



IEEE Trial-Use Standard for Wireless Access in Vehicular Environments (WAVE)—Multi-channel Operation

IEEE Vehicular Technology Society

Sponsored by the
Intelligent Transportation Systems Committee

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IEEE Trial-Use Standard for Wireless Access in Vehicular Environments (WAVE)—Multi-channel Operation

Sponsor

**Intelligent Transportation Systems Committee
of the
IEEE Vehicular Technology Society**

Approved 30 October 2006

IEEE-SA Standards Board

Abstract: Multi-channel operation is an extension to the IEEE 802.11™ WAVE mode that describes how to support a multi-channel system with the IEEE 802.11 medium access control (MAC) and physical layers (PHYs) via a control channel (CCH) and multiple service channels (SCHs). Specifically, the multi-channel operation (channel coordination) provides mechanisms for prioritized access, channel routing and coordination, and data transmission.

Keywords: channel coordination, multi-channel operation, OBU, RSU, user priority, WAVE, wireless access in vehicular environments

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Introduction

This introduction is not part of IEEE Std 1609.4-2006, IEEE Trial-Use Standard for Wireless Access in Vehicular Environments (WAVE)—Multi-channel Operation.

A WAVE system is a radio communications system intended to provide seamless, interoperable services to transportation. These services include those recognized by the U.S. National Intelligent Transportation Systems (ITS) Architecture [B3]^a and many others contemplated by the automotive and transportation infrastructure industries. These services include vehicle-to-roadside as well as vehicle-to-vehicle communications. Networking services provides data delivery services between WAVE devices and management services to all layers. This is but one component in the overall WAVE architecture, which includes IEEE P1609.1TM, IEEE Std 1609.2TM,^b IEEE P1609.3TM, and IEEE P802.11pTM.

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^aThe numbers in brackets correspond to those of the bibliography in Annex A.

^bInformation on references can be found in Clause 2.

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IEEE Trial-Use Standard for Wireless Access in Vehicular Environments (WAVE)—Multi-channel Operation

1. Overview

1.1 Scope

This standard describes multi-channel wireless radio operations, WAVE mode, medium access control (MAC) and physical layers (PHYs), including the operation of control channel (CCH) and service channel (SCH) interval timers, parameters for priority access, channel switching and routing, management services, and primitives designed for multi-channel operations.

1.2 Purpose

To enable effective mechanisms that control the operation of upper layer across multiple channels, without requiring knowledge of PHY parameters, and describe the multi-channel¹ operation channel routing and switching for different scenarios.

2. Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std 802.11TM, 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.^{2, 3}

¹A *channel* is defined as a physical channel specified in IEEE Std 802.11, as amended by IEEE P802.11pTM. WAVE devices may implement a multi-channel or multi-radio capability in future standards or non-standardized implementations. Multi-radio/channel implementations are permitted, but are outside the scope of this standard.

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IEEE P802.11™-REVma (Draft 8.0, August 2006), Draft Standard for Information Technology—Telecommunications and information exchange between systems—Local and metropolitan area network—Specific requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications.⁴

IEEE P802.11p™ (Draft 1.3, September 2006) Draft 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: Wireless Access in Vehicular Environments (WAVE).

IEEE P1609.3™ (Draft 19, March 2006), Draft Standard for Wireless Access in Vehicular Environments (WAVE) Networking Services.

IEEE Std 802.2™/ISO/IEC 8802-2, Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 2: Logical Link Control.

IEEE Std 1609.2™, IEEE Trial-Use Standard for Wireless Access in Vehicular Environments—Security Services for Applications and Management Messages.

ISO/IEC 8824-1, Information technology—Abstract Syntax Notation One (ASN.1): Specification of basic notation.⁵

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

RFC 1042, A standard for the transmission of IP datagrams over IEEE 802® networks.⁶

3. Definitions, abbreviations, and acronyms

3.1 Definitions

For the purpose of this document, the following terms and definitions apply. The glossary in Annex E or *The Authoritative Dictionary of IEEE Standards Terms* [B1]⁷ should be referenced for terms not defined in this clause.

3.1.1 communications zone: The space within which one device can communicate with another device. As these devices may have differing effective ranges of operation, the communication zone will be limited to the smallest operating range for the devices involved.

3.1.2 control channel (CCH): A radio channel used for exchange of management frames and WAVE short messages (WSMs).

⁴Numbers preceded by P are IEEE authorized standards projects that were not approved by the IEEE-SA Standards Board at the time this publication went to press. For information about obtaining drafts, contact the IEEE.

⁵ISO/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/>). ISO/IEC publications are also available in the United States from Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>). Electronic copies are available in the United States from the American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

⁶IETF publications are available from <http://www.ietf.org/>.

⁷The numbers in brackets correspond to those of the bibliography in Annex A.

3.1.3 EtherType: The Ethernet type field defined in RFC 1042,⁸ used to identify the higher layer protocol above logical link control (LLC).

3.1.4 onboard unit (OBU): A WAVE device that can operate when in motion and supports the information exchange with roadside units (RSUs) or other OBUs.

3.1.5 provider: Initiator of a WAVE basic service set (WBSS), or sender of WSMs.

3.1.6 roadside unit (RSU): A WAVE device that operates only when stationary and supports information exchange with OBUs.⁹

3.1.7 secured WSA: The WAVE service advertisement (WSA) signed by the security services specified in IEEE Std 1609.2 and IEEE P1609.3.

3.1.8 service channel (SCH): Secondary channels used for application specific information exchanges.

3.1.9 transmitter profile: A data object containing communication parameters to be used by the transmitter, including SCH number, power level, data rate and the adaptable status of power level, and data rate for Internet Protocol (IP)-based applications.

3.1.10 user: A device that acts on the received WAVE announcement action frames.

3.1.11 WAVE basic service set (WBSS): A set of two or more WAVE devices participating in communications among each other on an SCH. A WBSS is initiated by a WAVE device using a WAVE announcement action frame on the CCH.

3.1.12 WAVE device: A device that contains an implementation of the WAVE protocol standards, including IEEE Std 1609.2, IEEE P1609.3, IEEE Std 1609.4, and IEEE P802.11p.

3.1.13 WAVE management entity (WME): The set of management functions required to provide WAVE networking services. It is specified in IEEE P1609.3.

3.1.14 WAVE service advertisement (WSA): Configuration data, collected by the WME, identifying WAVE applications and associated network parameters.

3.1.15 WAVE service information element (WSIE): A field in a WAVE announcement action frame used to advertise the WAVE services being offered. The WSIE is comprised of a secured WSA, timing quality, and in the case of the RSU, the WAVE routing advertisement.

3.1.16 WAVE short message (WSM): A message specifically designed to operate in the WAVE band. It can be exchanged directly among WAVE devices without the overhead of IP or management associated with initiating a WBSS.

3.1.17 WAVE short message protocol (WSMP): The protocol used for WAVE short messages.

3.2 Abbreviations and acronyms

AC access category

ACI access category index

⁸Information on references can be found in Clause 2.

⁹Inter-RSU communications using WAVE may be subject to the rules of the regulatory domain.

AIFS	arbitration inter-frame space
AIFSN	AIFS Number
CCH	control channel
CW	contention window
DA	destination address
DIFS	distributed (coordination function) interframe space
EDCA	Enhanced Distributed Channel Access
GPS	Global Positioning System
IP	Internet Protocol
LLC	logical link control
MAC	medium access control
MIB	management information base
MLME	MAC sublayer management entity
MPDU	MAC protocol data unit
MSDU	MAC service data unit
OBU	onboard unit
PDU	protocol data unit
PHY	physical layer
PLME	PHY sublayer management entity
PPS	pulse per second
RCPI	received channel power indicator
RSU	roadside unit
SA	source address
SAP	service access point
SCH	service channel
SNAP	subnetwork access protocol
TSF	time synchronization function

TU	time unit
TXOP	transmit opportunity
UP	user priority
UTC	Coordinated Universal Time
WAVE	wireless access in vehicular environments
WBSS	WAVE basic service set
WME	WAVE management entity
WSA	WAVE service advertisement
WSIE	WAVE service information element
WSM	WAVE short message
WSMP	WAVE short message protocol

4. General description

WAVE devices shall be able to accommodate an architecture that supports a CCH and multiple SCHs. The CCH is used to transmit WSMs and announce WAVE services; the SCHs are used for application interactions/transmissions. The specific designations of these channels and the specification of the PHY are defined in IEEE Std 802.11, as amended by IEEE P802.11p.

In a WAVE system, there are two types of devices: *roadside units* (RSUs) and *onboard units* (OBUs). An RSU is a WAVE device that operates at a fixed position (usually along the road transport network) that supports communication and data exchange with OBUs. An OBU is a mobile or portable WAVE device that supports information exchange with RSUs and other OBUs. Upon startup, a device monitors the CCH (see IEEE P1609.3) until a WAVE service advertisement (WSA) is received that announces a service that utilizes an SCH, or the device chooses to utilize the SCH based on WAVE announcement frames it transmits. WAVE devices must also monitor the CCH for additional safety or private service advertisements during specific intervals known as *control channel intervals* (CCH intervals). If suspension of transactions in progress on an SCH is necessary when CCH monitoring is required, the data exchange may be resumed when CCH monitoring is no longer required (i.e., when the device can return to the SCH). This may occur, for example, in a single channel device that can perform exchanges on only one RF channel at a time, and in this case, it is recommended that a means be implemented to support buffering data packets while monitoring the CCH until the device can return to the SCH to complete transactions in progress.

To accommodate devices that want exchange data on SCHs, but can not monitor the CCH while doing so, synchronization is necessary. Synchronization is the procedure by which a device adopts the time reference of another source of time. In addition to being synchronized to each other, such devices must also know when it is permissible to cease monitoring the CCH, and for this purpose, CCH and SCH intervals are uniquely defined with respect to an absolute external time reference, Coordinated Universal Time (UTC). UTC is commonly provided by Global Positioning Systems (GPS); however, the time base accuracy requirements for WAVE devices are sufficiently lenient that management frames containing UTC time estimates from other devices can be used as well. Once synchronized, single-channel devices can ensure they meet the requirement to be monitoring the CCH during specified CCH intervals. It is important to note

that synchronization is not required to make data exchanges on SCHs. While synchronization is optional, internal time base generation is required for security purposes (see IEEE Std 1609.2).

4.1 Reference model

The basic reference model relevant to this standard is shown in Figure 1. A WAVE system supports both IP and non-IP based applications. Non-IP based applications are supported through the WAVE short message protocol (WSMP) defined in IEEE P1609.3.

This standard presents the architectural view, emphasizing the multi-channel coordination of the system. The channel coordination is an enhancement to the IEEE 802.11 MAC and interacts with the IEEE 802.2 logical link control (LLC) and IEEE P802.11p PHY. The WAVE management entity (WME) and corresponding network services are specified in IEEE P1609.3.

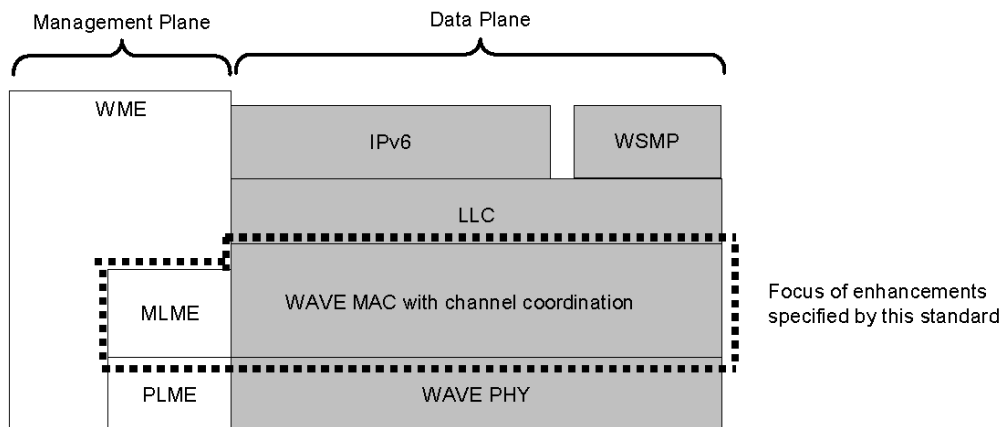


Figure 1—The reference model relevant to IEEE Std 1609.4

4.2 Overview of the services

The services provided by this standard, IEEE Std 1609.4, are used to manage channel coordination and to support MAC service data unit (MSDU) delivery.

4.2.1 Channel routing

This service controls the routing of data packets from the LLC to the designated channel within channel coordination operations in the MAC layer. This procedure is specified in 7.2.

4.2.2 User priority

IEEE Std 1609.4 supports a variety of safety and non-safety applications with up to 8 levels of priority as defined in IEEE P1609.3 and IEEE P802.11-REVma. The user priority (UP) is used to contend for medium access using Enhanced Distributed Channel Access (EDCA) functionality derived from IEEE P802.11-REVma. The procedures for utilizing the EDCA are specified in 6.3.

4.2.3 Channel coordination

This service coordinates the channel intervals according to the channel synchronization operations of the MAC layer so that data packets from the MAC are transmitted on the proper RF channel. This procedure is specified in 6.4.

4.2.4 MSDU data transfer

4.2.4.1 Control channel data transfer

WAVE short messages (WSMs) conforming to the WSMP can be exchanged directly among devices on the CCH. Transmission of IP datagrams is not permitted on the CCH.

4.2.4.2 Service channel data transfer

In order to initiate communications on an SCH, an RSU or an OBU transmits WAVE announcement action frames on the CCH to advertise offered services available on that SCH; such a device is the initiator of a WBSS called a *provider*. An OBU receives the announcement on the CCH and generally establishes communications with the provider on the specified SCH; such a device is called a *user*. The provider-user relationship can support either WSMP or IP-based applications; however, such a relationship only occurs on an SCH.

4.2.4.3 Data transfer services

Channel coordination does not change the format of the MAC data services defined in IEEE Std 802.11. The IEEE 802.11 MAC supports the following data service primitives between the LLC and MAC:

- MA-UNITDATA.request: This primitive requests a transfer of an MSDU from the local LLC sublayer to one or more peer LLC sublayer entities as defined in IEEE Std 802.11.
- MA-UNITDATA.indication: This primitive indicates the transfer of an MSDU from the MAC sublayer entity to the LLC sublayer entity as defined in IEEE Std 802.11.
- MA-UNITDATA-STATUS.indication: This primitive provides the LLC sublayer with status information for the corresponding preceding MA-UNITDATA.request primitive as defined in IEEE Std 802.11.

5. Frame formats

The general frame formats of MSDUs and management frames used by the MAC sublayer are described in IEEE Std 802.11. However, to support both WSMP and IP datagrams, the MAC shall be able to identify the type of a data packet indicated by its EtherType. For WSMs, the channel, transmit power, and data rate are specified in the WSMP header and may be modified on a per-message basis (see 6.2.1). For IP datagrams, the channel, transmit power, and data rate to be used are stored in a transmitter profile as described in 7.3.3.

5.1 Use of EtherType

For multiple protocols to coexist within a layer, it is necessary to determine which protocol is being invoked to process a service data unit delivered to the MAC layer. To permit multiple protocols above Layer 2 to coexist with one MAC entity, there is a unique EtherType value that identifies the protocol. A value of 0x86DD in the EtherType field indicates that an IP header follows. The EtherType value 0x88DC indicates the WSMP. These Ethertypes are typically registered with the WME or operating system environment in which the MAC sublayer entity is hosted.

This standard requires mandatory support of U-format protocol data units (PDUs) (unnumbered format) as described in IEEE Std 802.2. The use of I-format and S-format PDUs is not supported by this standard.

The format of MSDUs passed from the LLC to the MAC is illustrated in Figure 2. If the EtherType field indicates WSMP, the WSMP header and WSMP data follow; if the EtherType field indicated by the IEEE 802.2 header indicates IP, the IP header and IP datagram follow.

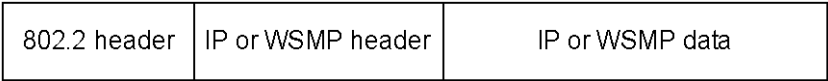


Figure 2—Illustration of MSDUs passed between the LLC and MAC

In Figure 2, the LLC control field is one octet, which requires mandatory and exclusive support of U-format PDUs (unnumbered format) as described in IEEE Std 802.2. The use of I-format and S-format PDUs is not supported by this standard.

The format of MSDUs passed from the LLC to the MAC is illustrated in Figure 2. If the EtherType field indicates WSMP, the WSMP header and WSMP data follow; if the EtherType field in the IEEE 802.2 header indicates IP, the IP header and IP datagram follow.

5.2 Secured WSA and WSIE

The timestamp and the WAVE service information element (WSIE) are two fields present in a WAVE announcement action frame defined in IEEE P802.11p. The WSIE consists of a secured WSA and timing information as shown in Figure 3. The secured WSA is defined in IEEE P1609.3 and indicates WAVE services on offer from the corresponding provider. The timing information is defined in 8.1.3 and can be used by WAVE devices receiving the WSA in conjunction with the timestamp for synchronization.

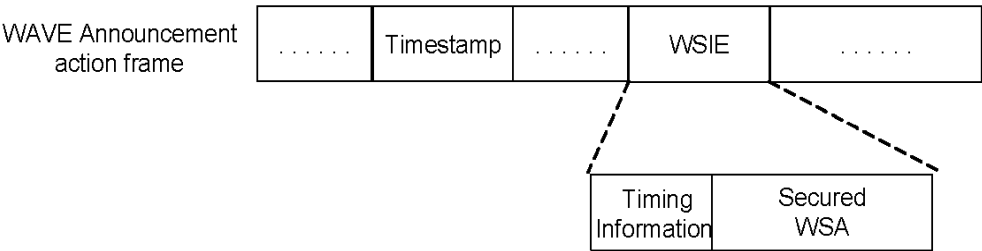


Figure 3—Illustration of the location of the timing Information field within the WAVE announcement action frame

6. Functional description

6.1 Overview

This clause defines functional extensions to IEEE Std 802.11 to enable multi-channel coordination. A WAVE system is required to support various applications on multiple RF channels defined at the physical layer (e.g., IEEE 802.11); however additional U-NII band channels or other RF channels in other regulatory domains may also be supported.

As stated in Clause 6, this standard specifies the channel coordination that controls the use of the CCH and SCHs. In order to communicate on an SCH, channel coordination management is required as specified in Clause 8.

An example of the WAVE MAC operation is shown in Figure 4. This reference design architecture is used to specify the following transmit operations services: channel routing, data buffers (queues) and prioritization, and channel coordination; however, actual implementations may depart from this example design. The WAVE MAC entity is described in IEEE Std 802.11, as amended by IEEE P802.11p. There are two IEEE P802.11p MAC entities in the example design described in this clause: one for the CCH and one for the SCH. Data is prioritized according to access category, as indicated by the buffers shown in Figure 4, which provide different contention and transmission parameters for different priority data frames. Prioritization is further specified in 6.3.

There are two types of information exchange on the WAVE medium: management frames and data frames. The primary management frame is the WAVE announcement defined in IEEE P802.11p. WAVE announcement frames are only permitted to be transmitted on the CCH. Other IEEE 802.11 management frames may be utilized on the SCH. For data exchanges, data frames containing WSMs (as indicated by the EtherType) may be exchanged among devices on both the CCH and SCH; however, IP data frames are only permitted on an SCH. SCH exchanges require the corresponding devices to be members of a WBSS. The process of joining a WBSS is described in Clause 8. Note that management frames are always transmitted before data frames. Management frames are transmitted using distributed (coordination function) interframe space (DIFS) and the corresponding contention window (CW) parameters. Refer to IEEE Std 802.11 for the definition of WAVE management frames and DIFS and contention parameters.

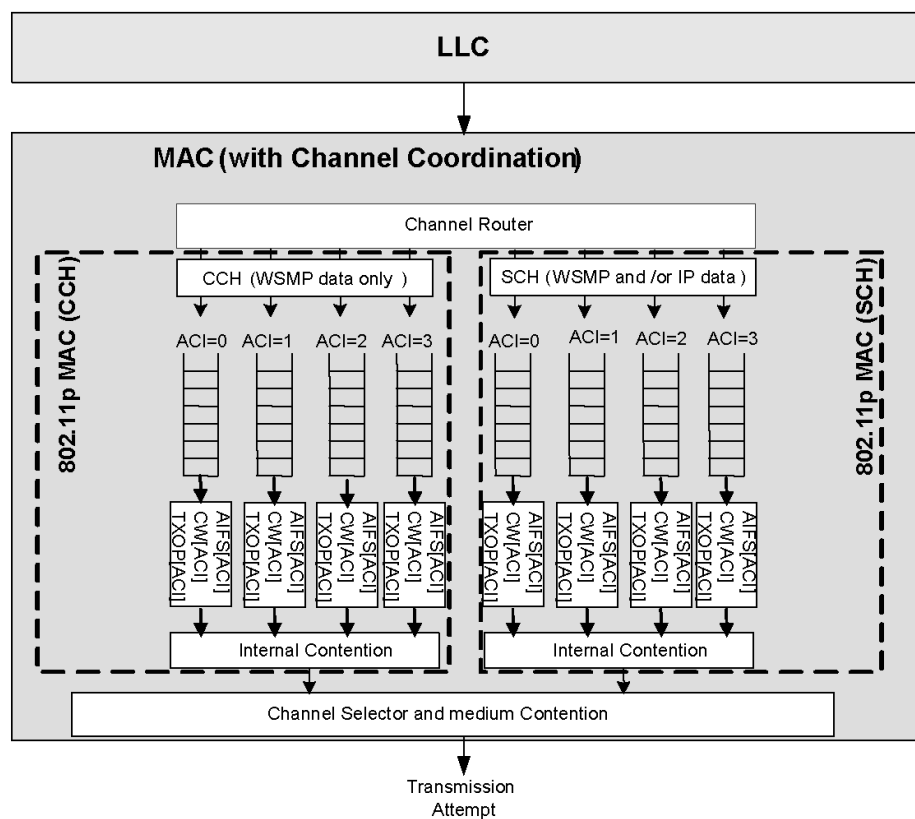


Figure 4—Reference architecture of the MAC with channel coordination

6.2 Channel routing

When an MSDU is passed from the LLC to the MAC, the MAC shall examine the EtherType field of the IEEE 802.2 header to determine whether the MSDU is a WSM or IP datagram. All permitted channel numbers (see the WAVE channel designations in IEEE P802.11p) shall be listed in dot4ChannelSet. The channel routing for WSMP data and IP datagrams is described in the following subclauses.

6.2.1 Routing for WSMP data

As shown in Figure 5, the WSMP header contains the channel, power level, and data rate associated with the data packet as specified in IEEE P1609.3. This permits an application to control these PHY transmit parameters for each individual data frame of the WSMP EtherType.

When the WSMP data is passed from the LLC to the MAC, the MAC shall route the packet to a proper buffer (queue) corresponding to the channel number contained in the WSMP header. The data packet shall be discarded in the case that the channel number contained in the WSMP header is not a valid channel number. A channel number is invalid if it does not correspond to the CCH number or the current SCH number (defined by dot4JoinedServiceChannelNumber in Annex D).

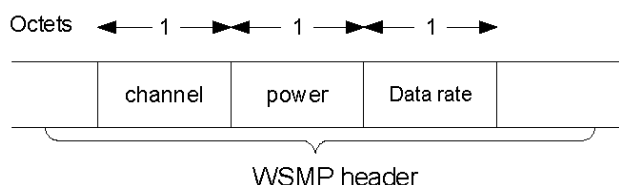


Figure 5—Portion of the WSMP header used to control PHY transmit parameters

6.2.2 Routing for IP datagrams

Before initializing IP data exchanges, the transmitter profile shall be registered in the MLME. The management primitives for transmitter profile registration are specified in 7.3.3, and the management processes are specified in Clause 8. The transmitter profile contains an SCH number, power level, data rate, and the adaptable status of power level and data rate.

Only one transmitter profile may be active at any given time. When IP data is passed from the LLC to the MAC, the MAC shall route the packet to a data buffer that corresponds to the current SCH. If there is no transmitter profile registered, or the transmitting WAVE device is not a member of any WBSS, the data shall be discarded.

6.3 User priority

User priority per channel shall use the IEEE 802.11e EDCA mechanism as specified in the following subclauses. The general architecture of prioritized access for data transmission on one channel is shown in Figure 6. When an MSDU arrives at the MAC sublayer, and the appropriate channel routing is completed (see 7.2), the MAC shall buffer the data by mapping its user priority (UP) to access category index (ACI). This mapping is defined in Table 20.23 of IEEE Std 802.11.

Each access category (AC) has an independent channel access function. The differentiation in priority between AC for channel access parameters is implemented using the appropriate EDCA parameter set values. The default values for the EDCA parameter set may differ from IEEE Std 802.11 in this standard. These EDCA parameters are described here for convenience:

- Arbitration inter-frame space (AIFS): The minimum time interval between the wireless medium becoming idle and the start of transmission of a frame.
- Contention window (CW): An interval from which a random number is drawn to implement the random back-off mechanism.
- Transmit opportunity (TXOP) limit: The maximum time duration (in milliseconds) for which a station can transmit after obtaining a TXOP. If the TXOP limit is 0, the transmit opportunity only permits the transmission of a single MSDU.

The internal contention algorithm according to IEEE Std 802.11 calculates the back-off independently for each AC based on access parameters. The AC with the smallest back-off wins the internal contention, and the winning AC then contends externally for the wireless medium.

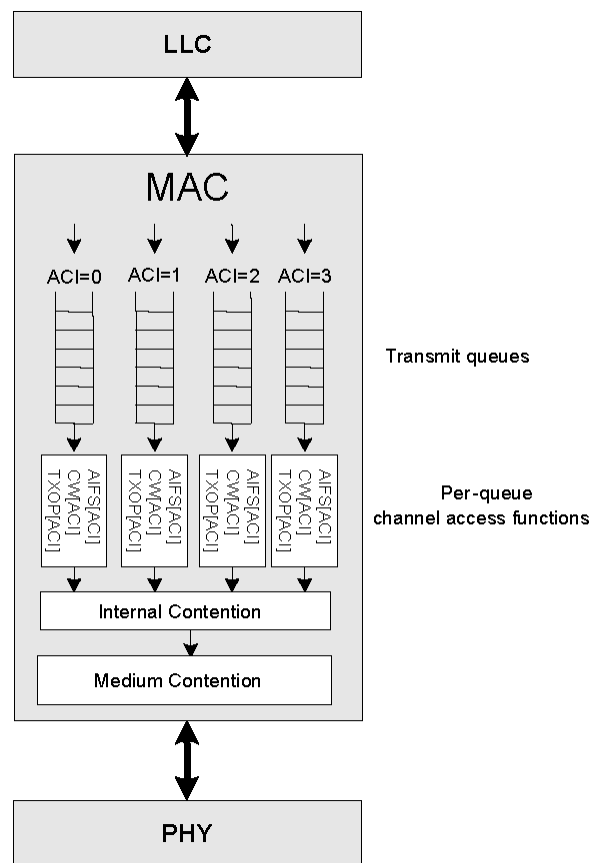


**Figure 6—Prioritized access for data transmission on one channel
(see IEEE Std 802.11)**

6.3.1 Control channel priority

The EDCA parameter set used on the CCH is optimized for WSMP data transfer. The EDCA parameter set shown in Table 1 shall be used for all WAVE devices when operating on the CCH. The values of aCWmin and aCWmax are specified in 20.4.4 of IEEE P802.11p. The EDCA parameter set on the CCH shown in Table 1 shall not change and shall be preconfigured in the IEEE 1609.4 management information base (MIB). The resulting implementation is illustrated in Annex B.

Table 1—EDCA parameter set used on the CCH

ACI	AC	CWmin	CWmax	AIFSN	TXOP Limit OFDM PHY
1	Background	aCWmin	aCWmax	9	0
0	Best effort	$(aCWmin + 1)/2 - 1$	aCWmin	6	0
2	Video	$(aCWmin + 1)/4 - 1$	$(aCWmin + 1)/2 - 1$	3	0
3	Voice	$(aCWmin + 1)/4 - 1$	$(aCWmin + 1)/2 - 1$	2	0

6.3.2 Service channel priority

Both IP and WSMP data frames are permitted on an SCH. For data transactions on an SCH, if the EDCA parameter set is received within the provider's WAVE announcement frame, this EDCA parameter set shall be used within this WBSS. The default EDCA parameter set specified in IEEE Std 802.11 is shown in Table 2. The values of aCWmin and aCWmax are specified in 20.4.4 of IEEE P802.11p. A provider may adapt it according to its own requirements or changes in offered load. The default EDCA parameter set on the SCH is stored in the IEEE 1609.4 MIB.

Table 2—Default EDCA parameter set on the SCH

ACI	AC	CWmin	CWmax	AIFSN	TXOP Limit OFDM/ CCK-OFDM PHY
1	Background	aCWmin	aCWmax	7	0
0	Best Effort	aCWmin	aCWmax	3	0
2	Video	$(aCWmin + 1)/2 - 1$	aCWmin	2	0
3	Voice	$(aCWmin + 1)/4 - 1$	$(aCWmin + 1)/2 - 1$	2	0

6.4 Channel coordination

Channel coordination relies on the synchronization procedure specified in 8.1 and is required to support data exchanges between one or more devices that are not capable of simultaneously monitoring the CCH and exchanging data on SCHs. Such devices are herein termed single-channel WAVE devices. All WAVE devices shall monitor the CCH during a common time interval (e.g., CCH interval) during which all high-priority WSMP messages (priority 4 and higher) with the CCH number indicated in the WSMP header and WSAs shall be transmitted (these messages may also be transmitted on the CCH during the SCH interval). For devices remaining on the CCH during the SCH interval, low-priority frames (user priority 3 or less) may be transmitted at any time.

When a single-channel WAVE device joins a WBSS, synchronization and channel coordination are required to ensure that all single-channel WAVE devices are monitoring the CCH during periods when CCH messages that are high-priority safety messages and WSAs are required to be transmitted. The synchronization procedure is specified in 8.1.

A sync interval and its CCH interval and SCH interval components are shown in Figure 7. The length of the sync interval shall be dot4SyncInterval. The values of CCH and SCH interval are stored in dot4CchInterval and dot4SchInterval respectively,¹⁰ and the values of these attributes shall sum to the length of the sync interval (dot4SyncInterval). For WAVE devices choosing to synchronize to a common time base, UTC shall be used as the reference for estimating the common time base as described in Clause 8. Sync intervals shall start at the instant the time synchronization function (TSF) timer modulo dot4SyncInterval is zero. All WAVE devices shall monitor the CCH during the CCH interval.¹¹

At the beginning of each scheduled channel interval, a guard interval, shown in Figure 7, shall be used to account for variations in channel interval time and timing inaccuracies among different devices. The value of the guard interval is dot4SyncTolerance + dot4MaxChSwitchTime (see 8.1.4). Transmissions shall not be permitted during the guard interval. At the scheduled channel interval, the prioritized MAC activities on the previous channel may be suspended, and the prioritized access activities on the current channel shall be started or resumed if they were suspended. To prevent devices from attempting to transmit simultaneously at the end of a guard interval, a medium busy shall be declared during the guard interval so that all transmission attempts are subject to a random back-off at the start of each channel interval (see Annex C). The channel coordination function shall also prevent packets from being transmitted on the incorrect RF channel.

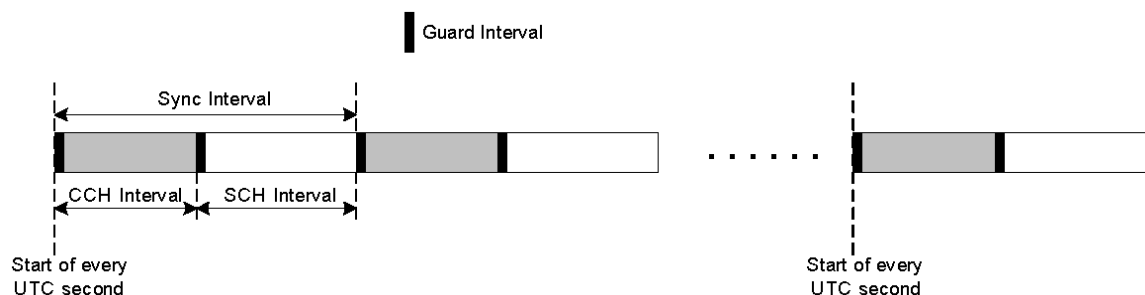


Figure 7—Sync interval, guard interval, CCH interval, and SCH interval

6.5 Transmit operations

An example process flow for transmitting a packet is as follows (the transmit process is further illustrated in Figure 8):

- a) The LLC passes an MSDU to the MAC.
- b) The channel router examines the EtherType field of the MSDU:
 - 1) If the EtherType field indicates WSMP, the channel router looks up the channel number in the WSMP header and designates the MSDU to the AC based on the channel and the user priority. The MSDU is discarded if the channel number is invalid.
 - 2) If the EtherType field indicates IP, the channel router designates the MSDU to the AC assigned to the SCH and the user priority.¹²
- c) Through the channel coordination procedure specified in 6.4, the data buffers allocated to the current channel are served.

¹⁰The CCH and SCH intervals may be adaptable in the future versions of this standard, however, the sum of the CCH and SCH intervals is fixed.

¹¹A device that supports more than one WAVE channel simultaneously does not require all radio resources to be tuned to the CCH.

¹²The LLC and MAC data SAPs could be extended to include channel, power, and rate as parameters of the data SAPs.

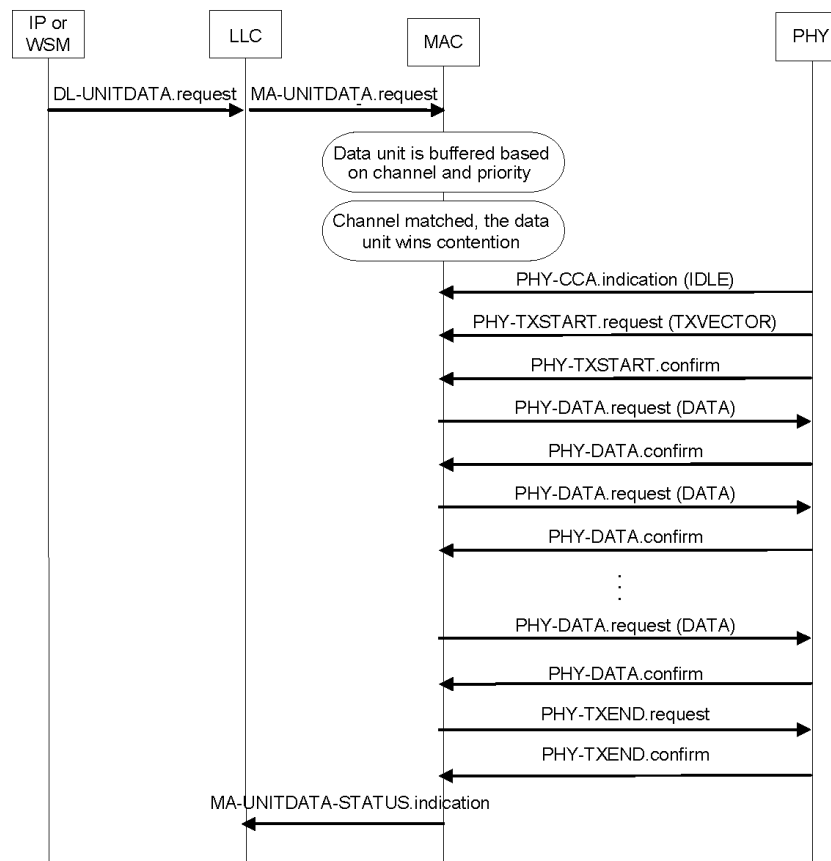


Figure 8—Transmit process flow

- d) The MAC selects the MSDU that wins the internal contention on the current channel. The EtherType field of the MSDU is examined again:
 - 1) If the data unit is a WSM, then the transmit power and data rate stored in the WSMP header are used for the packet transmission.
 - 2) If the data unit is an IP datagram, then the transmit power and data rate stored in the registered transmitter profile (see 8.3.3) are used for the packet transmission.
- e) The values of the power level and data rate are set in the TXVECTOR.¹³ The procedure between MAC/PHY to transfer an MPDU is specified in 17.3.11 of IEEE Std 802.11, which is summarized as follows:
 - 1) The PHY reports a clear channel to the MAC by issuing a PHY-CCA.indication(IDLE).
 - 2) The MAC issues a PHY-TXSTART.request(TXVECTOR) to the PHY. A confirmation is issued back to the MAC after the PHY sets the desired power level and data rate.
 - 3) The data is then exchanged between MAC/PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC, and PHY-DATA.confirm primitives issued by the PHY.
 - 4) After the transmission of the final bit of the last MPDU octet, the transmission is terminated by the MAC through the primitive PHY-TXEND.request.

¹³ The TXVECTOR represents a list of parameters that the MAC sublayer provides to the local PHY entity in order to transmit the data unit, as described in 17.2.2 of IEEE Std 802.11.

- f) If transmission of an MPDU is not completed at the scheduled guard interval, the transmission shall be canceled by the MAC through the primitive PHY-TXEND.request. This premature termination can be avoided via implementing safeguards described in Annex C.
- g) The LLC waits for a status indication from the MAC if required.

6.6 Receive operations

A WAVE device that is not transmitting on the current channel operates in the IEEE 802.11 receive mode. When the MAC receives an MSDU, the MAC issues an MA-UNITDATA.indication to report the received MSDU to the LLC. If the PHY is in the process of receiving a data frame when the guard interval occurs, the PHY sublayer should issue a PHY-RXEND.indication (RXERROR = CarrierLost) to the MAC sublayer, as described in IEEE Std 802.11. The corresponding partially received frame should be discarded by the MAC (treated as a CRC error).

7. Layer management

7.1 Overview of management model

Figure 9 depicts the relationship among management entities. For the purposes of describing the functionality specified by this standard, the MAC layer management entity is divided into two parts: the MAC management extension and IEEE 802.11 MLME. In implementation, these two entities would likely be combined into one MAC layer management entity.

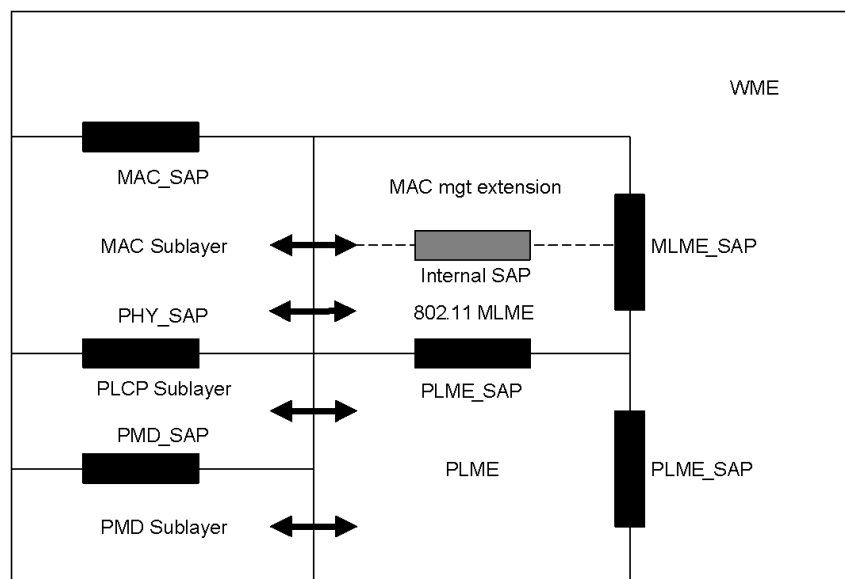


Figure 9—SAP interfaces relevant to IEEE Std 1609.4

The MAC and PHY layers conceptually include management entities, called *MAC sublayer management* and *PHY sublayer management entities* (MLME and PLME, respectively). These management entities provide the layer management service interfaces through which layer management functions may be invoked. The WME is a layer-independent entity that may be viewed as residing in a separate management plane or as residing “off to the side.” In general this entity may be viewed as being responsible for such functions as the gathering of layer-dependent status from the various layer management entities, and similarly setting the value of layer-specific parameters. The WME would typically perform such functions

on behalf of general system management entities and would implement standard management protocols. The interactions between the various entities are through a service access point (SAP) across which defined primitives are exchanged. The management SAPs within this model are the following:

- WME-MLME SAP
- WME-PLME SAP
- MLME-PLME SAP

The latter two SAPs support identical primitives, and in fact may be viewed as a single SAP (called the *PLME SAP*) that may be used either directly by MLME or WME, or other management entities not defined by the basic WAVE reference model.

Channel coordination is a part of the MAC layer and its management is provided by a MAC management extension and the IEEE 801.11 MLME. An internal SAP is defined between MAC management extension and the IEEE P802.11p MLME. The functionality of the MAC management extension is described in 8.2.

7.2 Generic management primitives

The management information specific to each layer is represented as a MIB for that layer. The MAC and PHY layer management entities are viewed as “containing” the MIBs for those layers. The generic model of MIB-related management primitives exchanged across the management SAPs is to allow the SAP user-entity to either GET the value of a MIB attribute or to SET the value of a MIB attribute. The invocation of a SET.request primitive may require that the layer entity perform certain defined actions.

The GET and SET primitives are represented as REQUESTs with associated CONFIRM primitives. These primitives are prefixed by MLME or PLME depending upon whether the MAC or PHY layer management SAP is involved. In the following, XX denotes MLME or PLME:

XX-GET.request (MIBAttribute)

Requests the value of the given MIBAttribute.

XX-GET.confirm (status, MIBAttribute, MIBAttributevalue)

Returns the appropriate MIB attribute value if status = “success,” otherwise returns an error indication in the Status field. Possible error status values include “invalid MIB attribute” and “attempt to get write-only MIB attribute.”

XX-SET.request (MIBAttribute, MIBAttributevalue)

Requests that the indicated MIB attribute be set to the given value. If this MIBAttribute implies a specific action, then this requests that the action be performed.

XX-SET.confirm (status, MIBAttribute)

If status = “success,” this confirms that the indicated MIB attribute was set to the requested value, otherwise it returns an error condition in status field. If this MIBAttribute implies a specific action, then this confirms that the action was performed. Possible error status values include “invalid MIB attribute” and “attempt to set read-only MIB attribute.” Additionally, there are certain requests (with associated confirms) that may be invoked across a given SAP that do not involve the setting or getting of a specific MIB attribute. One of these is supported by each SAP, as follows:

XX-RESET.request: where XX is MLME or PLME as appropriate

XX-RESET.confirm

This service is used to initialize the management entities, the MIBs, and the datapath entities. It may include a list of attributes for items to be initialized to non-default values. The corresponding.confirm indicates success or failure of the request.