according to the procedures defined in 9.2.0b.10, 9.10.7.5, 9.10.8.3, 9.15.4, and 9.19.3.</p> |
| 1                         | 0     | <p>No Ack The addressed recipient takes no action upon receipt of the frame. More de-tails are provided in 9.11. The Ack Policy subfield is set to this value in all directed frames in which the sender does not require acknowledgment. This combination is also used for group addressed frames that use the QoS frame format. This combination is not used for QoS data frames with a TID for which a Block Ack agreement exists.</p> <p><u>If dot11MCCAActivated is true this value is permissible for the Ack Policy subfield for group addressed QoS Null (no data) frames.</u></p>                                                                                                                                        |

*Insert the following new subclauses after 7.1.3.5.8:*

### 7.1.3.5.9 Mesh Control Present subfield

The Mesh Control Present subfield is 1 bit in length, and indicates the presence of a Mesh Control field in the frame body. When the Mesh Control Present subfield is 1, the Frame Body field contains a Mesh Control field as defined in 7.1.3.6.3. The mesh STA sets the Mesh Control Present subfield to 1 in the Mesh Data frame containing an unfragmented MSDU, an A-MSDU, or the first fragment of an MSDU.

### 7.1.3.5.10 Mesh Power Save Level subfield

The Mesh Power Save Level subfield is 1 bit in length and indicates whether the mesh STA's peer-specific mesh power mode will be deep sleep mode or light sleep mode after the successful completion of the frame exchange sequence.

When the Power Management field in the Frame Control field in the frame is 1, the following applies:

In individually addressed Mesh Data frames, a value of 0 indicates that the mesh STA's peer-specific mesh power mode for the recipient mesh STA will be light sleep mode (see 11C.13.8.4). In individually addressed Mesh Data frames, a value of 1 indicates that the mesh STA's peer-specific mesh power mode for the recipient mesh STA will be deep sleep mode (see 11C.13.8.5).

In group addressed Mesh Data frames, a value of 0 indicates that none of the peer-specific mesh power modes of the mesh STA will be deep sleep mode. In group addressed Mesh Data frames, a value of 1 indicates that at least one of the peer-specific mesh power modes of the mesh STA is deep sleep mode.