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Part 22: Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and Procedures for Operation in the TV Bands

AMENDMENT 2: Enhancement for broadband services and monitoring applications

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

Partie 22: Spécifications du contrôle d'accès du milieu sans fil cognitif (MAC) et de la couche physique (PHY) : Politiques et procédures pour le fonctionnement dans les bandes TV

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IEEE Std 802.22b™-2015
(Amendment to
IEEE Std 802.22™-2011
as amended by IEEE Std 802.22a™-2014)

**IEEE Standard for Information Technology—
Telecommunications and information exchange
between systems
Wireless Regional Area Networks (WRAN)—
Specific requirements**

Part 22: Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and Procedures for Operation in the TV Bands

Amendment 2: Enhancement for Broadband Services and Monitoring Applications

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Abstract: Alternate physical layer (PHY) and necessary medium access control layer (MAC) enhancements to IEEE Std 802.22-2011 are specified in this amendment for operation in very high frequency/ultra-high frequency (VHF/UHF) television broadcast bands between 54 MHz and 862 MHz to support enhanced broadband services and monitoring applications. The amendment supports aggregate data rates greater than the maximum data rate supported by the IEEE Std 802.22-2011. This amendment defines new classes of IEEE 802.22™ devices to address these applications and supports more than 512 devices in a network. This amendment also specifies techniques to enhance communications among the devices and makes necessary amendments to the cognitive, security, and parameters and connection management clauses. This amendment supports mechanisms to enable coexistence with other IEEE 802® systems in the same band.

Keywords: broadband wireless access network, enhanced broadband services, high capacity, high throughput, IEEE 802.22™, IEEE 802.22b™, monitoring applications, WRAN standard

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Introduction

This introduction is not part of IEEE Std 802.22b™-2015, IEEE Standard for Information Technology—Telecommunications and information exchange between systems—Wireless Regional Area Networks (WRAN)—Specific requirements—Part 22: Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and Procedures for Operation in the TV Bands—Amendment 2: Enhancement for Broadband Services and Monitoring Applications.

This amendment specifies alternate physical layer (PHY) and necessary medium access control layer (MAC) enhancements to IEEE Std 802.22-2011 for operation in very high frequency/ultra high frequency (VHF/UHF) television broadcast bands between 54 MHz and 862 MHz to support enhanced broadband services and monitoring applications. PHY specifications (i.e., Operation Mode 1 and Operation Mode 2) in Clause 9 and Clause 9a are designed to meet the needs required by channel models. A multi-channel operation (7.24), high modulation and coding (9.2 and 9a.2), and multiple-input, multiple-output (MIMO) (9.15 and 9a.15) provide higher throughput (compared to the IEEE Std 802.22-2011), which may be achieved by individual use or combinational use. Point-to-multipoint connections and relay connections are specified in Clause 7.

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IEEE Standard for Information Technology—Telecommunications and information exchange between systems Wireless Regional Area Networks (WRAN)—Specific requirements

Part 22: Cognitive Wireless RAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Policies and Procedures for Operation in the TV Bands

Amendment 2: Enhancement for Broadband Services and Monitoring Applications

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1. Overview

1.3 Reference application

Insert the following paragraphs after the third paragraph in 1.3:

The Advanced Wireless Regional Area Networks (A-WRANs) for which this standard has been developed are expected to support enhanced broadband services and monitoring applications such as real-time and/or near real-time monitoring, emergency broadband services, remote medical services, etc. The A-WRAN provides all essential functionalities of PHY, MAC, security, and cognitive radio technologies defined in the IEEE 802.22 WRAN and supports an additional PHY mode and additional functionalities of multi-hop relay operations, multiple channel operations, multiple-input-multiple-output (MIMO) operations, and advanced security to extend regional area broadband services to the regional monitoring applications and the enhanced broadband services.

Figure 1a illustrates an A-WRAN. An advanced base station (A-BS) complying with this standard shall be able to provide broadband services for the customer premise equipments (CPEs) such as an advanced CPE (A-CPE) and a subscriber CPE (S-CPE) through direct or multi-hop relay connectivity. An advanced customer premise equipment (A-CPE) can provide multi-hop relay connectivity for the S-CPEs, which allows for enhancing connection reliability between the A-BS and S-CPEs and reducing the network management overhead of the A-BS as well as could extend the service coverage of A-WRAN.

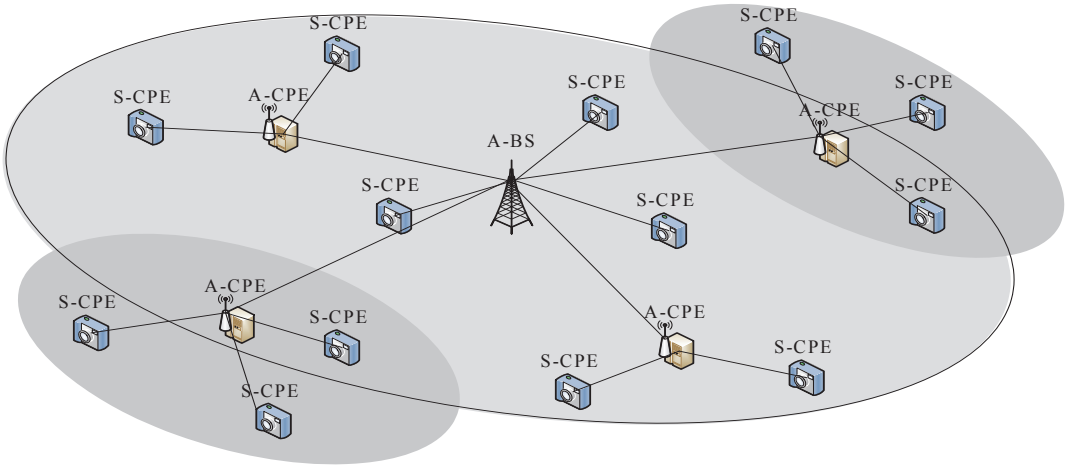

Figure 1a—An A-WRAN with an A-BS, A-CPEs, and S-CPEs

3. Definitions

Insert the following definitions in alphabetical order and renumber appropriately:

3.x access zone (AZ): A communication zone between an A-BS and A-CPE or between an A-BS and S-CPE in a frame.

3.x advanced base station (A-BS): A generalized equipment set providing connectivity, management and control of the customer premise equipment (CPE) such as the advanced customer premise equipment (A-CPE) and the subscriber CPE (S-CPE). The functionalities attributed to the A-BS, in the context of this standard, may be implemented by a device or a collection of devices. Anything that is not an A-BS shall be either of S-CPE or A-CPE.

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3.x advanced customer premise equipment (A-CPE): A generalized equipment set providing direct or relay connectivity between an A-BS and S-CPEs. A-CPE operates one of two modes: centralized scheduling mode and distributed scheduling mode.

3.x Advanced Wireless Regional Area Network (A-WRAN): The A-WRAN provides all essential functionalities of PHY, MAC, security, and cognitive radio technologies defined in the IEEE 802.22 WRAN and supports additional functionalities of an additional PHY mode, multi-hop relay operations, multiple channel operations, multiple-input-multiple-output (MIMO) operations, and advanced security to extend regional area broadband services to the regional monitoring applications and the enhanced broadband services.

3.x centralized relay zone (CRZ): A communication zone between a centralized scheduling A-CPE and S-CPE in a frame.

3.x centralized scheduling A-CPE: A generalized equipment set providing relay connectivity between an A-BS and S-CPEs.

3.x centralized scheduling mode: A mode where an A-CPE operates as a centralized scheduling A-CPE.

3.x distributed relay zone (DRZ): A communication zone between a distributed scheduling A-CPE and S-CPE in a frame.

3.x distributed scheduling A-CPE: A generalized equipment set providing relay connectivity between an A-BS and S-CPEs, and providing connectivity, management and control of the subscriber CPEs (S-CPEs) within a local network.

3.x distributed scheduling mode: A mode where an A-CPE operates as a distributed scheduling A-CPE.

3.x group resource allocation (GRA): The group is composed of one A-CPE and many S-CPEs. The A-BS allocates the resources on a group basis, and manages the backup and candidate channels on a group basis.

3.x local cell: A cell is formed by a distributed scheduling A-CPE and zero or more S-CPEs associated with and under control of the distributed scheduling A-CPE. The coverage area of this local cell extends up to the point where the signal received from the distributed scheduling A-CPE is sufficient to allow S-CPEs to associate and maintain communication with the A-BS on relay connection.

3.x multiple channel: Refers to more than one specific physical radio frequency (RF) channel in the TV broadcast frequency bands, which may be 6 MHz, 7 MHz, or 8 MHz wide depending on the relevant regulatory domains.

3.x multiple-input, multiple-output (MIMO): A system employing at least two transmit (Tx) antennas and at least two receive (Rx) antennas to improve the system capacity, coverage, or throughput.

3.x PHY Operation Mode 1 (PHY-OM1): A physical layer mode supporting the system defined in Clause 9 of IEEE Std 802.22b-2015.

3.x PHY Operation Mode 2 (PHY-OM2): A physical layer mode supporting the system defined in Clause 9a of IEEE Std 802.22b-2015.

3.x receive/transmit transition gap (RTG): A gap between the last sample of the upstream (US) subframe and the first sample of the subsequent downstream (DS) subframe at the antenna port of the BS in a time division duplex (TDD) transceiver. This gap allows time for the BS to switch from receive (Rx) to transmit (Tx) mode. During this gap, the BS is not transmitting modulated data but simply allowing the BS transmitter carrier to ramp up and the Tx/Rx antenna switch to actuate.

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3.x relay receive/transmit transition gap (RRTG): A gap between the last sample of the downstream (DS) access zone and the first sample of the subsequent DS relay zone at the antenna port of the A-CPE in a time division duplex (TDD) transceiver. This gap allows time for the A-CPE to switch from receive (Rx) to transmit (Tx) mode. During this gap, the A-CPE is not transmitting modulated data but simply allowing the A-CPE transmitter carrier to ramp up and the Tx/Rx antenna switch to actuate.

3.x relay transmit/receive transition gap (RTTG): A gap between the last sample of the upstream (US) access zone and the first sample of the subsequent US relay zone at the antenna port of the A-CPE in a time division duplex (TDD) transceiver. This gap allows time for the A-CPE to switch from transmit (Tx) to receive (Rx) mode. During this gap, the A-CPE is not transmitting modulated data but simply allowing the A-CPE transmitter carrier to ramp down and the Tx/Rx antenna switch to actuate, and the A-CPE receiver section to activate.

3.x relay zone (RZ): A communication zone between any A-CPE and an S-CPE or A-BS. A relay zone is operated as one of the following two relay zones: centralized relay zone (CRZ) and distributed relay zone (DRZ).

3.x subscriber customer premise equipment (S-CPE): A generalized equipment set providing connectivity between a A-BS and a subscriber premise, or between an A-CPE and a subscriber premise. S-CPE is used for any CPE that is not an A-CPE.

3.x transmit/receive transition gap (TTG): A gap between the last sample of the downstream (DS) subframe and the first sample of the subsequent upstream (US) subframe at the antenna port of the BS in a time division duplex (TDD) transceiver. This gap allows time for the BS to switch from transmit (Tx) to receive (Rx) mode. During this gap, the BS is not transmitting modulated data but simply allowing the BS transmitter carrier to ramp down and the Tx/Rx antenna switch to actuate, and the BS receiver section to activate.

3.x urgent coexistence situation (UCS): A situation where a WRAN detects incumbents in the current operating channel.

4. Abbreviations and acronyms

Insert the following abbreviations and acronyms in alphabetical order:

A-BS	advanced base station
A-CPE	advanced customer premise equipment
AZ	access zone
A-WRAN	advanced wireless regional area network
CRZ	centralized relay zone
CAM	channel allocation manager
CHU	channel transceiver unit
DL	downlink
DRZ	distributed relay zone
DTT	downstream transit test
Ex-FCH	extended frame control header
GRA	group resource allocation
LCU	local cell update
MD-TCM	multidimensional trellis coded modulation
MIMO	multiple-input, multiple-output
OSIC	ordered successive interference cancellation
OSTBC	orthogonal space-time block codes
PHY-OM1	Physical Layer Operation Mode 1

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PHY-OM2	Physical Layer Operation Mode 2
QP	quiet period
RRTG	relay receive/transmit transition gap
RTTG	relay transmit/receive transition gap
S-CPE	subscriber CPE
STC	space time coding
UL	uplink
ZF	zero-forcing

7. MAC Common Part sublayer

Change the preliminary text of Clause 7 as follows:

This clause describes the MAC layer used by the IEEE 802.22 WRAN point-to-multipoint medium access control standard and the IEEE 802.22b advanced WRAN (A-WRAN) multi-hop relay medium access control standard. The MAC provides tools for protection of TV bands incumbent services as well as for coexistence. The A-WRAN MAC provides all functionalities of the WRAN MAC and additionally supports multi-hop relay operations, multiple channel operations, multiple-input-multiple-output (MIMO) operations, etc. ~~The MAC is~~ Both WRAN and A-WRAN MACs are connection-oriented and provide~~s~~ flexibility in terms of QoS support. ~~The MAC regulates~~ The WRAN MAC and the A-WRAN MAC regulate downstream medium access by TDM, ~~while~~ and the upstream is managed by using a DAMA/OFDMA system. In the WRAN MAC, the BS manages all the activities within its IEEE 802.22 cell, and the associated CPEs are under the control of the BS. The A-WRAN MAC provides point-to-multipoint connections and relay connections between the advanced base station (A-BS) and the CPEs within an A-BS's cell. The multi-hop relaying is facilitated by an advanced CPE (A-CPE). An A-CPE shall operate one of two modes (centralized scheduling mode and distributed scheduling mode) depending on capability or network situations. The A-CPE that operates in the centralized scheduling mode (called a *centralized scheduling A-CPE*) provides relay connections for the subscriber CPEs (S-CPEs) under the management of the A-BS. The A-CPE that operates in the distributed scheduling mode (called a *distributed scheduling A-CPE*) may configure a local cell and has similar capabilities to that of A-BS, in that it manages S-CPEs within the local cell. The A-BS manages the A-WRAN cell's CPEs and local cells. A higher throughput compared to the IEEE Std 802.22™-2011 may be achieved by individual use or combinational use of multi-channel operation (7.24), high modulation and coding (9.2, 9a.2), or MIMO (9.15, 9a.15).

7.1 General

Insert the following paragraph after the first paragraph of 7.1:

In an A-WRAN cell consisting of CPEs (e.g., A-CPEs and S-CPEs), all A-CPEs and multiple S-CPEs are managed by a single A-BS, and other S-CPEs are managed by distributed scheduling A-CPEs. The downstream is TDM where the A-BS transmits and the CPEs receive. The upstream transmissions, where the CPEs transmit and the A-BS receives, are shared by the CPEs on a demand basis, according to a DAMA/OFDMA scheme. Within a local cell consisting of a distributed scheduling A-CPE and S-CPEs, multiple S-CPEs are managed by the distributed scheduling A-CPE. The downstream within a local cell is TDM where the distributed scheduling A-CPE transmits and the S-CPEs receive. The upstream transmissions within a local cell, where the S-CPEs transmit and the distributed scheduling A-CPE receives, are shared by the S-CPEs on a demand basis, according to a DAMA/OFDMA scheme.

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Change the now third and fourth paragraphs in 7.1 as follows:

~~The~~ Both WRAN MAC and A-WRAN MAC implement~~s~~ a combination of access schemes that efficiently control contention between CPEs within a cell and overlapping cells sharing the same channel while at the same time attempting to meet the latency and bandwidth requirements of each user application. This is accomplished through four different types of upstream scheduling mechanisms that are implemented using unsolicited bandwidth grants, polling, and two contention procedures (i.e., MAC header and CDMA based). The use of polling simplifies the access operation and attempts to allow applications to receive service on a deterministic basis if it is required.

~~The~~ Both WRAN MAC and A-WRAN MAC ~~is~~ are connection-oriented, and as such, connections are a key component that require active maintenance and hence can be dynamically created, deleted, and changed as the need arises. A connection defines both the mapping between convergence processes at CPEs and BS or A-BS and the related service flow (one connection per service flow). For the purposes of mapping to services on CPEs and associating varying levels of QoS, all data communications are instantiated in the context of a connection, and this provides a mechanism for upstream and downstream QoS management. In particular, the QoS parameters are integral to the bandwidth allocation process as the CPE requests upstream bandwidth on a per connection basis (implicitly identifying the service flow). The BS, A-BS, or the distributed scheduling A-CPE, in turn, grants bandwidth to a CPE as an aggregate of grants in response to per-connection requests from the CPE.

Insert the following paragraph at the end of 7.1:

An A-WRAN may support multiple connections between A-BS and A-CPE(s) or S-CPE(s), or between A-CPE and S-CPE(s), by using multiple channels (7.24). When multiple channels are available and used for the connections between A-BS and A-CPE(s) or S-CPE(s), or between A-CPE and S-CPE(s), a frame is assigned to the connection on the different channel into multiple channels. The frame format on each channel shall follow the frame format described in 7.4, 7.4a, and 7.4b.

7.2 Addressing and connections

Insert the following paragraph after the first paragraph in 7.2:

Each A-BS and CPE in an A-WRAN shall have a 48-bits universal MAC address, as defined in IEEE Std 802®. This address uniquely defines the A-BS and CPE from within the set of all possible vendors and equipment types. It is used as part of the authentication process by which the A-BS and CPE each verifies the identity of the other at the time of network association. The A-BS MAC address is broadcast by the A-BS on superframe control header (SCH) on PHY Operation Mode 1 (Clause 9) or frame control header (FCH) on PHY Operation Mode 2 (Clause 9a) and is present in every CBP burst. Each A-WRAN device regularly broadcasts a CBP burst containing its Device ID and Serial Number. This is done as part of the device's self-identification process that helps identify potential interference sources to incumbent services and for coexistence purposes.

Change the now third and fourth paragraphs of 7.2 as follows:

Connections are identified by two items, a ~~9~~13-bit station ID (SID) and a 3-bit flow ID (FID). The SID uniquely identifies a station that is under the control of the BS, the A-BS, or the distributed scheduling A-CPE. A SID can be for a unicast station, when referencing a single CPE, or for a multicast station, when referencing a multicast group (of CPEs). A FID identifies a particular traffic flow assigned to a CPE. The tuple of SID and FID (SID | FID) forms a connection identifier (CID) that identifies a connection for the CPE. The SID is signaled in the DS/US-MAP allocation, and the FID is signaled in the generic MAC header (GMH) of a MAC PDU. This allows for a total of up to ~~512~~ 8192 stations, each with a maximum of eight flows that can be supported within each downstream and upstream channel.

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At CPE initialization, three flows shall be dedicated for management connections (see 12.2) for the purpose of carrying MAC management messages and data between a CPE and the BS/A-BS or the distributed scheduling A-CPE. The three flows reflect the fact that there are inherently three different levels of QoS for traffic sent on management connections between a CPE and the BS/A-BS or the distributed scheduling A-CPE. The basic flow is used by the BS/A-BS MAC or the distributed scheduling A-CPE MAC and CPE MAC to exchange short, time-urgent MAC management messages; whereas, the primary management flow is used by the BS/A-BS or the distributed scheduling A-CPE MAC and CPE MAC to exchange longer, more delay-tolerant MAC management messages (Table 19 specifies which MAC management messages are transferred on which type of connections). Finally, the secondary management flow is used by the BS/A-BS or the distributed scheduling A-CPE and CPE to transfer more delay-tolerant, standards-based (e.g., DHCP, TFTP, and SNMP) messages that are carried in IP datagrams. The secondary management flow may be packed and/or fragmented, similarly to the primary management except that no ARQ should be used for the latter since it is more time critical.

Change the now seventh paragraph of 7.2 as follows:

Many higher-layer sessions may operate over the same wireless connection. For example, many users within a company may be communicating with Transmission Control Protocol (TCP)/IP to different destinations, but since they all operate within the same overall service parameters, all of their traffic is pooled for request/grant purposes. A service flow is a unidirectional flow of traffic (BS/A-BS to CPE, or CPE to BS/A-BS, distributed scheduling A-CPE to CPE, or CPE to distributed scheduling A-CPE) that defines the mapping of higher-layer application service parameters (e.g., QoS) to a FID assigned to a particular CPE's unicast SID or multicast group (multicast SID).

7.3 General superframe structure

Insert the following paragraphs as the first three paragraphs of the preliminary text in 7.3:

The A-WRAN supports two PHY operation modes: PHY Operation Mode 1 (PHY-OM1, Clause 9) and PHY Operation Mode 2 (PHY-OM2, Clause 9a).

The WRAN system and the A-WRAN system on PHY-OM1 shall support the following superframe structure.

The A-WRAN on PHY-OM2 does not support the following superframe structure.

Change the now fourth paragraph of the preliminary text in 7.3 as follows:

The ~~IEEE 802.22~~ WRAN system and the A-WRAN system on PHY-OM1 include~~s~~ two operational modes: a normal mode and a self-coexistence mode. In normal mode, one WRAN/A-WRAN cell occupies one or more channels and operates on all the frames in a superframe. In self-coexistence mode, multiple WRAN and/or A-WRAN cells share the same channel, and each coexisting WRAN and/or A-WRAN cell operates on one or several different frames exclusively.

Change the title of 7.4 as follows:

7.4 General frame structure (on PHY-OM1)

Insert the following paragraph as the first paragraph in 7.4:

The WRAN system and the A-WRAN system on PHY-OM1 described in Clause 9 shall support the following frame structure.

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Insert the following subclauses (7.4a and 7.4b and their subclauses, figures, and tables) after 7.4:

7.4a General frame structure (on PHY-OM2)

The A-WRAN on PHY-OM2 described in Clause 9a shall support the following frame structure.

The A-WRAN on PHY-OM2 includes two operational modes: a normal mode and a self-coexistence mode. In normal mode, one A-WRAN cell occupies one or more channels and operates on all the frames. In self-coexistence mode, multiple A-WRAN cells share the same channel, and each coexisting WRAN cell operates on one or several different frames exclusively.

The A-WRAN on PHY-OM2 shall transmit the Frame Control Header (FCH) (7.5.2a, Table 2a) at the beginning of every frame on the operating channel in both normal mode and self-coexistence mode. An A-WRAN runs in normal mode by default and transits to self-coexistence mode when the A-WRAN can detect and decode an FCH or a CBP from an adjacent A-WRAN cell on its operating channel.

7.4a.1 General frame structure for normal mode

The A-WRAN frame structure depicted in Figure 12 shall be used and the first frame shall be constituted of the following:

— A PHY frame preamble (Clause 9a)
— A Frame Control header (FCH) (7.5.2a)
— The rest of the first frame including its frame header and data payload

At the beginning of every frame, the A-BS shall transmit the frame preamble and the FCH on the operating channel using the modulation/coding specified in 9a.2 and Table 231e, respectively. In order to associate with an A-BS, a CPE must receive the FCH to establish communication with the A-BS. During each MAC frame, the A-BS shall manage the upstream and downstream operations, which may include ordinary data communication, measurement activities, coexistence procedures, and so on.

7.4a.2 General frame structure for self-coexistence mode

The A-WRAN frame structure in self-coexistence mode is shown in Figure 13a. The self-coexistence mode is for the scenario when multiple A-BSs with overlapping coverage have to share the same channel. The frequency reuse factor cannot be maintained as one due to the mutual interference of these A-BSs. In this case, the A-BSs shall share the channel on a per-frame basis, i.e., each A-BS is allocated the frames on a non-interference basis. The negotiation process of frame allocation can be found in 7.20.

In self-coexistence mode, the A-BS and CPEs in an A-WRAN cell shall transmit only during the active frames allocated to that A-WRAN cell. They can transmit during other frames only when a self-coexistence window (SCW) has been scheduled. During the frames not allocated to the present cell, the A-BS and CPEs may monitor the channel for any transmission from neighboring A-WRAN cells to improve self-coexistence.

7.4a.3 Frame format

The A-WRAN system on PHY-OM2 described in Clause 9a shall support the following frame structure.

The top-down time division duplex (TDD) frame structure employed in the MAC is illustrated in Figure 12.

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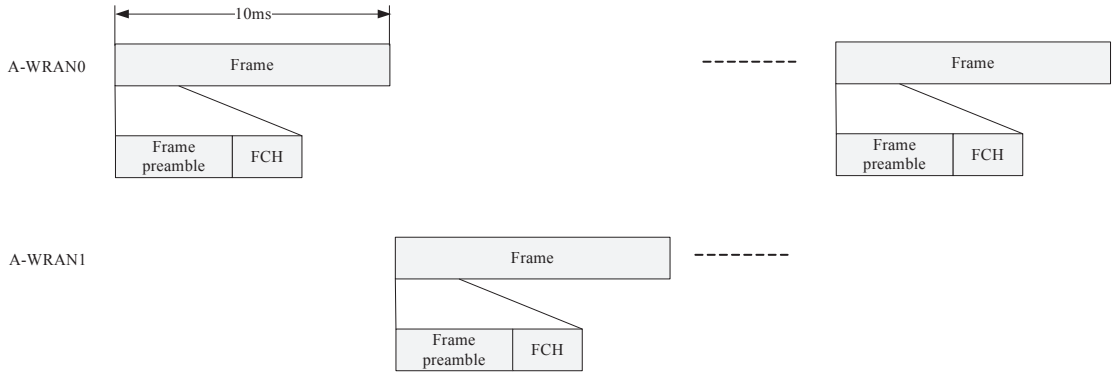

Figure 13a—General frame structure on PHY-OM2 for self-coexistence mode

As illustrated in Figure 13b, a frame comprises two parts: a downstream (DS) subframe and an upstream (US) subframe. A portion of the US subframe may be allocated as a window to facilitate self-coexistence. This SCW may be scheduled by the A-BS at the end of the US subframe when necessary to allow transmission of opportunistic coexistence beacon protocol bursts. The SCW includes the necessary time buffers to absorb the difference in propagation delay between nearby and distant A-BSs and CPEs operating on the same channel. The boundary between the DS and US subframes shall be adaptive to adjust to the DS and US relative capacity. The US subframe may contain scheduled US PHY PDUs, each transmitted from different CPEs for their US traffic. It may also include contention intervals scheduled for the following:

— CPE association (initial ranging)
— CPE link synchronization, power control, and geolocation (periodic ranging)
— Bandwidth request
— Urgent coexistence situation (UCS) notification
— Quiet period (QP) resource adjustment

The definitions of the fields/messages are given in 7.6 and 7.7.

The PHY PDUs may be transmitted across several subchannels as shown in Figure 13b, which depicts how a frame may be transmitted (in time and frequency) by the PHY.

Figure 13b shows an example of the two-dimensional (2D) (time/frequency) structure of the MAC frame that shall consist of an integer number of fixed-size OFDM slots. Each slot shall consist of 4 OFDM symbols by one subchannel (i.e., 1 OFDM slot for DS = 4 symbols × 1 subchannel) for DS and shall consist of 7 OFDM symbols by subchannel (i.e., 1 OFDM slot for US= 7 symbols × 1 subchannel) for US (9a.1.3.1). A subchannel consists of 16 subcarriers. In Figure 13b, the MAC packets are assumed to be structured in a linear TDM manner (see Figure 12), and the PHY packets are arranged in a 2D time/frequency domain (symbol in the horizontal direction, logical subchannels in the vertical direction). For the FCH, DS/US-MAP, DCD, UCD, and DS payload, the MAC information is first laid vertically by subchannels and then stepped horizontally in the time direction. This vertical layering allows early scheduling of DS bursts assigned to distant CPEs to compensate for propagation delays and to avoid potential interference at the CPE if overlapping A-WRAN cells with different DS/US capacity split.

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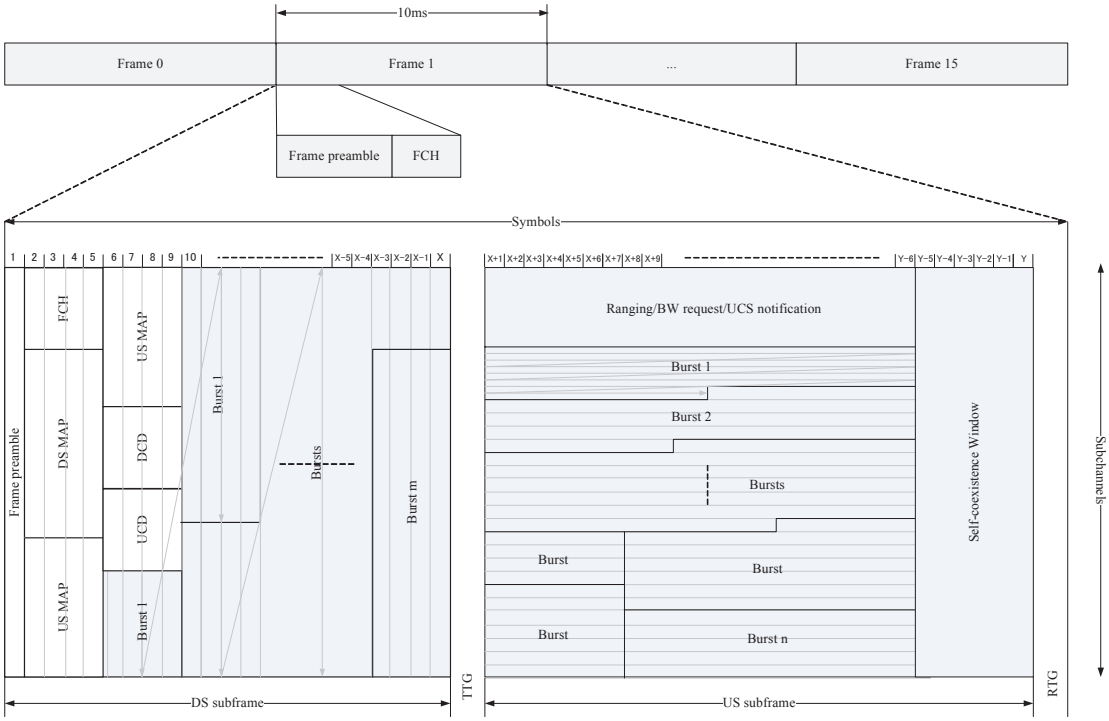

Figure 13b—Example of a time/frequency structure of a MAC frame for PHY-OM2

The MAC data elements, starting from the FCH and including the first broadcast burst, shall be entered into the portion between the second OFDM symbol and fifth OFDM symbol, which is based on the number of symbols defined in a tile (9a.1.3.1), as shown in Figure 13b, in the increasing order of logical subchannels until all logical subchannels are occupied. Then, the subsequent data elements, if they have not all been mapped, shall be placed in the same order on the following OFDM symbols. The balance of the last OFDM symbols shall be padded with zeros. The modulation and coding schemes for the padding zeros are defined by the DIUC for the last DS burst in the DS-MAP. Note that the DS-MAP indicates the length of the contiguous DS MAC elements, not their absolute position in the DS subframe.

The MAC data elements that are contained in US bursts shall be mapped to the US subframe in a different order as shown in Figure 13b. They are first mapped horizontally, 7 OFDM symbols by 7 OFDM symbols, in the same logical subchannel. Once a logical subchannel has been filled to the end of the US subframe, the balance of the MAC data elements shall be mapped to the next logical subchannel, in an increasing subchannel order. This process continues until all of the subchannels and symbols allocated to the burst are filled. If the quantity of MAC data elements is insufficient to fill an US burst so that an integer number of OFDMA slots is occupied once encoded, zero padding shall be inserted at the end.

Alternatively, the horizontal laying of the MAC data elements may fill one subchannel with at least 7 OFDM symbols at a time and continue on the following subchannels. However, when all logical subchannels have been filled, the next MAC data elements shall be placed in the first available logical subchannel in the following burst. The width of the last vertical burst will be between 7 and 13 symbols depending on the total number of symbols in the US subframe.

The long US packet structure, where a logical subchannel is completely filled before moving to the next subchannel, is used to maximize the allowed power per subcarrier for a given CPE EIRP limit, i.e., this horizontal laying reduces the EIRP required by the CPE for its US burst by minimizing the number of

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subchannels needed. In the US, the shorter burst alternative shown in Figure 13b is used to reduce latency by allowing advance of the US burst in the US subframe to give the base station time to react before the start of the next frame, at the cost of reduced transmit power and efficiency (e.g., video game near real-time versus transmission efficiency).

The format of the FCH MAC burst is described in 7.5.2a. The FCH is modulated using the data mode selected (e.g., Mode 2) (Table 231e). Binary convolutional coding (BCC; 9a.7.2.1) shall also be applied to the FCH burst. The FCH specifies the burst profile and the length of either the DS-MAP, if transmitted, or the US-MAP. If neither the DS-MAP nor the US-MAP is transmitted, the value shall be set to zero. The DS-MAP message, if transmitted, shall be the first MAC PDU in the burst following the FCH. A US-MAP message, if transmitted, shall immediately follow either the DS-MAP message, if transmitted, or the FCH. If DCD and UCD messages are transmitted in the frame, they shall immediately follow the DS-MAP and US-MAP messages. The symbols containing these broadcast MAC control messages shall be modulated using data mode 2 as described in Table 231e with the mandatory BCC mode (see 9a.7.2.1).

In the US direction, if a CPE does not have any data to transmit in its US allocation, it shall transmit an US PHY burst containing a generic MAC header (see 7.6.1.1) with its basic FID, together with a Bandwidth Request subheader (see 7.6.1.2.1). This would allow the A-BS to reclaim this CPE's allocation in the following frames and use the resource for some other purpose.

The A-BS may schedule up to five types of contention windows (see 7.13):

— The Initial Ranging window is used for initializing the association.
— The periodic ranging window is used for regularly adjusting the timing and power at the CPE.
— The BW request window is used by CPEs to request US bandwidth allocation from the A-BS.
— The UCS notification window is used by CPEs to report a UCS with incumbents.
— The SCW is employed by CBP packets for signaling information to adjacent and overlapping A-WRAN cells for self-coexistence, signaling the device identification for resolving interference situations with incumbents when requested by local regulation, and carrying out terrestrial geolocation between CPEs of the same A-WRAN cell.

However, CBP burst transmissions for terrestrial geolocation shall have lower priority than any other coexistence transmission on the CBP burst.

The SCW shall be scheduled at the end of the frame as depicted in Figure 13b. The CBP packets (9a.5) are transmitted by selected CPEs or the A-BS and carry information, among other things, about the A-WRAN cell as a whole and the device that transmits it as well as information to support the self-coexistence mechanism (see 7.20).

A CBP packet shall be transmitted by each CPE associated to an A-BS as specified by the parameter "T34" in Table 272 for periodic identification of its device ID and serial number and the associated base station ID as may be required by local regulations (see Annex A).

Whenever a CPE is neither receiving nor sending data to its A-BS (idle state), it shall be capable of decoding CBP packets transmitted by nearby CPEs belonging to other A-WRAN cells, on the same channel (N), or on adjacent channels (N±1), or on alternate channels (N±2 and beyond). This capability shall also be available at CPE initialization. In addition, A-BS frame synchronization is based on the absolute local start time of their frame period to the start of every minute referenced to UTC as specified in 7.23. Hence, multiple co-located or nearby A-BS cells can efficiently communicate with each other and align their SCW for CBP exchange as well as their quiet periods for sensing incumbents.

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7.4b General frame structure for a relay network

The A-WRAN system on both PHY-OM1 and PHY-OM2 shall support the following frame structure for relay.

A general frame structure has two different modes for relay: a centralized scheduling mode and a distributed scheduling mode.

For centralized scheduling mode, a centralized scheduling A-CPE relays frames including control frames or data frames received from (to) the A-BS to (from) the S-CPE, which will enhance connection reliability between the A-BS and S-CPEs. Moreover, a centralized scheduling A-CPE may relay network management information received from an A-BS such as the preamble, FCH, MAPs, etc., to S-CPEs to assist the network management of the A-BS

For distributed scheduling mode, a distributed scheduling A-CPE configures a local cell containing more than one S-CPE within an A-WRAN cell and manages the S-CPEs locally by producing and transmitting network management information (such as a local frame preamble, distributed relay zone (DRZ)-FCH (7.5.2b), MAPs, etc.), which allows for reducing the network management overhead of the A-BS as well as could extend the service coverage of A-WRAN.

7.4b.1 General frame structure for a centralized scheduling mode

Each of the DS and US subframes for a centralized scheduling mode may include two zones: access zone (AZ) and centralized relay zone (CRZ) as shown in Figure 13c. Each AZ in the DS and US subframes is used for transmission between an A-BS and CPEs (i.e., centralized scheduling A-CPEs or S-CPEs), and each CRZ in the DS and US subframes is used for transmission between a centralized scheduling A-CPE and S-CPEs.

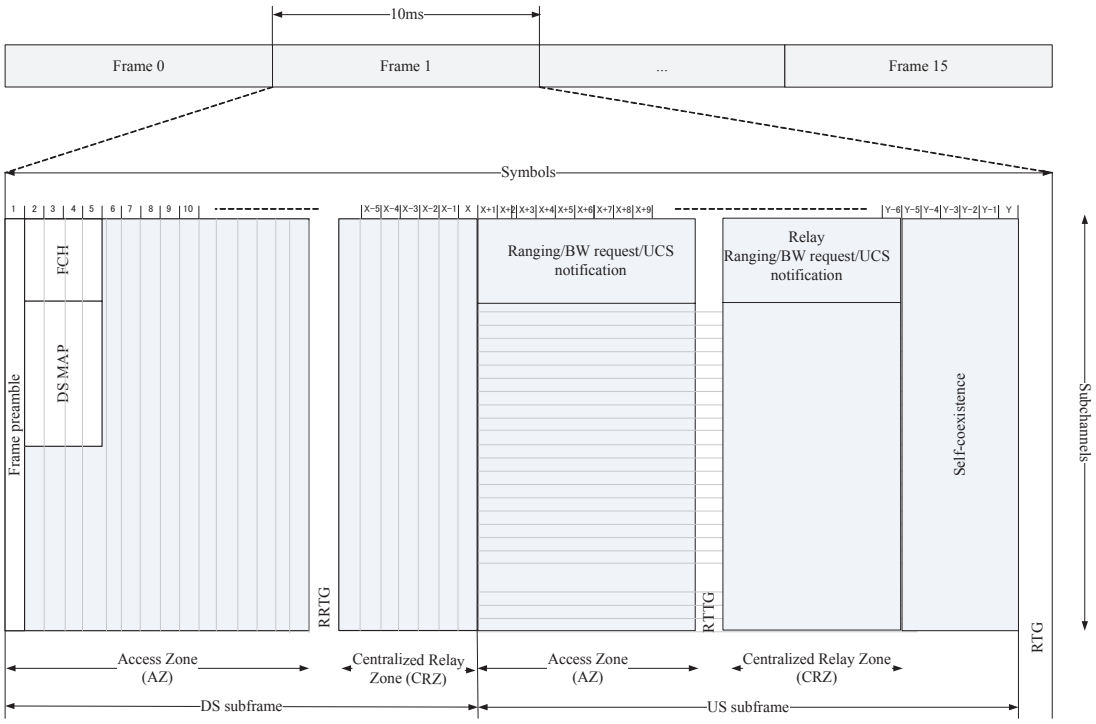

Figure 13c—Example of a time/frequency structure of a MAC frame for a centralized scheduling mode on PHY-OM2

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For centralized scheduling mode, both the AZs and CRZs in the DS and US subframes are managed by an A-BS. The AZ of the DS subframe shall appear earlier than other zones of the AZ of the US subframe or the CRZs of the DS and US subframes. Except for the AZ of the DS, the order of the AZ of the US subframe, the CRZ of the DS subframe, and the CRZ of the US subframe in the frame may be changed during the operations.

7.4b.2 General frame structure for a distributed scheduling mode

Each of the DS and US subframes for a distributed scheduling mode may include two zones: access zone (AZ) and distributed relay zone (DRZ) as shown in Figure 13d. Each AZ in the DS and US subframes is used for transmission between an A-BS and CPEs (i.e., distributed scheduling A-CPEs or S-CPEs), and each DRZ in the DS and US subframe is used for transmission between a distributed scheduling A-CPE and S-CPEs.

Both the AZs and DRZs in the DS and US subframes are scheduled by an A-BS. For distributed scheduling mode, the AZs in the DS and US subframes are managed by an A-BS, and the DRZs in the DS and US subframes are controlled by a distributed scheduling A-CPE, which is capable of configuring and maintaining a local cell within an A-WRAN cell. The AZ of the DS subframe shall appear earlier than other zones of the AZ of the US subframe or the DRZs of the DS and US subframes. Except for the AZ of the DS, the order of the AZ of the US subframe, the DRZ of the DS subframe, and the DRZ of the US subframe in the frame may be changed during the operations.

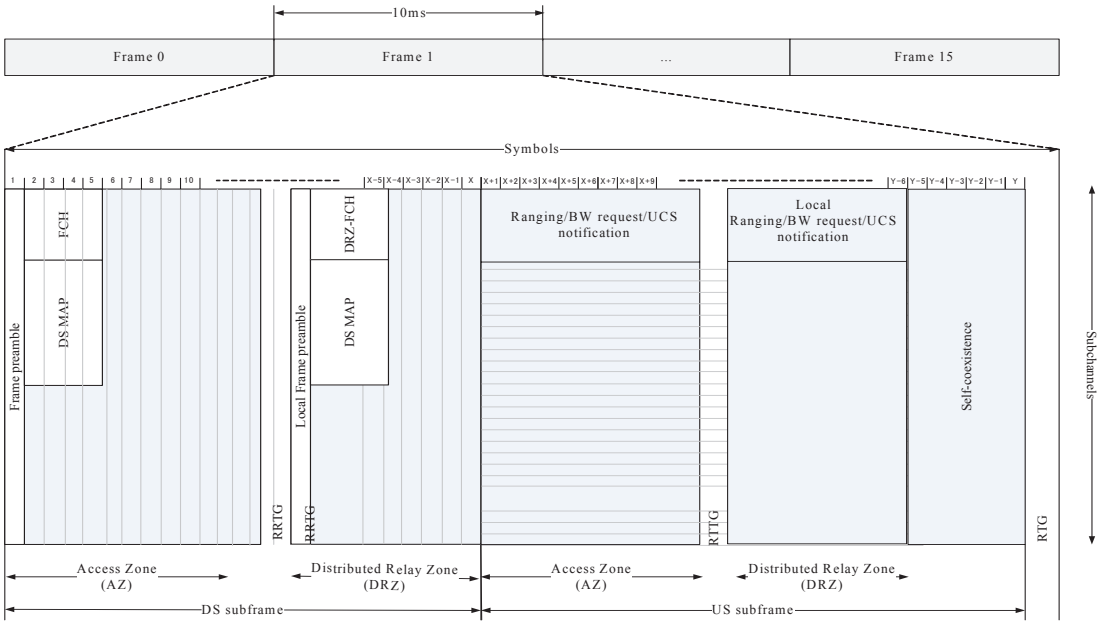

Figure 13d—Example of a time/frequency structure of a MAC frame for a distributed scheduling mode on PHY-OM2

For the A-WRAN on either PHY operation mode, the subchannels of the DRZs in the DS and US subframes can be grouped by up to three segments with the fixed number of subchannels as shown in Figure 13e. The segment bandwidth is scalable up to the occupied subchannel as shown in Figure 13f. For PHY-OM1 and PHY-OM2, each segment includes the number of subchannels defined in Table A1. For the DS of PH-OM2, the number of tiles per occupied channel bandwidth is not divided by 3. Thus segments 1, 2, and 3 have a different number of tiles, i.e., 72, 68, and 68 tiles, respectively. Figure 13f shows all the combinations of three segment bandwidths and three start positions. As shown in Figure 13g, the number of segment

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bandwidth modes is 3, 2, and 1 for the first, second, and third start positions, respectively. The configuration of the segmentation scheme can be identified by local frame preamble as defined in 9.4.1.5 and 9a.4.1.1. The segmentation can be scheduled by the A-BS, and each segment is assigned to the different distributed scheduling A-CPEs. This segmentation is used to increase network capacity.

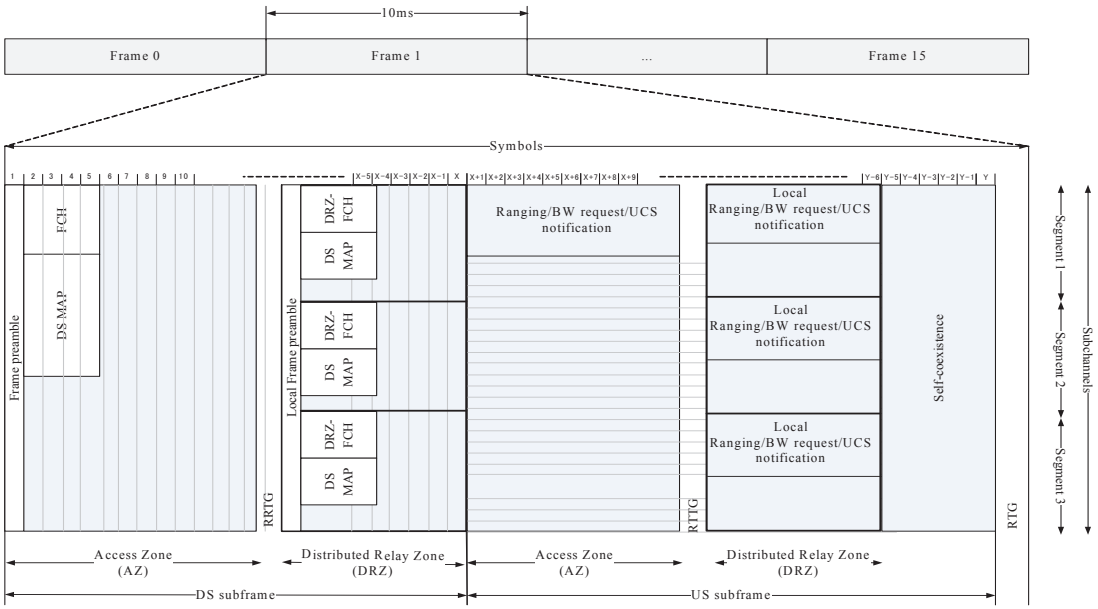

Figure 13e—Example of a time/frequency structure of a MAC frame for a distributed scheduling mode on segmentation on PHY-OM2

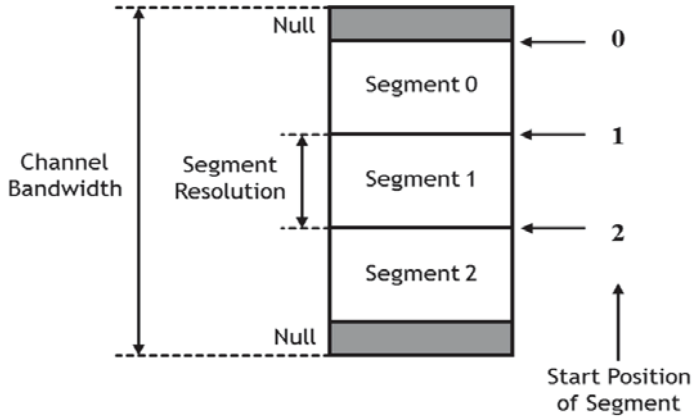

Figure 13f—Segment structure

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Table A1—Segment bandwidth

	PHY-OM1		PHY-OM2	
	DS (subchannels)	US (subchannels)	DS (tiles)	US (tiles)
Size of Segment 1	10	20	72	70
Size of Segment 2	10	20	68	70
Size of Segment 3	10	20	68	70

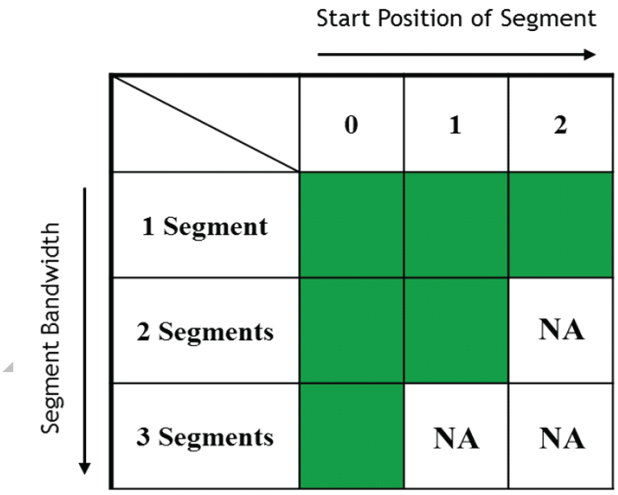

Figure 13g—Combination of segment start position and segment bandwidth

7.4b.3 Detail of zones

7.4b.3.1 Access zone (AZ)

At the beginning of every superframe in AZ on PHY-OM1, the A-BS shall transmit the superframe preamble and the SCH on the operating channel using the modulation/coding specified in 9.4.1.2 and Table 202, respectively. At the beginning of every frame in AZ on PHY-OM2, on the other hand, the A-BS shall transmit the frame preamble and the FCH on the operating channel using the modulation/coding specified in 9a.2 and Table 231e, respectively. In order to associate with an A-BS, a CPE must receive the SCH or FCH to establish communication with the A-BS.

An AZ in the US subframe may contain scheduled US PHY PDUs, each transmitted from different CPEs for their US traffic. It may also include contention intervals scheduled for the following:

— CPE association (initial ranging)
— CPE link synchronization, power control, and geolocation (periodic ranging)
— Bandwidth request
— UCS notification
— Quiet period resource adjustment

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The 2D (time/frequency) structure of the MAC frame shall consist of an integer number of fixed-size OFDM slots. For PHY-OM1, each slot shall consist of one OFDM symbol by one subchannel (i.e., 1 OFDM slot = 1 symbol × 1 subchannel) for both DS and US. For PHY-OM2, on the other hand, each slot shall consist of 4 OFDM symbols by one subchannel (i.e., 1 OFDM slot for DS = 4 symbols × 1 subchannel) for DS and shall consist of 7 OFDM symbols by subchannel (i.e., 1 OFDM slot for US = 7 symbols × subchannel) for US (9a.1.3.1). For the FCH, DS/US-MAP, DCD, UCD, and DS payload in an AZ, the MAC information is first laid vertically by subchannels and then stepped horizontally in the time direction. This vertical layering allows early scheduling of DS bursts assigned to distant CPEs to compensate for propagation delays and to avoid potential interference at the CPE if overlapping A-WRAN cells with different DS/US capacity split.

In an AZ, the MAC data elements, starting from the SCH/FCH and including the first broadcast burst, shall be mapped to the DS subframe in the manner described in 7.4 for PHY-OM1 and 7.4a.3 for PHY-OM2.

In an AZ, the MAC data elements that are contained in US bursts shall be mapped to the US subframe in the manner described in 7.4 for PHY-OM1 and 7.4a.3 for PHY-OM2.

7.4b.3.2 Centralized relay zone (CRZ)

During a CRZ in the DS subframe, the centralized scheduling A-CPE transmits the MAC frames, which may be transferred from the A-BS during an AZ in the DS subframe, to the S-CPE on the scheduled slots determined by the A-BS.

A CRZ in the US subframe may contain scheduled US PHY PDUs, each transmitted from different S-CPEs for their US traffic, which forwards the centralized scheduling A-CPE. It may also include contention intervals scheduled for the following:

— CPE relay association (7.15.2.3.3)
— CPE link synchronization, relay power control, and geolocation (7.15.2.4.3)
— Relay bandwidth request
— Relay UCS notification
— Quiet period resource adjustment

The 2D (time/frequency) structure of the MAC frame in a CRZ is the same manner as that in an AZ (7.4b.3.1).

If a CRZ appeared in the DS subframe, the CRZ shall be followed by the DS AZ in the MAC frame. The MAC data bursts in the CRZ shall be entered into the first subchannel within the portion, calculated by CRZ Start Offset and Length in CRZDS-MAP IE (7.7.2.1.2.4), in the increasing order of logical subchannels until all logical subchannels are occupied in the portion. Then, the subsequent data elements, if they have not all been mapped, shall be placed in the same order on the following OFDM symbols. The balance of the last OFDM symbols within the portion shall be padded with zeros. The modulation and coding schemes for the padding zeros are defined by the DIUC for the last DS burst in CRZDS-MAP IE.

If a CRZ appeared in the US subframe, the MAC data elements that are contained in relay US bursts shall be mapped to the CRZ in the US subframe in the same manner as US subframe mapping in AZ (7.4b.3.1).

The A-BS may schedule up to four types of contention windows (see 7.13) in the CRZ:

— The relay initial ranging window is used for initializing the relay association.
— The relay periodic ranging window is used for regularly adjusting the timing and power at the CPE.

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— The relay BW request window is used by CPEs to request relay US bandwidth allocation from the A-BS.
— The relay UCS notification window is used by CPEs to report a UCS with incumbents.

7.4b.3.3 Distributed relay zone (DRZ)

For local cell operations within an A-WRAN, the A-BS will schedule a DRZ for a distributed scheduling A-CPE, which is capable of managing a local cell. During a DRZ, the distributed scheduling A-CPE shall transmit the local frame preamble (9.4.1.5, 9a.4.1.1) and the DRZ-FCH (7.5.2b) on the operating channel using the modulation/coding specified in 9.2 and Table 202 for PHY-OM1 and 9a.2 and Table 231e for PHY-OM2. In order to associate with the distributed scheduling A-CPE, an S-CPE must receive the DRZ-FCH to establish communication with the distributed scheduling A-CPE. During each DRZ in the DS and US subframes, the distributed scheduling A-CPE shall manage the US and DS operations within its local cell, which may include ordinary data communication, measurement activities, coexistence procedures, and so on.

A DRZ in the US subframe may contain scheduled US PHY PDUs, each transmitted from different CPEs for their US traffic to the distributed scheduling A-CPE. It may also include contention intervals scheduled for the following:

— CPE local association (7.15.2.3.2)
— CPE local link synchronization, power control, and geolocation (7.15.2.4.2)
— Local bandwidth request
— Local UCS notification
— Quiet period resource adjustment

The 2D (time/frequency) structure of the MAC frame in a DRZ is the same manner as that in an AZ (7.4b.3.1).

If a DRZ appeared in the DS subframe, the DRZ shall be followed by the DS AZ in the MAC frame. The MAC data elements that are contained in DS bursts shall be mapped to the DRZ in the DS subframe in the same manner as the AZ in DS subframe mapping.

If a DRZ appeared in the US subframe, the MAC data elements that are contained in US bursts shall be mapped to the DRZ in the US subframe in the same manner as the AZ in US subframe mapping (7.4b.3.1).

The format of the DRZ-FCH MAC burst is described in 7.5.2b. The DRZ-FCH is modulated using the data mode selected. BCC (9.7.2.1 for PHY-OM1, 9a.7.2.1 for PHY-OM2) shall also be applied to the DRZ-FCH burst. The DRZ-FCH specifies the burst profile and the length of either the DS-MAP, if transmitted, or the US-MAP. If neither the DS-MAP nor the US-MAP is transmitted, the value shall be set to zero. The DS-MAP message, if transmitted, shall be the first MAC PDU in the burst following the DRZ-FCH. A US-MAP message, if transmitted, shall immediately follow either the DS-MAP message, if transmitted, or the DRZ-FCH. If DCD and UCD messages are transmitted in the frame, they shall immediately follow the DS-MAP and US-MAP messages. The symbols containing these broadcast MAC control messages shall be modulated using data mode 5 as described in Table 202 for PHY-OM1 or data mode 3 as described in Table 231e for PHY-OM2 with the mandatory BCC mode (see 9.7.2.1).

The distributed scheduling A-CPE may schedule up to four types of contention windows (see 7.13):

— The local Initial Ranging window is used for initializing the association.
— The local periodic ranging window is used for regularly adjusting the timing and power at the CPE.

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— The local BW request window is used by CPEs to request local US bandwidth allocation from the distributed scheduling A-CPE.
— The local UCS notification window is used by CPEs to report a UCS with incumbents.

7.4b.3.4 Application of PHY Operation Mode to Zone Type

When the A-BS is operating in PHY-OM1, the DS AZ and DS CRZ shall be operated by PHY-OM1. A-CPEs shall use PHY-OM1 to communicate with the A-BS in the DS AZ and DS CRZ.

When the A-BS is operating in PHY-OM2, the DS AZ and DS CRZ shall be operated by PHY-OM2. A-CPEs shall use PHY-OM2 to communicate with the A-BS in the DS AZ and DS CRZ.

The A-CPEs operating in the DS DRZ, may be operated by either PHY-OM1 or PHY-OM2, independent of what PHY operation mode the A-BS employs in the DS.

The A-BS may switch between PHY operation modes. Switching between PHY operation modes shall be done only on a frame-by-frame basis. The A-BS and A-CPE indicate the PHY operation mode by selecting one of several different local frame preamble types (9.4.1.5, 9a.4.1.1).

The corresponding US portion of a zone shall use the same PHY operation mode as the DS portion of the zone.

WRAN CPEs (called Legacy CPEs) shall operate only in AZs, CRZs, or DRZs that are configured for PHY-OM1. To support Legacy CPEs, which can process only the Frame Preamble defined in 9.4.1, the A-BS and distributed A-CPE shall transmit only the Frame Preamble defined in 9.4.1 in the AZ/DRZ.

7.5 Control header

7.5.1 Superframe Control header

Change the following rows in Table 1:

Table 1—Superframe Control header format

Syntax	Size	Notes
MAC version	8 bits	IEEE 802.22 MAC version to which the message originator conforms. 0x01: IEEE Std 802.22 0x02: IEEE Std 802.22b 0x03–0xFF: *Reserved*
Padding bits	~~56~~48 bits	Padding bits to fill the rest of the 360 bits of the SCH symbol. All bits shall be set to 0.

7.5.2 Frame Control header

Change the first sentence of 7.5.2 as follows:

The format of the FCH for PHY-OM1 is shown in Table 2.

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Insert the following subclauses (7.5.2a and 7.5.2b and their subclauses and tables) after 7.5.2:

7.5.2a Frame control header for PHY-OM2

7.5.2a.1 General

The format of the FCH for PHY-OM2 is shown in Table 2a. Since FCH decoding is critical, the FCH shall be encoded using the modulation specified by the PHY-OM2 as described in Table 231e. The FCH contains the length of either the DS-MAP or US-MAP that immediately follows the FCH (note that Length = 0 indicates the absence of any burst in the frame). When the DS-MAP is specified, the US-MAP length information shall be contained in the first DS-MAP information element. When the US-MAP length is indicated in the FCH, there shall be no DS burst in the current frame. DCD and UCD messages, if present, are carried by the next DS bursts specified by the DS-MAP. Location and profile of the data bursts are specified in the rest of the DS-MAP and US-MAP management messages. A HCS field occupies the last byte of the FCH.

Table 2a—Frame control header format for PHY-OM2

Syntax	Size	Note
Frame_Control_Header_Format () {		
A-BS ID	48 bits	MAC address that uniquely identifies the BS transmitting the FCH.
Length of the frame	6 bits	Indicates the length of the frame in number of OFDM symbols from the start of the frame including all preambles.
Length of the MAP message	10 bits	Specifies the length of the MAP information element following the FCH in OFDM slots. A length of 0 (zero) indicates the absence of any burst in the frame.
Frame Number	8 bits	Positive integer that represents the frame number (modulo 256). This field shall be incremented by 1.
CP	2 bits	Cyclic Prefix Factor Specifies the size of the cyclic prefix used by the PHY in the frame transmissions in this frame. Predetermined values are as follows: 00: 1/4 T_{FFT} 01: 1/8 T_{FFT} 10: 1/16 T_{FFT} 11: 1/32 T_{FFT}
Self-coexistence Capability Indicator	4 bits	0000: no self-coexistence capability supported 0001: only Spectrum Etiquette 0010: Spectrum Etiquette and Frame Contention 0011–1111: *Reserved*
Extended FCH	2 bits	00: No Extended FCH 01: Extended FCH appears following this FCH 10-11: *Reserved*

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Table 2a—Frame control header format for PHY-OM2 *(continued)*

Syntax	Size	Note
MAC version	8 bits	IEEE 802.22 MAC version to which the message originator conforms. 0x01: IEEE Std 802.22 0x02: IEEE Std 802.22b 0x03–0xFF: *Reserved*
HCS	8 bits	Header Check Sequence
}		

7.5.2a.2 Extended frame control header (Ex-FCH)

The Ex-FCH specification is shown in Table 2b. The Ex-FCH decoding is the same as FCH. The Ex-FCH provides information about the A-WRAN cell in order to protect incumbents, support self-coexistence mechanisms, and support the intra-frame and inter-frame mechanisms for management of quiet periods for sensing.

Table 2b—Extended frame control header format

Syntax	Size	Notes
Extended_FCH_Format() {		
Length	8 bits	Length of Extended FCH
Current Intra-frame Quiet Period Cycle Length	8 bits	Specified in number of frames, it indicates the spacing between the frames for which the intra-frame quiet period specification is valid. For example, if this field is set to 1, the Quiet Period Cycle repeats every frame; if it is set to 2, the Quiet Period Cycle repeats every 2 frames; etc. If this field is set to 0, no intra-frame quiet period is scheduled, or the current intra-frame quiet period is canceled.
Current Intra-frame Quiet Period Cycle Offset	8 bits	Valid only if Current Intra-frame Quiet Period Cycle Length > 0. Specified in number of frames, it indicates the offset from this Extended FCH transmission to the beginning of the first frame in the Current Intra-frame Quiet Period Cycle Length.
Current Intra-frame Quiet Period Cycle Frame Bitmap	16 bits	Valid only if Current Intra-frame Quiet Period Cycle Length > 0. Valid for each frame identified by the Current Intra-frame Quiet Period Cycle Length. Each bit in the bitmap corresponds to one frame within the frame. If the bit is set to 0, no intra-frame quiet period shall be scheduled in the corresponding frame. If the bit is set to 1, an intra-frame quiet period shall be scheduled within the corresponding frame for the duration specified by the Current Intra-frame Quiet period Duration.
Current Intra-frame Quiet Period Duration	8 bits	Valid only if Current Intra-frame Quiet Period Cycle Length > 0. If this field is set to a value different from 0 (zero), it indicates the number of symbols starting from the end of the frame during which no transmission shall take place.

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Table 2b—Extended frame control header format *(continued)*

Syntax	Size	Notes
Claimed Intra-frame Quiet Period Cycle Length	8 bits	Specified in number of frames, it indicates the spacing between the frames for which the intra-frame quiet period specification claimed by an A-BS would be valid. For example, if this field is set to 1, the Quiet Period Cycle would repeat every frame; if it is set to 2, the Quiet Period Cycle would repeat every 2 frames; etc. If this field is set to 0, no intra-frame quiet period is claimed by the A-BS.
Claimed Intra-frame Quiet Period Cycle Offset	8 bits	Valid only if Claimed Intra-frame Quiet Period Cycle Length > 0. Specified in number of frames, it indicates the offset from this Extended FCH transmission to the time where the Claimed Quiet Period Cycle resulting from the inter-BS negotiation (see 7.21.2) shall become the Current Intra-frame Quiet Period Cycle.
Claimed Intra-frame Quiet Period Cycle Frame Bitmap	16 bits	Valid only if Claimed Intra-frame Quiet Period Cycle Length > 0. Valid for each frames identified by the Claimed Intra-frame Quiet Period Cycle Length. Each bit in the bitmap corresponds to one frame within each specified frame. If the bit is set to 0, no intra-frame quiet period will be scheduled in the corresponding frame. If the bit is set to 1, an intra-frame quiet period will be scheduled within the corresponding frame for the duration specified by Claimed Intra-frame Quiet period Duration.
Claimed Intra-frame Quiet Period Duration	8 bits	Valid only if Claimed Intra-frame Quiet Period Cycle Length > 0. If this field is set to a value different from 0 (zero), it indicates the number of symbols starting from the end of the frame during which no transmission will take place.
Synchronization Counter for Intra-frame Quiet Period Rate	8 bits	Valid only if Claimed Intra-frame Quiet Period Cycle Length > 0. This field is used for synchronizing the Claimed Intra-frame Quiet Period rate among overlapping A-BSs in order to allow dynamic reduction of the Intra-frame Quiet Period rate. This Quiet Period rate is defined as the number of frames with quiet periods identified by the Cycle Frame Bitmap in the frames designated by the Cycle Length, divided by this Quiet Period Cycle Length (see 7.21.2).
Synchronization Counter for Intra-frame Quiet Period Duration	8 bits	Valid only if Claimed Intra-frame Quiet Period Duration > 0. This field is used for synchronizing the Claimed Intra-frame Quiet Period Durations among overlapping A-BSs in order to allow dynamic reduction of the Intra-frame Quiet Period Duration (see 7.21.1).
Inter-frame Quiet Period Duration	4 bits	Duration of Quiet Period Indicates the duration of the next scheduled quiet period in number of frames. If this field is set to a value different from 0 (zero), it indicates the number of frames that shall be used to perform in-band inter-frame sensing.
Inter-frame Quiet Period Offset	12 bits	Time to Quiet Period Indicates the time span between the transmission of this information and the next scheduled quiet period for in-band inter-frame sensing. The 8 leftmost bits (MSB) indicate the frame number and the 4 rightmost bits (LSB) indicate the frame number when the next scheduled quiet.

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Table 2b—Extended frame control header format *(continued)*

Syntax	Size	Notes
SCW Cycle Length	8 bits	Specified in number of frames. If this field is set to 0, then no SCW cycle is scheduled. This field has to be 1 or larger to be effective. To limit the number of possibilities, the field shall be one of five following choices {1, 2, 4, 8, 16}. For example, if this field is set to 1, SCW Cycle repeats every frame; if it is set to 2, SCW Cycle repeats every 2 frames; etc.
SCW Cycle Offset	8 bits	Specified in number of frames, it indicates the offset from this Extended FCH transmission to the frame where the SCW cycle starts or repeats (i.e., the frame contains SCWs and is specified by the SCW Cycle Frame Bitmap). For example, if this field is set to 0, the SCW cycle starts from the current frame.
SCW Cycle Frame Bitmap	32 bits	Valid for a unit of frame, each 2-bit in the bitmap corresponds to one frame within the frame. If the 2-bit is set to 00, there is no SCW scheduled for this frame. If the 2-bit is set to 11, a reservation-based SCW (reserved by the current WRAN) is scheduled in the corresponding frame. If the 2-bit is set to 10, a reservation-based SCW has been scheduled by a direct-neighbor WRAN cell in the corresponding frame and needs to be avoided by other WRAN cells receiving this Extended FCH. If the 2-bit is set to 01, a contention-based SCW (that could be shared with other WRANs) is scheduled by the current WRAN cell in the corresponding frame. The number of reservation-based SCWs cannot exceed 2 per WRAN cell per SCW Cycle. At least one contention-based SCW shall be scheduled in one SCW Cycle (code 01). The A-BSs shall start scheduling their contention-based SCWs from the last frame of the frame, going backward for multiple contention-based SCWs. This bitmap applies only to the frames scheduled by the SCW Cycle. NOTE—Quiet period (QP) scheduling should be done prior to the SCW scheduling so that SCWs avoid frames already reserved for QP. If SCW conflicts with QP, QP overrides the SCW.
Current DS/US Split	6 bits	Effective start time (in OFDM symbols from the start of the frame including all preambles) of the first symbol of the US allocation when an A-BS-to-A-BS interference situation has been identified by direct reception of this parameter by an A-BS from a Extended FCH or a CBP burst transmitted by another A-BS. The Allocation Start Time as provided in the US-MAP (see Table 34) shall be equal to this value if A-BS-to-A-BS interference has been identified. This value shall be set to zero if no MA-BS-to-A-BS interference has been identified (i.e., A-BS has not received this parameter from another A-BS). In this case, the Allocation Start Time in the US-MAP (see Table 34) can be defined independently on a frame-by-frame basis by the respective A-BSs based on their traffic requirement.

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Table 2b—Extended frame control header format *(continued)*

Syntax	Size	Notes
Claimed US/DS Split	6 bits	Specified by each A-BS for A-BS-to-A-BS interference (i.e., when Extended FCH and/or CBP burst can be received by an A-BS directly from another A-BS) indicating the required DS/US split based in the traffic requirement of the transmitting A-BS and the negotiation process between the A-BSs (see 7.20.3). This value shall be set to zero if no A-BS-to-A-BS interference has been identified.
DS/US Change Offset	12 bits	Indicates the time span between the transmission of this information and the next scheduled change of the DS/US split where the "Claimed DS/US split" value will become the "Current DS/US split" value. The 8 leftmost bits (MSB) indicate the frame number and the 4 rightmost bits (LSB) indicate the frame number when the next DS/US split change shall take place. The value of this parameter is determined by the negotiation process between concerned A-BSs (see 7.20.3). This value shall be set to zero if no A-BS-to-A-BS interference has been identified.
Incumbent detection reporting inhibit timer	32 bits	When the BS is informed by the database service that it can continue operating on the current channel even though its CPEs are repetitively reporting an incumbent detection situation (i.e., on N or N±1), the A-BS can use this parameter to inhibit such reporting by the CPEs for a specified period of time. This will avoid the CPEs flooding the US subframe with unnecessary incumbent detection reports. Bit 0–4: Signal type (see Table 237) Bit 5–31: Inhibit Period (number of frames)
HCS	8 bits	Header Check Sequence
}		

7.5.2b Distributed relay zone (DRZ) Frame Control header (DRZ-FCH)

The DRZ-FCH is used in a DRZ for a distributed scheduling mode. The format of the DRZ-FCH is shown in Table 2c. The DRZ-FCH shall have the same encoding as the FCH in each mode of PHY-OM1 or PHY-OM2. The DRZ-FCH contains the length of either the DS-MAP or US-MAP that immediately follows the DRZ-FCH (note that Length = 0 indicates the absence of any burst in the frame). When the DS-MAP is specified, the US-MAP length information shall be contained in the first DS-MAP information element. When the US-MAP length is indicated in the DRZ-FCH, there shall be no DS burst in the current frame. DCD and UCD messages, if present, are carried by the next DS bursts specified by the DS-MAP. Location and profile of the data bursts are specified in the rest of the DS-MAP and US-MAP management messages. A HCS field occupies the last byte of the DRZ-FCH.

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Table 2c—DRZ Frame Control header (DRZ-FCH) format

Syntax	Size	Notes
DRZ Frame_Control_Header_Format() {		
Distributed Scheduling A-CPE ID	48 bits	MAC address that uniquely identifies the distributed scheduling A-CPE transmitting the DRZ-FCH.
Length of the MAP message	10 bits	Specifies the length of the MAP information element following the FCH in OFDM slots. A length of 0 (zero) indicates the absence of any burst in the frame.
Frame Number	8 bits	This field is same at the frame number indicated in FCH (Table 2)
CP	2 bits	Cyclic Prefix Factor Specifies the size of the cyclic prefix used by the PHY in the frame transmissions in this frame. Predetermined values are 00: 1/4 T_{FFT} 01: 1/8 T_{FFT} 10: 1/16 T_{FFT} 11: 1/32 T_{FFT}
MAC version	8 bits	This field is same as the MAC version indicated in the FCH.
HCS	8 bits	Header Check Sequence.
}		

7.6 MAC PDU formats

7.6.1 MAC headers

7.6.1.1 Generic MAC header

Change Table 4 as follows:

Table 4—Encoding of the Type field

Type bit	Values
4	Bandwidth Request subheader Indicates whether this is a bandwidth request frame, and hence contains a special payload related to bandwidth allocation (see Table 5) 1: present 0: absent
3	ARQ feedback payload 1: present 0: absent

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Table 4—Encoding of the Type field *(continued)*

Type bit	Values
2	Extended Subheader types Indicates whether the ~~present Packing or Fragmentation~~ Extended Type subheader is ~~extended~~present 1: Extended 0: not Extended. Applicable to connections where ARQ is not enabled
1	Fragmentation/Packing subheader 1: present 0: absent
0	In the upstream: Grant Management subheader 1: present 0: absent

7.6.1.2 MAC subheaders and special payloads

Change the first paragraph of the preliminary text of 7.6.1.2 as follows:

Five types of subheaders may be present. These subheaders can be categorized into two types: subheaders attached to each PDU (per-PDU) and subheaders attached to each packed SDU (per-SDU). The Fragmentation/Packing subheader is considered to be per-PDU when the "Purpose bit" in Table 6 is set to 0 (e.g., set to Fragmentation). The other per-PDU subheaders ~~(i.e.,~~ are the Bandwidth Request, ~~Fragmentation/ Packing~~Extended, Grant Management, and ARQ Feedback. The per-PDU subheaders may be inserted in MAC PDUs immediately following the generic MAC header. If indicated, the Bandwidth Request subheader shall always follow the Generic MAC header. In the upstream, if both the Grant Management subheader and Fragmentation/Packing subheader (set to Fragmentation) are indicated, the Grant Management subheader shall come first. If both the Grant Management subheader and Bandwidth Request subheader are indicated, the Grant Management subheader shall come first. If Extended Subheader and Bandwidth Request subheader are both present, the Extended Subheader comes first.

Insert the following paragraph after the first paragraph of the preliminary text of 7.6.1.2:

For the upstream, the following order for per-PDU subheaders, when multiple subheaders are present in the same MAC PDU, shall be followed: Grant Management, Extended, Bandwidth Request, Fragmentation/ Packing (set to Fragmentation), and ARQ Feedback Payload. For the DS, the following order of per-PDU subheaders shall be followed: Extended, Fragmentation/Packing (set to Fragmentation), and ARQ Feedback Payload.

Change the now third paragraph of the preliminary text of 7.6.1.2 as follows:

The only per-SDU subheader is the Fragmentation/Packing subheader set to packing. There can be more than one Fragmentation/Packing subheader in a MAC PDU, all configured for packing. There can only be one Fragmentation/Packing subheader in the MAC PDU if configured for fragmentation. The Fragmentation/Packing subheader may be inserted before each MAC SDU if so indicated by setting Bit 1 in the Type field of the generic MAC Header and by setting the "Purpose bit" in Table 6 to 1.

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Insert the following subclauses (7.6.1.2.5, 7.6.1.2.5.1, 7.6.1.2.5.2, and 7.6.1.2.6 and their tables) after 7.6.1.2.4:

7.6.1.2.5 Extended subheader types

7.6.1.2.5.1 General

Two types of Extended Subheaders are defined to be used by A-CPEs. The Extended Bandwidth Request Subheader is used by an A-CPE to request bandwidth to service CPEs in its relay zone. The Channel Aggregation Subheader is used during channel aggregation operation. Each Extended Subheader is defined by a Extended Subheader Type field that identifies the Extended Subheader and its functionality. Only two types (0x00 for Extended Bandwidth Request and 0x01 for Channel Aggregation) are defined; all other types (0x02–0xFF) are reserved.

7.6.1.2.5.2 Extended Bandwidth Request subheader

Extended Bandwidth Request subheaders are transmitted by the centralized scheduling A-CPE to the A-BS to request additional bandwidth for a CRZ connection. They shall be sent in a PDU by itself or in a PDU with other subheaders and/or data. (See Table 7a.)

Table 7a—Extended Bandwidth Request subheader format

Syntax	Size	Notes
Extended_BW_ Request_Subheader_Format() {		
Extended Subheader Type	8 bits	0x00 = Extended BW Request Subheader
Request Node	13 bits	SID of Centralized scheduling A-CPE
Number of BR CPEs ; n	8 bits	The number of CPEs, which require bandwidth request
For (i = 1; i ≤ n; i ++){	Variable	
BW Request Type	2 bits	00: CDMA bandwidth request 01: Bandwidth request subheader 10–11: *Reserved*
SID	13 bits	SID of CPE, which require bandwidth request
Type	1 bit	Indicates the type of the bandwidth request adjustment 0: incremental 1: aggregate
BR	20 bits	The number of bytes of US bandwidth requested by the CPE. The request shall not include any PHY overhead.
CRZ bandwidth ranging code	8 bits	CRZ bandwidth ranging codes when BW Request Type is set to 0
}		
}		

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7.6.1.2.5.3 Channel Aggregation subheader

The format of Channel Aggregation subheader is shown in Table 7b. This Channel Aggregation subheader is used to manage the aggregation data sequence during the multi-channel operation. The channel aggregation header with fixed-length size of 3 bytes shall be added to each PDU after the generic MAC header.

Table 7b—Channel Aggregation subheader format

Syntax	Size	Notes
Channel_Aggregation_Subheader_ Format() {		
Extended Subheader Type	8 bits	0x01 = Channel Aggregation Extended Subheader
Aggregation ID	16 bits	Indicates the sequence management ID of the transmitted data during multi-channel operation. The value of Aggregation ID is from 0 to 8191. The Aggregation ID shall be incremented by one after each transmission and shall be reset to 0 after the maximum value (8191).
}		

7.6.1.3 CBP MAC PDU format

Change the last sentence of the preliminary text in 76.1.3 as follows:

As discussed in 7.20.1, the coexistence beacon MAC PDU described in Table 8 (for PHY-OM1) and Table 8a (for PHY-OM2) is utilized by the CBP packets.

Change the title of Table 8 as follows:

Table 8—CBP_MAC_PDU format (PHY-OM1)

Insert the new Table 8a immediately after Table 8 in 7.6.1.3 as follows:

Table 8a—CBP_MAC_PDU format (PHY-OM2)

Syntax	Size	Notes
CBP_MAC_PDU_Format() {		
Length	8 bits	The length of bytes of the CBP MAC PDU including the MAC header and the CRC.

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Table 8a—CBP_MAC_PDU format (PHY-OM2) *(continued)*

Syntax	Size	Notes
FCH and Extended FCH Index	4 bits	FCH and Extended FCH Data included in the CBP_MAC_PDU contains the sum of the following elements (see Table A1 and Table 2a): 0000: 8 first parameters of the FCH for PHY-OM2 (Table A1) = 11 bytes 1000: 10 parameters related to intra-frame QP of the Extended FCH (Table 2a) = 12 bytes 0100: 2 parameters related to inter-frame QP of the Extended FCH (Table 2a) = 2 bytes 0010: 3 parameters on SCW scheduling of the Extended FCH (Table 2a) = 6 bytes 0001: 3 parameters on DS/US Split of the Extended FCH (Table 2a) = 3 bytes Note that this last 3-parameter segment can be included only in CBP bursts transmitted by A-BSs.
FCH and Extended FCH Data	Variable (integer number of bytes	Data extracted from the FCH and Extended FCH transmitted by A-BS sourcing this CBP. This data includes the A-BS_ID. Only the useful information contained in the FCH and Extended FCH should be replicated here. This indicates that the FCH and Extended FCH should be built with IEs only present when needed. Table A1 and Table 2a should be modified accordingly.
Frame Number	8 bits	The frame number in which the CBP burst was transmitted.
HCS	8 bits	Header Check Sequence.
IEs	Variable (integer number of bytes	CBP information elements (see 7.6.1.3.1).
}		

7.6.1.3.1 CBP information elements

Insert the following paragraph after the first paragraph of the preliminary text of 7.6.1.3.1:

If an A-BS is generating a CBP packet to be forwarded by a distributed A-CPE or an S-CPE attached to a distributed S-CPE, it may optionally add a CBP Local Cell ID IE to the CBP MAC PDU. The purpose of the CBP Local Cell ID IE is to provide the identity of the local cell maintained by a distributed A-CPE. The CBP MAC PDU header (which would contain contents of transmission types indicated in 7.20.4) would contain the MAC Address of the A-BS that serves the distributed A-CPE. When the CBP Local Cell ID IE is added to a CBP MAC PDU, the transmissions indicated in 7.20.4 would contain the MAC Address of the A-BS in the CBP MAC PDU header.

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