

IEEE 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 Standard for Wireless Access in Vehicular Environments (WAVE)— Multi-Channel Operation

Sponsor

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

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Abstract: Multi-channel wireless radio operations, Wireless Access in Vehicular Environments (WAVE) mode, medium access control (MAC), and physical layers (PHYs), including parameters for priority access, channel switching and routing, management services, and primitives designed for multi-channel operations are described in this standard.

Keywords: channel coordination, IEEE 1609.4™, multi-channel operation, user priority, WAVE, Wireless Access in Vehicular Environments

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Introduction

This introduction is not part of IEEE Std 1609.4™-2016, IEEE Standard for Wireless Access in Vehicular Environments (WAVE)—Multi-Channel Operation.

A Wireless Access in Vehicular Environments (WAVE) system is a radio communications system intended to provide seamless, interoperable services for surface transportation. These services include those recognized by the U.S. National Intelligent Transportation Systems (ITS) Architecture [B4]^a and many others contemplated by the automotive and transportation infrastructure industries. These services include vehicle-to-roadside communication, vehicle-to-vehicle communication, and potentially communication among other devices. Multi-channel operation provides medium-access control (MAC)-layer enhancements to the capabilities specified in IEEE Std 802.11™.^b This is but one component in the overall WAVE architecture, which is described in IEEE Std 1609.0™.

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

^b Information on references can be found in Clause 2.

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1. Overview

1.1 Scope

The scope of this standard is the specification of medium access control (MAC) sublayer functions and services that support multi-channel wireless connectivity between IEEE 802.11 Wireless Access in Vehicular Environments (WAVE) devices.

1.2 Purpose

The purpose of this standard is to enable effective mechanisms that control the operation of upper layer data transfers across multiple channels, without requiring knowledge of physical layer (PHY) parameters, and describe the multi-channel operation channel routing and switching for different scenarios.

1.3 Conformance

Per the *IEEE Style Manual* [B1],¹ this standard includes normative and informative information. Normative text may describe mandatory or optional features. A mandatory feature may have optional as well as mandatory components. For example, a mandatory message may have optional fields. An optional feature may have components that are mandatory if the feature is supported. For example, an optional message might require a certain field. Additionally, a feature may be conditional on support of another feature. For example, if A is supported, at least one of B or C must be supported.

In this standard, features are designated as mandatory, optional, or conditional in the introduction to the subclause specifying the feature. The designation applies to the requirements found in the subclause itself as well as any subordinate subclauses, unless otherwise indicated. The word *shall*, when applied to a component of an optional feature, indicates that the component is mandatory if the feature is supported, i.e., conditional on support for the feature. The protocol implementation conformance statement (PICS) in Annex G ~~tabulates~~summarizes the requirements of this standard~~and their components~~.

¹ The numbers in brackets correspond to those of the bibliography in Annex A.

[A summary of the minimum supported features necessary for compliance to this standard is provided in 4.1.](#)

1.4 Document conventions

Unless otherwise noted, conventions follow those in IEEE Std 802.11TM, including conventions for the ordering of information within data items.

Numbers are decimal unless otherwise noted. Numbers preceded by 0x indicate hexadecimal numbers, so that 0xFF is equivalent to “FF hexadecimal.” Field lengths are in octets unless otherwise noted.

Words in italics refer to data items that appear in the management information base (MIB), primitives, or over the air frames.

Descriptive, informative information is generally found at the beginning of a clause or subclause, with normative text following. Figures are used for illustration and are informative⁷ unless otherwise noted.

Unless otherwise noted, references to a MIB refer to the MLME MIB specified in Annex F.

2. Normative references

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

IEEE Std 802.11™, 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. [2](#), [3](#), [4](#)

~~² Numbers 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.~~

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~~IEEE Std P1609.0TM/D0.9, April 2010, Draft Standard~~ for Wireless Access in Vehicular Environments (WAVE)—Architecture.

IEEE [Std P1609.2TM](#), ~~D5, June 2010, Draft~~ IEEE Standard for Wireless Access in Vehicular Environments—Security Services for Applications and Management Messages.

~~IEEE Std 802[@], IEEE Standard for Local and Metropolitan Area Networks: Overview and Architecture.~~^{3,4,5}

~~IEEE Std 802.11kTM-2008, 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 1: Radio Resource Measurement of Wireless LANs.~~

~~IEEE Std 802.11pTM, 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 6: Wireless Access in Vehicular Environments.~~

IEEE Std 1609.3TM, IEEE Standard for Wireless Access in Vehicular Environments (WAVE)—Networking *Services*.

[IEEE Std 1609.12TM, IEEE Standard for Wireless Access in Vehicular Environments \(WAVE\)—Identifier Allocations.](#)

~~IETF RFC 1042, Standard for the Transmission of IP Datagrams over IEEE 802 Networks.~~⁶

~~ISO/IEC 8802-2 [IEEE Std 802.2TM], IEEE Standard for Information Technology—
Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area
Networks—Specific Requirements—Part 2: Logical Link Control.~~

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. ~~IEEE P1609.0 and~~ The *IEEE Standards Dictionary* [Online: Glossary of Terms & Definitions](#) should be consulted for terms not defined in this clause.⁵

channel coordination: The mechanisms specified in this standard that facilitate Wireless Access in Vehicular Environments (WAVE) operation of at least one physical layer (PHY) over multiple wireless channels, including synchronization.

⁵ [IEEE Standards Dictionary Online](http://ieeexplore.ieee.org/xpls/dictionary.jsp) subscription is available at: <http://ieeexplore.ieee.org/xpls/dictionary.jsp>.

⁶ ~~IETF publications are available from the Internet Engineering Task Force, IETF Secretariat, c/o Association Management Solutions, LLC (AMS), 48377 Fremont Boulevard, Suite 117, Fremont, CA 94538 (<http://www.ietf.org>).~~

⁷ ~~The IEEE Standards Dictionary: Glossary of Terms & Definitions is available at <http://shop.ieee.org/>.~~

common time reference: Coordinated Universal Time (UTC), modulo 1 second.

control channel (CCH): A ~~single~~ radio channel, ~~not a service channel, intended for~~ on which the exchange of management information, including Wireless Access in Vehicular Environments (only data frames allowed by the WAVE), ~~Service Advertisements, and~~ standards are those carrying WAVE Short Messages. See also: service channel.

~~**control channel (CCH) interval:** A specified periodic interval of time with respect to Coordinated Universal Time (UTC). During the CCH interval a device using alternating channel access will tune to the CCH, and outside the CCH interval the device will tune to a channel other than the CCH. A CCH interval and the subsequent service channel (SCH) interval comprise a sync interval.~~

~~**Ethertype:** The Ethernet Type field specified in IETF RFC 1042, used to identify the higher layer protocol above the Logical Link Control (LLC).~~

guard interval: A time interval at the start of each time slot, ~~control channel (CCH) interval and service channel (SCH) interval~~ during which devices using alternating ~~that are switching channels~~ access do not transmit.

~~**higher layer:** A functionality (e.g., an application), residing, in the context of the Open System Interconnection (OSI) protocol suite reference model, in the management or data plane above the services defined in this standard.~~

managed Wireless Access in Vehicular Environments (WAVE) device: A WAVE device that supports management through the use of an IEEE 1609 standards-defined management information base.

~~**management ID:** Identifier of an IEEE 1609 management entity used to indicate the source and destination of management information. The values are specified in IEEE P1609.0.~~

multi-channel operation: The operation of a Wireless Access in Vehicular Environments (WAVE) device to utilize more than one wireless channel, possibly involving ~~May involve~~ channel coordination.

~~**multi-physical layer (PHY) device:** A Wireless Access in Vehicular Environments (WAVE) device capable of simultaneous operation on multiple radio channels.~~

OCB~~Activated~~**Enabled:** Indicates communication~~operation~~ outside the context of a basic service set as specified in IEEE Std 802.11p (by setting *dot11OCB* ~~Activated~~**Enabled** to TRUE) (i.e., used for WAVE operation).

pseudonymity: A property wherein an entity's~~of a pseudonymous entity. A pseudonymous entity has the property that its~~ permanent or long-lived identities, and its long-term patterns of behavior, cannot be deduced from its network traffic and are only observable by~~available to~~ appropriately authorized parties.

service channel (SCH): Any channel that is not the control channel. See also: control channel; ~~intended for management frames and higher layer information exchanges (Wireless Access in Vehicular Environments [WAVE] Short Message [WSMs] and Internet Protocol version 6 [IPv6] packets).~~ There may be more than one service channel defined in a given spectrum.

~~**service channel (SCH) interval:** A recurring time interval during which a device using alternating channel access will tune to an SCH and outside of which the device will tune to the CCH. An SCH interval and the preceding CCH interval comprise a sync interval.~~

single-physical layer (PHY) device: A Wireless Access in Vehicular Environments (WAVE) device not capable of simultaneous operation on multiple radio channels.

switching device: A WAVE device with at least one physical layer (PHY) that is switching between channels, ~~(e.g., service channel {SCH} and control channel {CCH}).~~

sync interval: A repeating time interval comprised of one time slot 0 ~~control channel (CCH)~~ interval followed by one time slot 1 interval. *See also: time slot 0; time slot 1* ~~service channel (SCH) interval.~~

time slot 0: A recurring time interval during which a device using alternating channel access will tune to one channel (nominally the CCH) and outside of which the device will tune to another channel (nominally an SCH). *See also: time slot 1; sync interval.*

time slot 1: A recurring time interval during which a device using alternating channel access will tune to one channel (nominally an SCH) and outside of which the device will tune to another channel (nominally the CCH). *See also: time slot 0; sync interval.*

Timing Advertisement frame: A specific management frame ~~specified in IEEE Std 802.11p~~ used to carry timing information. (See IEEE Std 802.11)

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

~~**Vendor Specific Action frame:** A management frame specified in IEEE Std 802.11. Despite the name, when the first 36 bits of the *Organization Identifier* are equal to 0x0050C24A4, the contents are specified within the 1609 standards for use in carrying IEEE 1609 management information including Wireless Access in Vehicular Environments (WAVE) Service Advertisements.~~

Wireless Access in Vehicular Environments (WAVE) device: A device that is compliant to IEEE Std 1609.3, IEEE Std 1609.4, and IEEE Std 802.11 ~~communicating~~[operating](#) outside the context of a basic service set. ~~(See IEEE Std 802.11p specification of station [STA] transmission of data frames outside the context of a basic service set.)~~

Wireless Access in Vehicular Environments (WAVE) Management Entity (WME): A set of management functions required to provide WAVE networking services. ~~(See It is specified in IEEE Std 1609.3).~~

Wireless Access in Vehicular Environments (WAVE) Service Advertisement (WSA): A data structure [that may include](#) ~~specified in IEEE Std 1609.3 containing information including~~ the announcement of the availability of [application](#)-services. ~~(See IEEE Std 1609.3)~~

Wireless Access in Vehicular Environments (WAVE) Short Message Protocol (WSMP): A protocol ~~for rapid exchange of messages in a rapidly varying radio frequency (RF) environment where low latency is also an important objective. It is~~ specified in IEEE Std 1609.3. [that minimizes communications overhead.](#) ~~(See IEEE Std 1609.3)~~

wireless channel: An instance of one radio frequency (RF) channel within an operating class as defined in IEEE Std 802.11-2012/IEEE Std 802.11p-Annex E of IEEE P802.11REVmb.

3.2 Acronyms and abbreviations

AC access category

ACI access category index

AIFS arbitration interframe space

CCH control channel

CW contention window

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
MSDUMAC	service data unit
OCXO	oven stabilized crystal oscillator
PHY	physical layer
PICS	protocol implementation conformance statement
PLME	physical layer management entity
PPS	pulse per second
RCPI	received channel power indicator
RF	radio frequency

RFC	request for comments
SAP	service access point
SCH	service channel
~~SNAP~~	~~Subnetwork Access Protocol~~
STA	station
TA	Timing Advertisement (frame)
<u>TAI</u>	<u>Temps Atomique International</u>
TSF	timing synchronization function
TXOP	transmit opportunity
UP	user priority
UTC	Coordinated Universal Time
~~VSA~~	~~Vendor Specific Action (frame)~~

WAVE Wireless Access in Vehicular Environments

WME WAVE Management Entity

WSA WAVE Service Advertisement

WSM WAVE Short Message

WSMP WAVE Short Message Protocol

4. General description

4.1 Overview

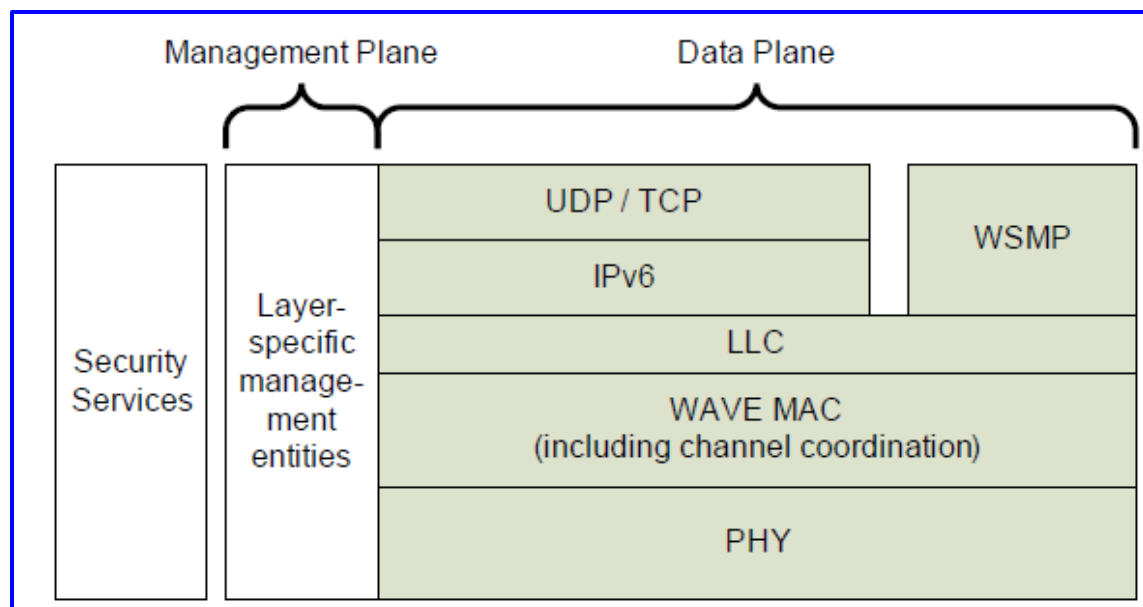
~~4.2 Reference model~~

WAVE provides a communication protocol stack optimized for the vehicular environment, employing both customized and general-purpose elements, as illustrated in Figure 1 [and](#) Figure 2.

~~IEEE P1609.0 provides a description of the WAVE system architecture and operations. To operate over multiple wireless channels while in operation with OCBAEnabled, there is a need to perform channel coordination. OCBAEnabled indicates operation outside the context of a basic service set as specified in IEEE Std 802.11p (by setting *dot11OCBAEnabled* to TRUE) (i.e., WAVE operation).~~

Channel coordination is specified in this standard and consists of additional features for OCBEnabled operations in the MAC sublayer specified in IEEE Std 802.11p. Both data plane and management plane features are included as shown in Figure 1. These features are introduced in 4.2 and 4.3 and specified in Clause 5 and Clause 6.

The basic reference model relevant to this standard is shown in Figure 1. WAVE supports both IP- and non-IP-based data transfers, although individual devices might support only one networking ~~stack protocol~~. Non-IP-based data transfers are supported through the WAVE Short Message Protocol (WSMP) specified in IEEE Std 1609.3. Channel coordination is a collection of ~~extensions~~ ~~enhancements~~ to the IEEE 802.11 MAC, ~~and interacts with the IEEE 802.2 LLC and IEEE 802.11 PHY~~. The WAVE Management Entity (WME) and corresponding network services are specified in IEEE Std 1609.3. WAVE security services are specified in IEEE ~~Std P1609.2~~. [IEEE Std 1609.0 provides a description of the WAVE system architecture and operations.](#)



(New)

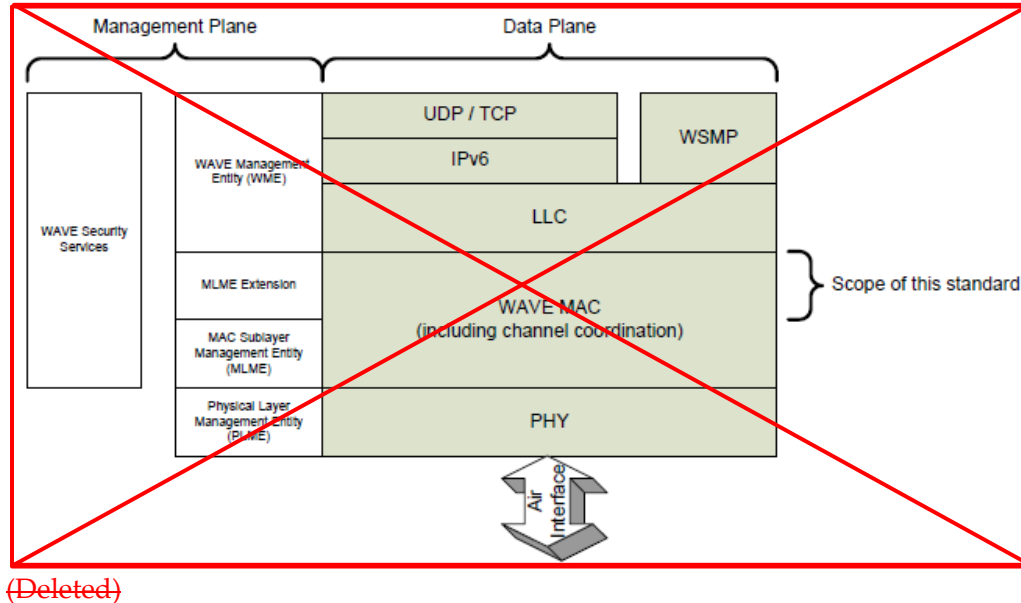


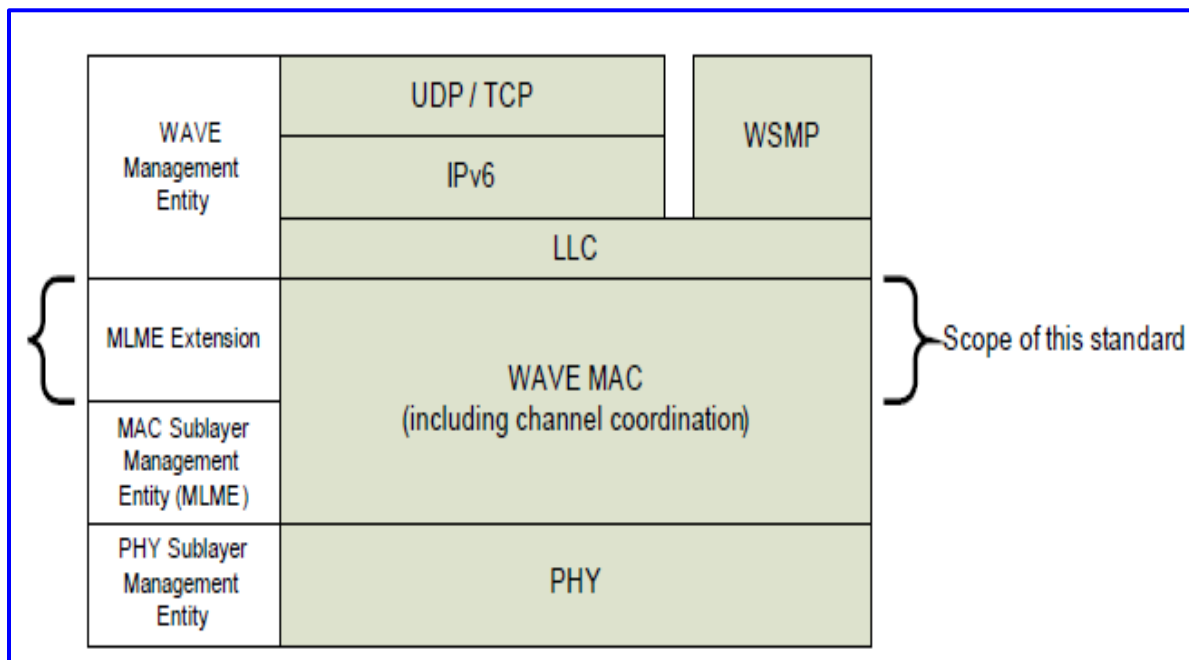
Figure 1—WAVE reference model

To operate over multiple wireless channels while OCBAActivated, there is a need to perform channel coordination. OCBAActivated indicates communication outside the context of a basic service set as specified in IEEE Std 802.11 (by setting *dot11OCBAActivated* to TRUE) (i.e., WAVE operation). Channel coordination is specified in this standard and consists of additional features for OCBAActivated communication in the MAC sublayer specified in IEEE Std 802.11. Both data plane and management entities are included as shown in Figure 2. These features are introduced in 4.2 and specified in Clause 5 and Clause 6.

The scope of this standard is shown in Figure 2. This standard specifies extensions to the IEEE 802.11 MAC sublayer. These extensions include channel coordination features in support of multi-channel operation (see 5.2) and additions to the primitives used for transmitting data (see 5.3). The result is an extended variant of the MAC sublayer specified in IEEE Std 802.11 rather than a new sublayer in the protocol stack.

The MAC and PHY layers conceptually include management entities, called MAC sublayer management and PHY layer management entities (MLME and ~~physical layer management entity~~ ~~{PLME}~~, respectively). These management entities provide the layer management service interfaces through which layer management functions may be invoked. In Clause 6, this document specifies [an](#) extension to the IEEE 802.11

~~MAC sublayer management entity~~ (~~_MLME~~; ~~as amended by IEEE Std 802.11p~~) to provide channel coordination. The interactions between the various entities are through service access point (SAPs) across which defined primitives are exchanged; see Clause 7.



(New)

Figure 2— Scope of this standard

At a minimum, a WAVE device implements at least the following features specified in this standard (see Annex G).

⊗ OCBActivated communication

⊗ Transmit or receive, or both

⊗ When transmitting, EDCA and user priority

4.2 Overview of the services

4.2.1 General

The services specified~~provided~~ by this standard are used to manage channel coordination and to support MAC service data unit (MSDU) delivery. Both data plane and management ~~plane~~ features are specified.

4.2.2 Data plane services

The MAC sublayer~~MLME~~ data services specified in Clause 5 comprise the following:

- Channel coordination

The MAC sublayer coordinates device resources~~channel intervals~~ so that data packets are transmitted on the proper wireless~~RF~~ channel in~~at~~ the correct~~right~~ time slot.

- Channel routing

The MAC sublayer handles inbound and outbound higher layer data. This specification includes routing of data packets from a higher layer~~the LLC~~ to the designated channel, and setting parameters (e.g., transmit power) for WAVE transmissions. On the receive side, it includes delivery of data to the correct higher layer protocol.

- User priority

WAVE accommodates~~supports~~ a variety of safety and non-safety applications with up to eight levels of MAC-sublayer priority as specified~~defined~~ in IEEE Std 802.11. The use of user priority (UP) and related access category (AC) supports quality of service using enhanced distributed channel access (EDCA) functionality specified in IEEE Std 802.11.

4.2.3 Management ~~plane~~ services

The MLME ~~management~~ services specified in Clause 6 comprise the following:

- Multi-channel synchronization

The MLME uses information that may be derived locally ~~or~~ received over the air to provide a synchronization function with the objective of aligning time slots~~channel intervals~~ among communicating WAVE devices. The MLME provides the capability to generate Timing Advertisement (TA) frames for the ~~to~~ distribution of system timing information, and the capability to monitor received TA frames.

- Channel access

The MLME controls the access to specific radio channels in support of communication requests received from the WME.

- ~~Vendor Specific Action frames~~

~~The MLME will accept incoming VSA frames and pass them to the WAVE Management Entity; the MLME will also generate VSA frames for transmission at the request of WME.~~

- Other IEEE 802.11 services

The MLME allows access to IEEE 802.11 services, which may be invoked on a per-channel basis.

- MIB maintenance

The MLME maintains a management information base (MIB) containing configuration and status information.

- Readdressing

The MLME allows device MAC address changes ~~to be triggered~~ in support of pseudonymity.

5. Data plane services

5.1 General

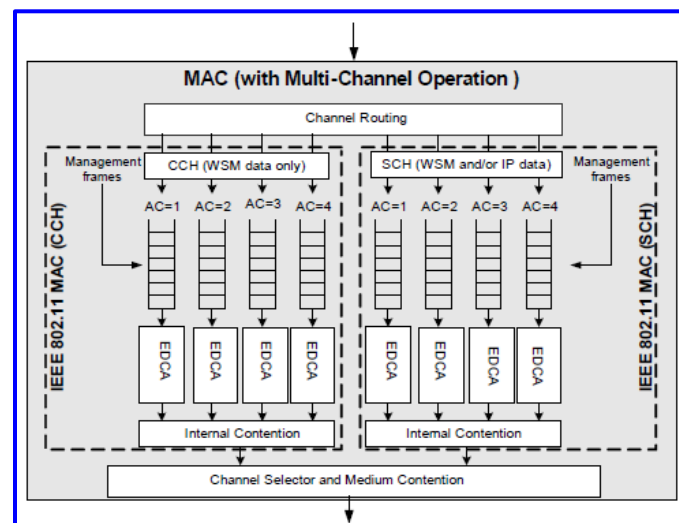
WAVE devices shall communicate outside the context of an IEEE 802.11 basic service set (i.e., with *dot11OCB* ~~Activated~~*Enabled* equal true), as specified in IEEE Std 802.11p. A transmitting WAVE device shall support WSMP traffic, IP traffic, or both.

A conceptual diagram~~An example~~ of a WAVE multi-channel MAC internal architecture is shown in Figure 3. This diagram facilitates the specification of ~~reference design architecture is used to specify~~ the following transmit operations: channel routing, data queueing and prioritization, and channel coordination;~~however~~. Actual implementations may depart from this conceptual diagram ~~example design~~. A WAVE MAC entity uses one or more instances of the MAC sublayer entity specified in IEEE Std 802.11, communicating~~as amended by IEEE Std 802.11p, operating~~ outside the context of a basic service set, with the extensions defined herein. There are two IEEE Std 802.11~~p~~ MAC entities in the conceptual diagram~~example design~~ described in this clause: one for the CCH and one for a~~the~~ SCH. Data is prioritized according to access category (directly related to user priority), as indicated by the queues shown in Figure 3, which provide different contention and transmission parameters for ~~different priority~~ data frames with different priorities. Prioritization is further specified in 5.4.

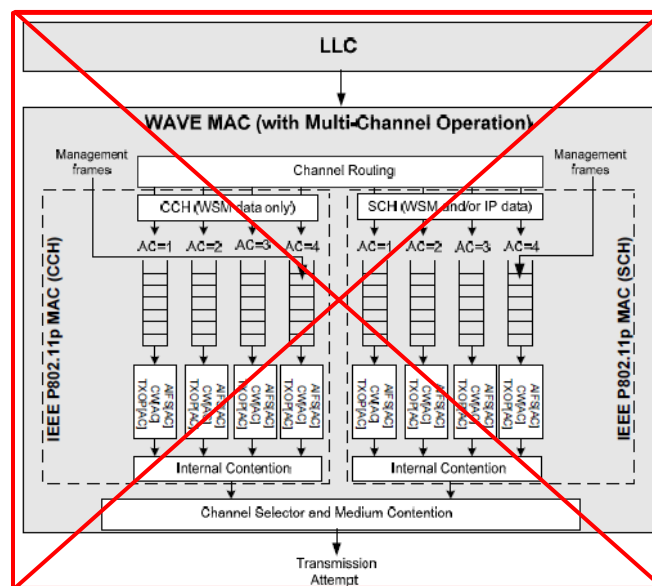
There are three types of over the air information specified by IEEE Std 802.11~~exchanged on the WAVE medium~~: management frames, data frames, and control frames. Control frames may be used per IEEE Std 802.11 and are not addressed in this standard. Management frames used by WAVE enter the data plane at the MAC layer. The only management frame specified for use by a WAVE device is the TA frame specified in IEEE Std 802.11. Timing Advertisement frames are used to distribute time synchronization information as specified in 6.2.

~~The primary management frames are the TA frame specified in IEEE Std 802.11p and the VSA frame specified in IEEE Std 802.11 and amended by IEEE Std 802.11p. Timing Advertisement frames are used to distribute time synchronization information. VSA frames are used to exchange management information such as WAVE Service Advertisements (WSAs). VSAs and TAs may be transmitted on any channel.~~

For higher layer data exchanges, WAVE ~~supports~~ standards specify use of both ~~the~~ WSMP specified in IEEE Std 1609.3₂ and IP version 6. Data frames containing WSMs ~~(as indicated by the Ethertype)~~ may be exchanged among devices on either the CCH or an SCH; however, data frames containing IP datagrams are only allowed on service channels. The management process of accessing the CCH or an SCH is specified in 6.3.



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Figure 3—Conceptual ~~Reference~~ internal architecture of the transmit side of the MAC with channel coordination

5.2 Channel coordination

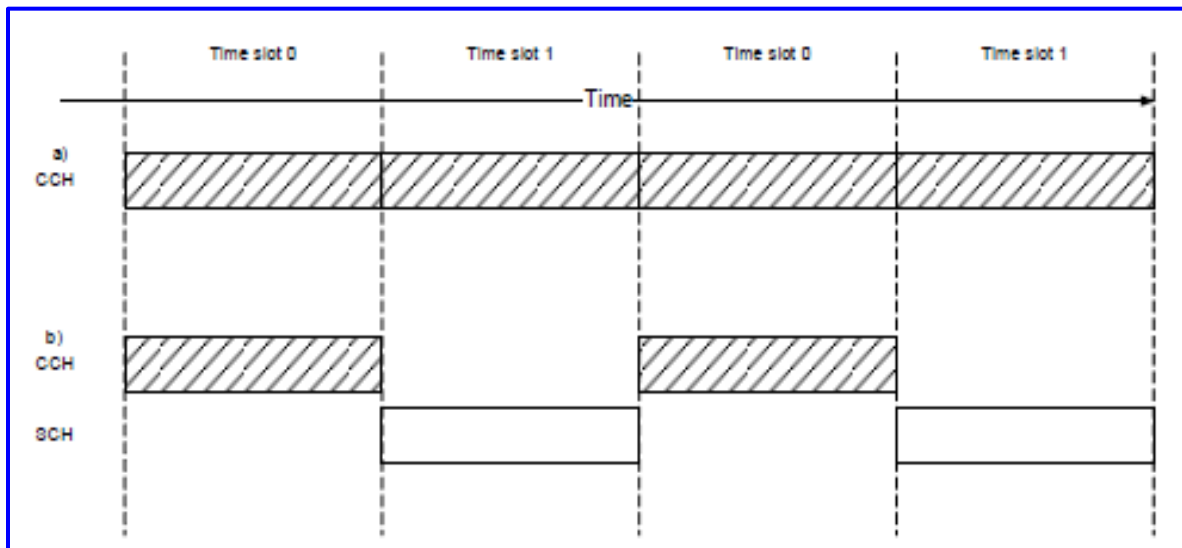
5.2.1 General

Channel coordination ~~is designed to~~ supports data exchanges involving one or more switching devices with concurrent alternating operation on ~~multiple channels~~~~the CCH and an SCH~~. This allows, for example, a single-PHY device access to high-priority data and management traffic ~~onduring~~the CCH ~~during time slot 0~~~~interval~~, as well as general higher layer traffic ~~on an SCH~~ during the ~~time slot 1~~~~SCH interval~~. Figure ~~43~~ illustrates two examples of channel access: continuous access, which requires no channel coordination, and alternating access, which does require channel coordination. ~~The figure illustrates continuous access on the CCH; continuous access on an SCH is also possible. Alternating access is illustrated for the case of switching between CCH and SCH; switching between two SCHs is also possible. An~~ additional options of immediate ~~and extended~~ access ~~are~~~~is~~ described in 6.3. ~~Time slots~~~~CCH and SCH intervals~~ are described in 5.2.2.

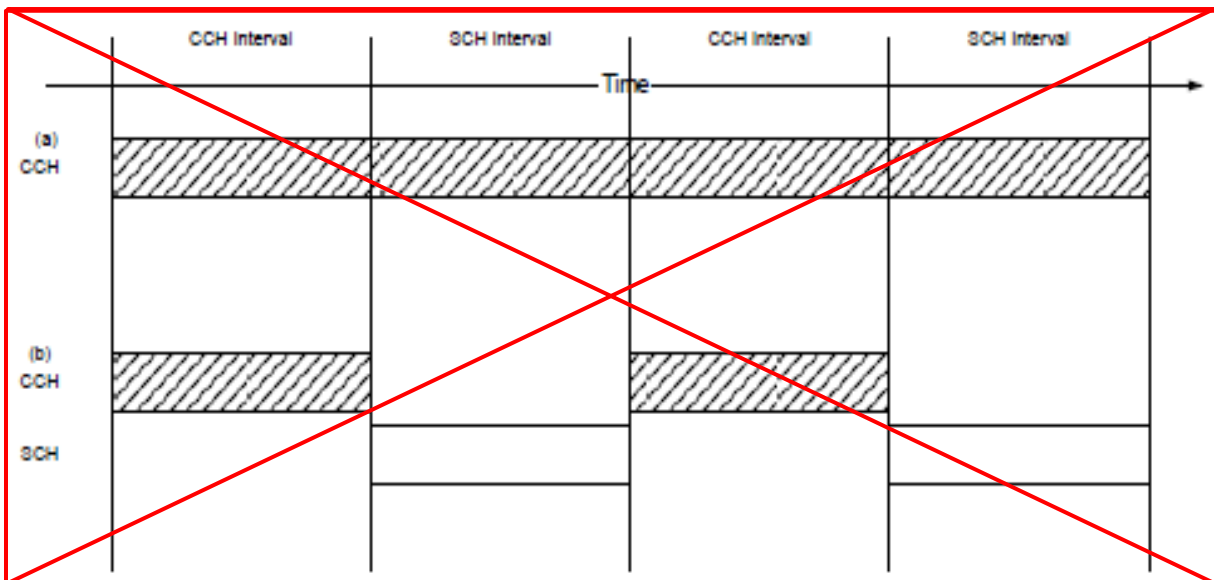
This standard does not specify what channels are accessed during which intervals, though other standards may specify behaviors. Examples: Device X may access the CCH during time slot 0 and access an SCH during time slot 1; Device Y may access an SCH during time slot 0 and the CCH during time slot 1; Device Y at some later time may access two different SCHs, one during time slot 0 and the other during time slot 1.

Alternating access depends on the participating devices being synchronized to a common time reference as specified in 6.2.

The channel coordination function also ensures that packets are transmitted on the intended ~~wireless~~~~RF~~ channel.



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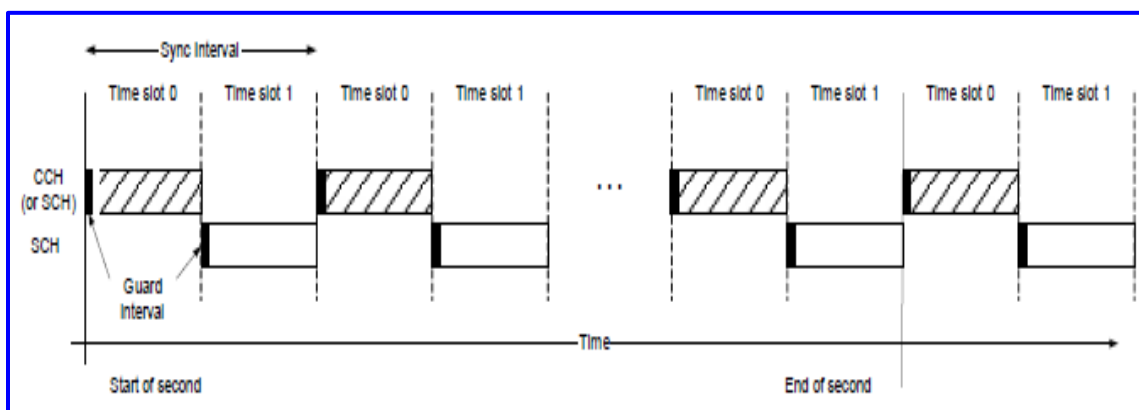
Figure 4—Channel access examples: (a) continuous and (b) alternating

5.2.2 Time slots~~Channel intervals~~ and guard interval

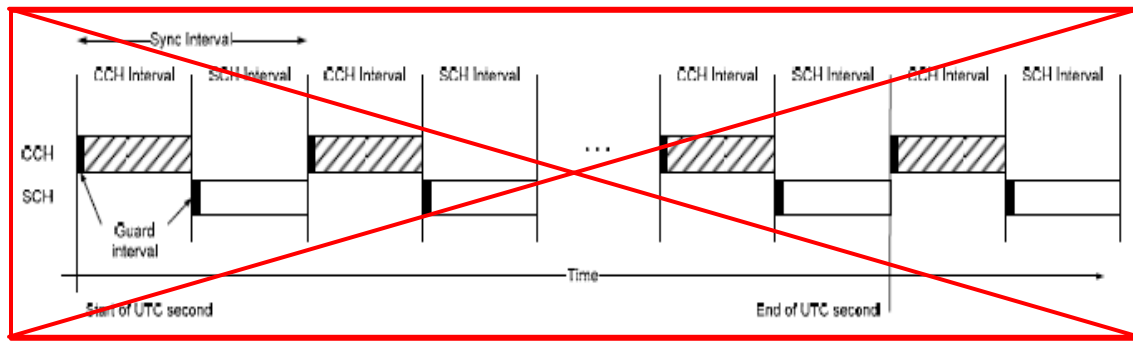
A sync interval and its time slot~~CCH interval and SCH interval~~ components are shown in Figure 5. The ~~values are specified in Annex H. The~~ duration of time slot 0~~the CCH~~ and time slot 1~~SCH intervals~~ are stored in the MIB attributes *Ts0Duration*~~CchInterval~~ and *Ts1Duration*~~SchInterval~~, respectively, and the values of these attributes sum to the length of the sync interval. Values for system characteristics, including *Ts0Duration* and *Ts1Duration* are specified in Annex H. ~~There shall be an integer number of sync intervals in 1 s. Coordinated Universal Time (UTC) defines the common time base for WAVE channel coordination.~~

Subclause 6.2 includes requirements for switching devices to synchronize to a common time base~~UTC~~ and a description of time~~UTC~~ estimation procedures. ~~At each UTC second,~~ The beginning of a sync interval shall align with the beginning of the common time reference~~UTC~~ second, as shown in Figure 5. There shall be an integer number of sync intervals in 1 second.

At the beginning of each time slot~~channel interval (CCH interval or SCH interval)~~ is a guard interval, shown in Figure 5, used to account for radio switching effects and timing inaccuracies among different devices. See 6.2.5 for further specification of the guard interval.



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Figure 5— Sync interval, guard interval, time slot 0~~CCH interval~~, and time slot 1~~SCH interval~~

5.2.3 Transmit restrictions on CCH and SCH

A WAVE device shall support transmit or receive operations, and it may support both. A WAVE device shall support [IEEE 802.11 data frames with a WSM in the frame body or data frames with an IP packet in the frame body](#)~~at least one~~, and it may support [both](#). A WAVE device may support [IEEE 802.11 management frames of type Timing Advertisement](#)~~more than one, of the following IEEE 802.11 frame types:~~

- ~~Management frame of type Timing Advertisement~~
- ~~Management frame of type Action with subtype Vendor Specific~~
- ~~Data frame, when carrying a WSM~~
- ~~Data frame, when carrying an IP packet~~

This standard does not prohibit the transmission of other frame types. This standard does not constrain frames of a specific type to~~Any of the preceding frame types may~~ be transmitted in a specific time slot~~either the CCH interval or the SCH interval~~. Frames carrying IP packets shall not be transmitted on the CCH and may be transmitted on an SCH. Supported control and service channels are identified in the MIB, with the CCH specified in Annex H. Other frames~~s~~types may be transmitted on either the CCH or an SCH. Note that regulations and other standards might limit the use of any given channel.

5.3 Channel routing

5.3.1 General

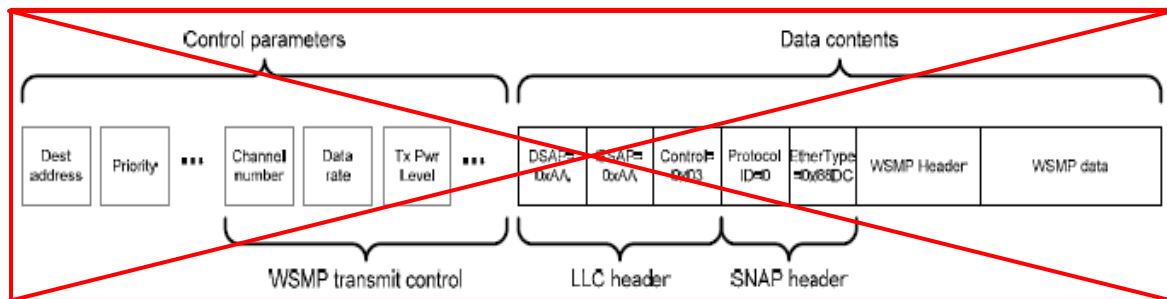
Channel numbers available for use by the device are listed in the MIB attribute *ChannelSetTable*. *ChannelSetTable* shall contain operating classes as specified in IEEE Std 802.11~~p~~and IEEE P802.11REVmb. The MAC ~~extension~~sublayer receives data for transmission ~~in from~~ the ~~LLC sublayer~~ in the form of MA-UNITDATA.requests for IP data or MA-UNITDATA.requests for WSMP data, as illustrated in Figure 5 and Figure 6. IP data and WSMP data are also distinguished by the *EtherType* field of the subnetwork access protocol (SNAP) header within the *Data* field, which is used by the LLC on the receiving side to deliver the data to the proper higher layer protocol.

For WSMs, the channel, transmit power, and data rate are set by higher layers on a per-message basis. For IP datagrams, the channel, transmit power, and data rate to be used are stored in a transmitter profile.

The channel routing for data and management frames is specified in 5.3.2 through 5.3.4~~6~~.

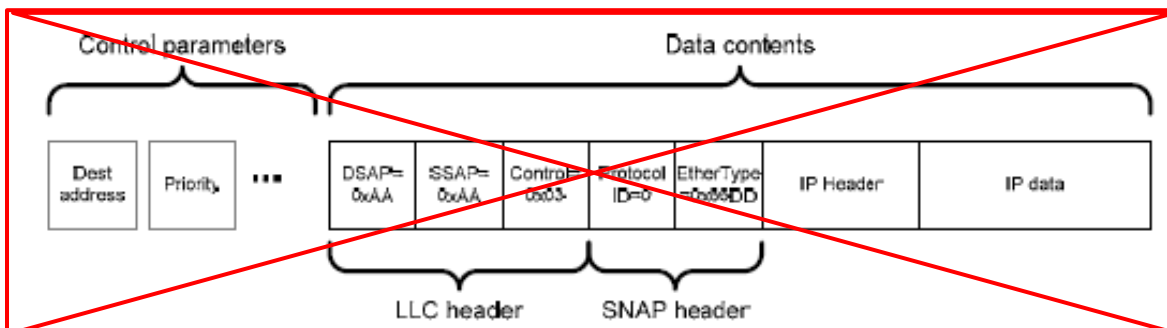
5.3.2 Overview of data frame transmit operations

Figure 5 illustrates the contents of the MA-UNITDATA.req request from the LLC to the MAC for WSMP data. *Ethertype* is passed to the MAC in the SNAP header. Channel number, data rate, transmit power level, destination MAC address, and priority are passed to the MAC through parameters in the MA-UNITDATA.req request. A similar example for IP data is shown in Figure 6. A transmitting WAVE device shall support WSMP traffic, IP traffic, or both.



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Figure 5—MA-UNITDATA.req fields for WSMP data



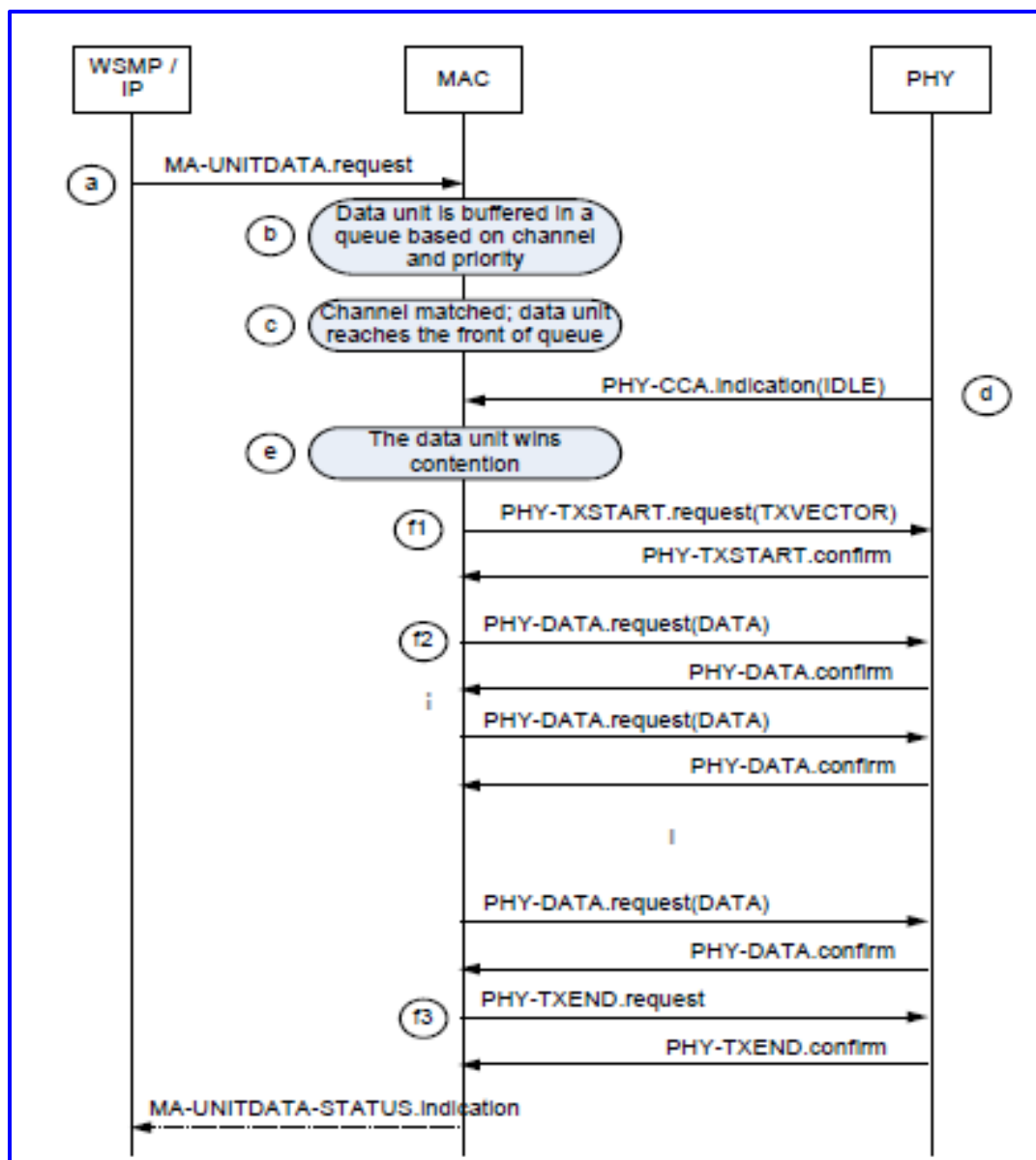
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Figure 6—MA-UNITDATA.req fields for IP data

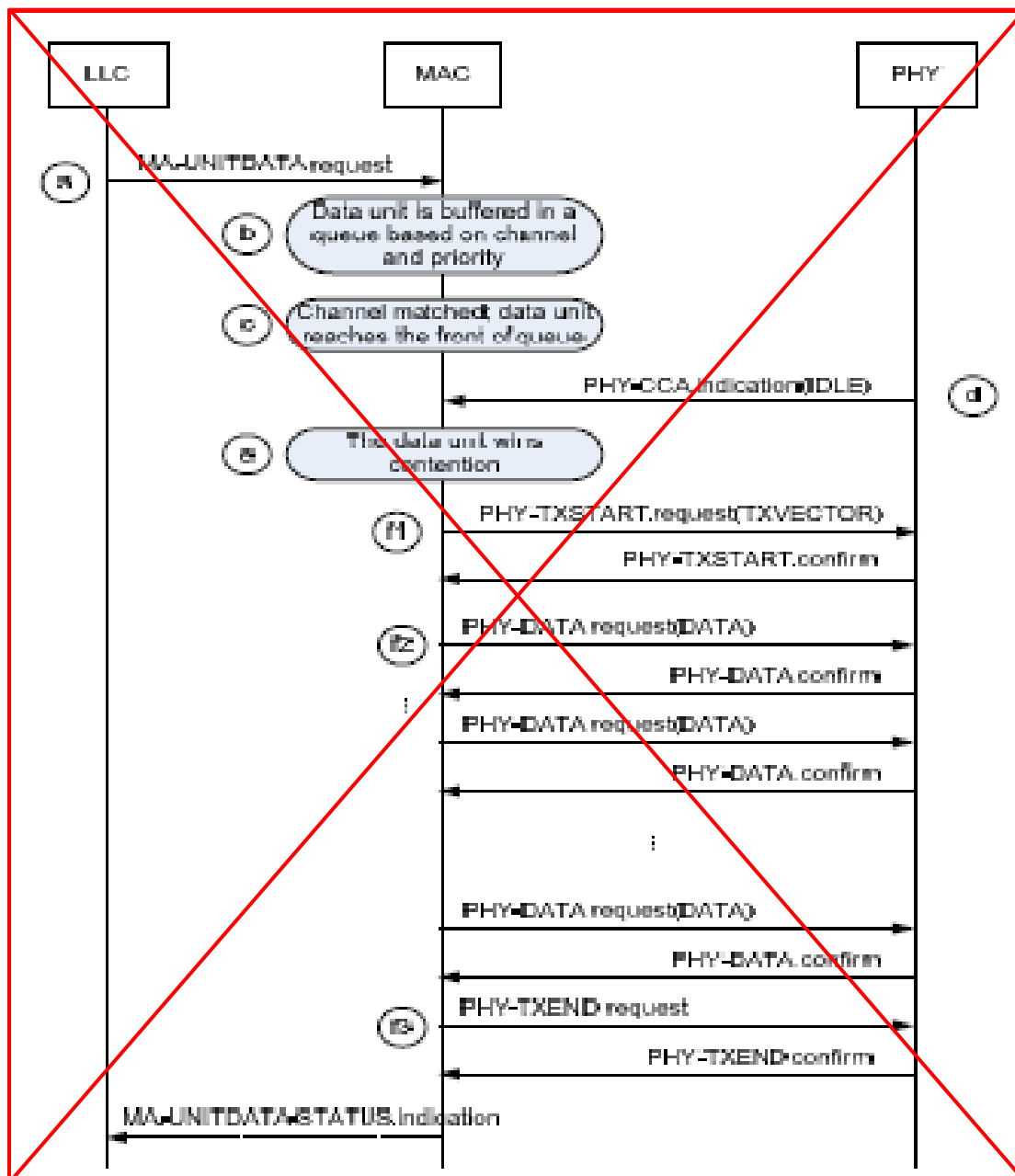
An example IEEE 802.11 process flow for transmitting a packet is illustrated in Figure 6. MAC-PHY interactions are specified in IEEE Std 802.11. The MAC controls the data rate and power level used by the PHY via values in the TXVECTOR of the PHY-TXSTART.request.

Per IEEE Std 802.11 specification of Transmit Power Control procedures, the MLME prevents transmit power from exceeding the maximum allowed power. The maximum allowed power for a channel is stored in the IEEE 1609.3 MIB, either in attribute *UserAvailableTransmitPowerLevel* or attribute *ProviderChannelInfoTransmitPowerLevel*.

Receipt of MLMEX-CANCELTX.request causes any data in the indicated transmit queue to be flushed, i.e., not transmitted.



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a) A higher layer passes an MSDU to the MAC via an MA-UNITDATA.request (IP) or MA-UNITDATA.request (WSMP).

- b) The MAC channel routing function queues the data for transmission~~examines the *Ethertype* field of the MSDU:~~
- 1) ~~For~~If the ~~*Ethertype* field indicates~~ WSMP, the MAC assigns the MSDU to the access category (see 5.4) based on the user priority from the MA-UNITDATA.request. The MAC combines the MSDU with MAC protocol information (see IEEE Std 802.11) to form an MAC protocol data unit (MPDU) and places the MPDU in a queue appropriate for the assigned access category and the channel parameter passed in the primitive.
 - 2) For ~~If the *Ethertype* field indicates~~ IP, the MAC assigns the MSDU to an access category (see 5.4) based on the user priority associated with the channel of operation. The MAC combines the MSDU with MAC protocol information (see IEEE Std 802.11) to form an MPDU and places the MPDU in a queue appropriate for the assigned access category and the SCH obtained from the transmitter profile.
- c) The set of data queues associated with the current channel is identified.
- 1) If the frame contains a WSM, then the transmit power and data rate received in the MA-UNITDATA.request are used.
 - 2) If the frame contains an IP datagram, then the transmit power and data rate stored in the MIB attribute *TransmitterProfileTable* are used.
- d) The PHY reports a clear channel to the MAC by issuing a PHY-CCA.indication (*IDLE*).

- e) The MAC selects the MPDU that wins the internal contention on the current channel via EDCA.
- f) The values of the power level and data rate are set in a *TXVECTOR*. The procedure to transfer an MPDU between the MAC and PHY is specified in IEEE Std 802.11, which is summarized as follows:
 - 1) 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.
 - 2) 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.
 - 3) 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.
- g) If the device is switching channels on time slot boundaries (e.g., performing alternating channel access) and transmission of an MPDU is not completed when ~~by the time the~~ current time slot~~channel interval~~ ends, the transmission may be canceled by the MAC through the primitive PHY-TXEND.request. This premature termination can be avoided via implementing the safeguards described in Annex C.

Figure 6— Example transmit process flow

5.3.3 Internal routing for WSMP data on transmit

The MA-UNITDATA.request primitive ([see](#) 7.4.2) includes the *priority*, *Channel Identifier*, *TxPwr_Lvl*, ~~and Data Rate~~, and Time Slot associated with the WSMP data packet. This permits a higher layer to control these PHY transmit parameters for each individual packet.

When the WSMP data is ~~received~~passed in an MA-UNITDATA.request, following normal MAC processing per IEEE Std 802.11, ~~from the LLC to the MAC, the MAC shall route the~~ packet is placed in the ~~to a~~ proper transmit queue corresponding to the *Channel Identifier* and *priority*. The data packet shall not be queued for transmission in the case that the *Channel Identifier* does not refer to a valid channel. A channel is invalid if it does not correspond to a channel for which the MLME is providing access via one of the mechanisms specified in 6.3.

The MAC shall cause the packet to be transmitted within in a time slot indicated by *Time Slot* in the MA- UNITDATA.request.

DATARATE in the PHY-TXSTART.request (TXVECTOR) shall be set to *Data Rate* from the MA-UNITDATA.request.

TXPWR LEVEL in the PHY-TXSTART.request (TXVECTOR) shall be set to *TxPwr Level* from the MA- UNITDATA.request.

For WSMP data, if *Expiry Time* is present in the MA-UNITDATA.request, and the MAC supports *Expiry Time*, then the MAC sublayer shall not begin transmitting the data ~~after if it has not been transmitted before~~ the *Expiry Time*.

5.3.4 Internal routing for IP datagrams on transmit

~~Sending IP data requires that~~ A transmitter profile ~~is first be~~ registered in the MIB attribute *TransmitterProfileTable* via an MLMEX-*_REGISTERTXPROFILE.request* or other mechanism: to support sending IP data. The transmitter profile contains an SCH number, power level, and the adaptable status of ~~the power level and~~ data rate. The priority is set by the higher layer for each MSDU.

When IP data is ~~received passed~~ in an MA-UNITDATA.request, following normal ~~from the LLC to the MAC, the~~ MAC processing per IEEE Std 802.11 ~~shall route~~ the packet is placed into a data queue that corresponds to the SCH and requested priority. If there is no transmitter profile registered for the SCH, or if the MLME is not providing access to the SCH, the data is not transmitted ~~shall be discarded~~.

5.3.5 ~~Overview of~~ Data frame receive operations

When the MAC receives an MPDU, it extracts the MSDU and passes it to the appropriate higher layer protocol via LLC. ~~It uses~~ an MA-UNITDATA.indication primitive regardless of whether the frame contains a WSM or an IPv6 packet. If the PHY is in the process of receiving a data frame when channel switching occurs, causing an interruption of the reception, the PHY issues a PHY-RXEND.indication (*RXERROR* = *CarrierLost*) to the MAC sublayer as specified in IEEE Std 802.11. The corresponding incomplete frame is discarded by the MAC (i.e., treated as a receive error) as specified in IEEE Std 802.11.

5.3.6 Routing for management data

~~Routing of management information received in the form of MLME_VSPECIFIC.indication, whose Organization Identifier most significant bits equal 0x 00 50 C2 4A 4 (indicating IEEE 1609 usage), is specified in 6.4.2.~~

~~Routing of timing information received in the form of an MLME_TIMING_ADVERTISEMENT.indication is specified in 6.2.7. The recipient of the information is not specified in this standard.~~

~~Management frame transmissions shall be controlled by the data rate and power parameters in the MIB attribute ChannelSetTable entry for that channel.~~

5.4 User priority

5.4.1 General

The WAVE MAC shall use the IEEE 802.11 EDCA mechanism per channel as described in the following subclauses. [Figure 3 is conceptual diagram illustrating](#)~~The general architecture of~~ prioritized access for data transmission~~is illustrated in Figure 2~~. When an MA-UNITDATA.request or MA-UNITDATA.request arrives at the MAC sublayer, and the appropriate channel routing is completed (see 5.3), the MAC shall queue the data by mapping its UP (range, 0 to 7) to AC (range, 1 to 4) and access category index (ACI; range, 0 to 3). These mappings are specified in IEEE Std 802.11. Management frames are [inserted at the MAC sublayer and the default AC to which a given management frame type is assigned as specified in](#)~~the highest AC (i.e., 4, or AC_VO) per~~ IEEE Std 802.11. Service providers may announce SCH EDCA parameters via the service advertisement mechanism described in IEEE Std 1609.3. [The EDCA parameter set to be used for a given channel might be specified in regulations or other standards.](#)

Each access category has an independent channel access function, with ~~priority~~ access governed by the appropriate EDCA parameter set values. [Use of EDCA parameters is specified in IEEE Std 802.11.](#) The values for a WAVE EDCA parameter set may differ from the default set specified in IEEE Std 802.11. ~~These EDCA parameters are described here for convenience:~~

- ~~— Arbitration inter-frame space: 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 transmit 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 MPDU.~~

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.

5.4.2 Control channel priority

The default EDCA parameter set specified in IEEE Std 802.11~~p~~ for OCB [Activated communication Enabled operation](#) is optimized for short message transfer and is recommended to be used when [communicating](#) ~~operating~~ on the CCH. ~~(See IEEE Std 802.11p specification of the EDCA Parameter Set element.)~~

5.4.3 ~~Service channel priority~~

~~Both IP and WSMP data packets, as well as management frames, are permitted on an SCH. On an SCH,~~ If an EDCA parameter set is received in the MLMEX-SCHSTART.request, this EDCA parameter set ~~is shall be~~ used for transmissions on [the indicated channel](#); ~~this SCH~~ otherwise, the default EDCA parameter set [for STA communication when dot11OCBAActivated is true](#), specified in IEEE Std 802.11p ~~is shall be~~ used.

6. Management ~~plane~~ services

6.1 General

This standard specifies an extension to the MAC sublayer management entity (MLME) specified in IEEE Std 802.11 ~~and IEEE Std 802.11p~~. It includes time synchronization and channel access features in support of channel coordination, as well [as channel-specific access to other IEEE 802.11 services, MIB maintenance, and readdressing](#) ~~periodic transmission of management frames~~.

6.2 Multi-channel synchronization

6.2.1 General

The synchronization function specified in this clause is based on a common time reference that allows WAVE devices to perform the channel coordination function specified in 5.2. [WAVE devices switching channels on time slot boundaries, e.g., performing alternating channel access, shall synchronize to a common time base, as specified in 6.2.2 and 6.2.5. The timing information used for synchronization may be derived by a timing management function from information received over the air from other WAVE devices, or may be obtained from a local source.](#)

~~Devices without a local timing source can acquire timing information over the air from other WAVE devices. Over the air synchronization procedures utilize the *Timestamp* field and *Time Advertisement* information element in the Timing Advertisement frame as inputs in estimating UTC time. Refer to IEEE Std 802.11 for the format of the *Timestamp* field, which indicates the value of the sender's timing synchronization function (TSF) timer. The value of the TSF timer is an integer modulo 2^{64} , incremented in units of microseconds. The *Time Advertisement* information element provides an offset from sending device TSF timer to general UTC time. Refer to IEEE Std 802.11p for the format of the *Time Advertisement* information element.~~

Synchronization to UTC, as specified in 6.2.5, is mandatory for WAVE devices switching channels on channel interval boundaries. The timing information used for synchronization may be derived by a timing management function from information received over the air from other WAVE devices, or may be obtained from a local time reference. The MLME maintains the estimated UTC time used for channel coordination; the timing management function that derives the UTC estimate may be internal or external to the MLME. An external timing management function may set the MLME UTC estimate (and its error characteristics) via the MLMEX.SETUTCTIME.request.

6.2.2 Common time ~~reference~~**base** definition

~~The synchronization function uses UTC as~~The common time ~~base~~, reference used for multi-channel synchronization is Coordinated Universal Time (UTC), modulo 1 second, or equivalently, Temps Atomique International (TAI), modulo 1 second. UTC is defined in ITU-R TF.460 [B2] and can be derived ~~obtained~~ from many sources including Global Positioning System (GPS) equipment. ~~receivers typically provide a precise 1 pulse per second (PPS) UTC signal (with an error less than 100 ns), and these precise 1 PPS signals can be used for timing and synchronization. The MLME shall use its UTC estimate to determine channel interval timing.~~