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

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

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

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Approved 3 September 2015

IEEE-SA Standards Board

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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The following members of the individual balloting committee voted on this amendment. Balloters may have voted for approval, disapproval, or abstention.

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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.

Contents

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 is based on IEEE 802.22™-2011 as amended by IEEE Std 802.22a™-2014.)

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

[1]Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

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.

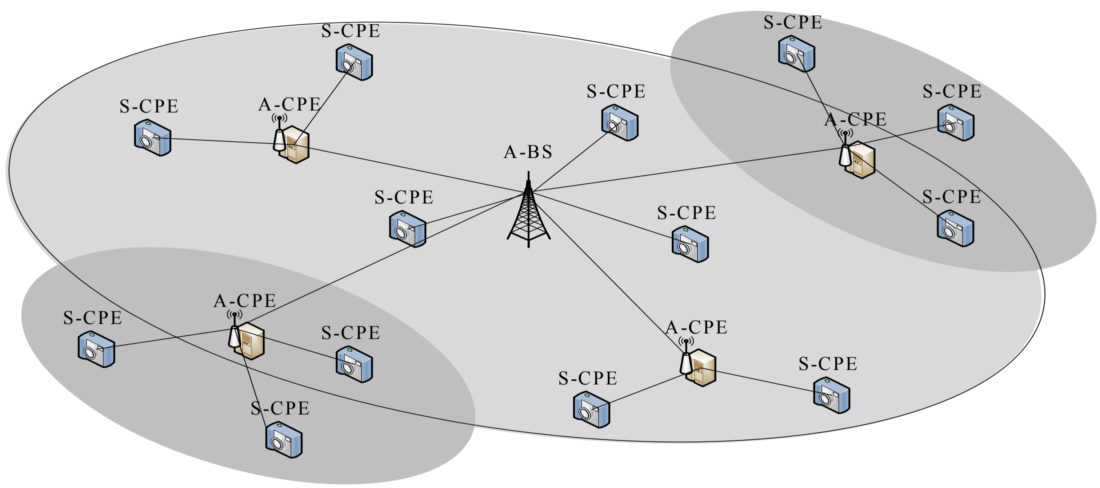


Figure 1a—An A-WRAN with an A-BS, A-CPEs, and S-CPEs

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.

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.

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

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.

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.

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.

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.

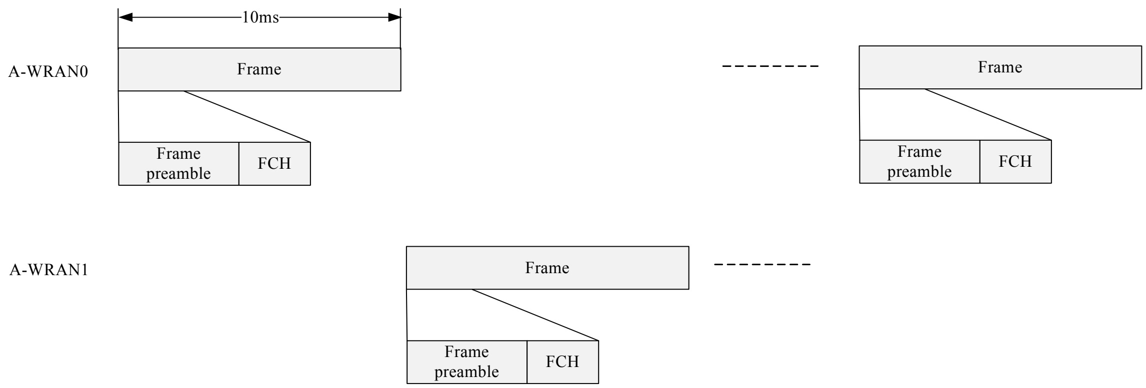


Figure 13a—General frame structure on PHY-OM2 for self-coexistence mode

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.

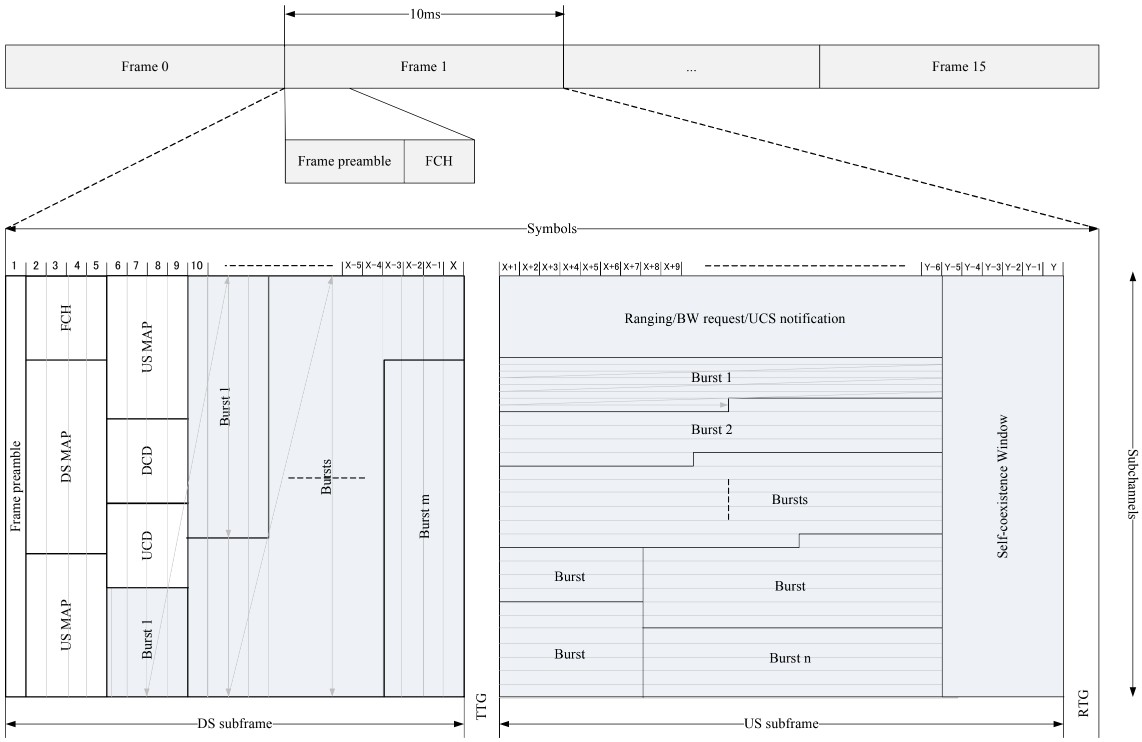


Figure 13b—Example of a time/frequency structure of a MAC frame for PHY-OM2

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 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.

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.

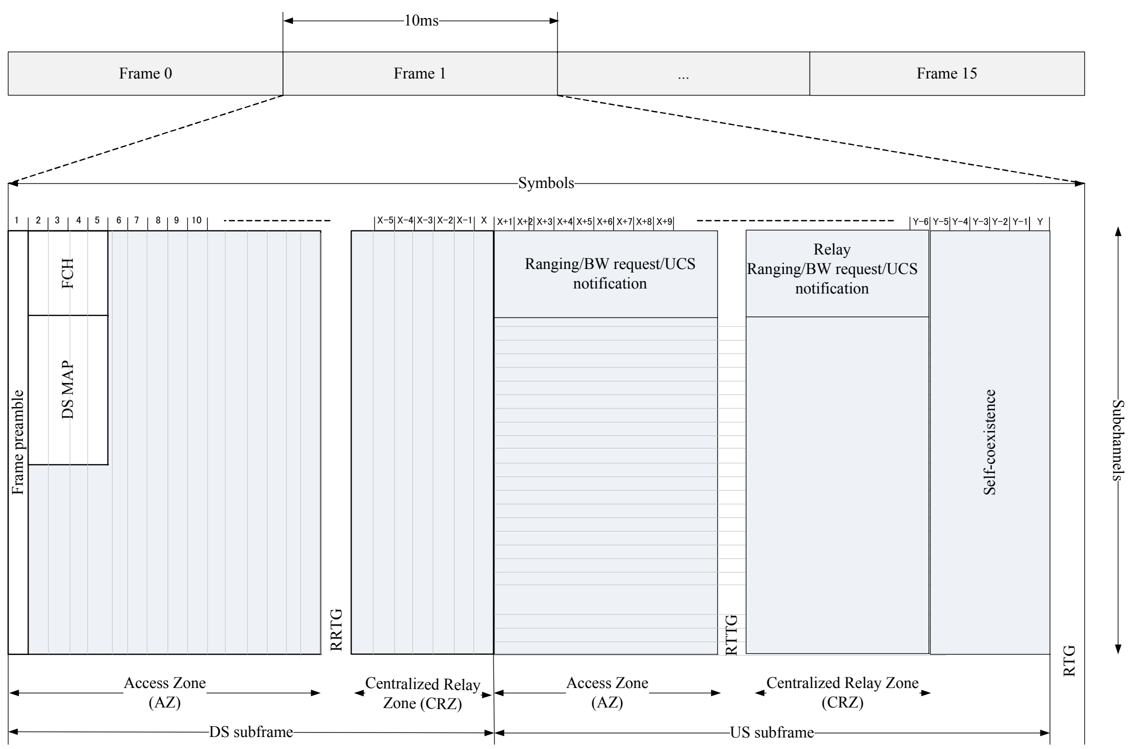


Figure 13c—Example of a time/frequency structure of a MAC frame for a centralized scheduling mode on PHY-OM2

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.

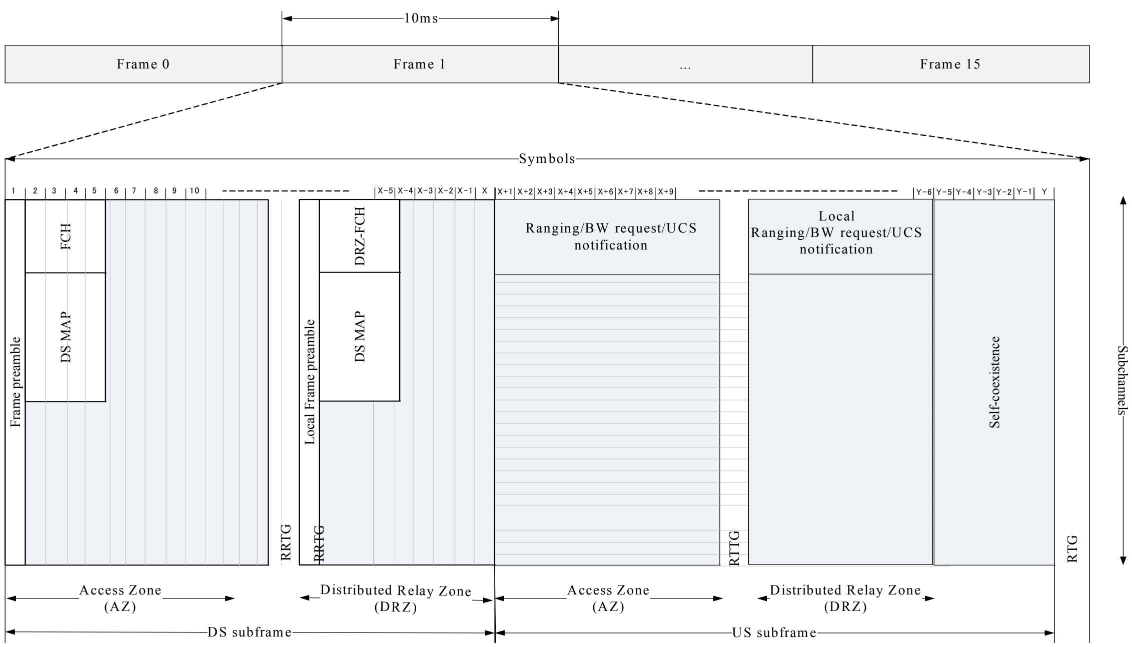


Figure 13d—Example of a time/frequency structure of a MAC frame for a distributed scheduling mode on PHY-OM2

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 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.

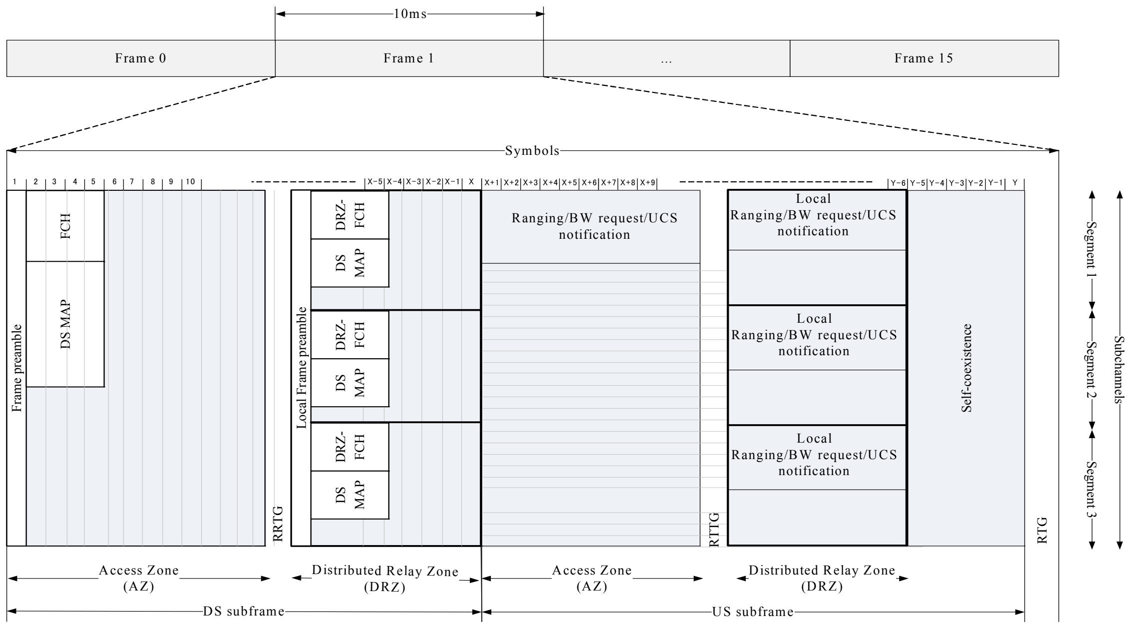


Figure 13e—Example of a time/frequency structure of a MAC frame for a distributed scheduling mode on segmentation on PHY-OM2

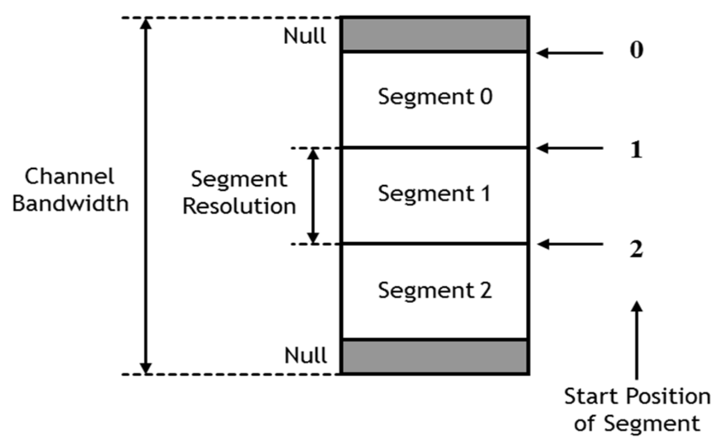


Figure 13f—Segment structure

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

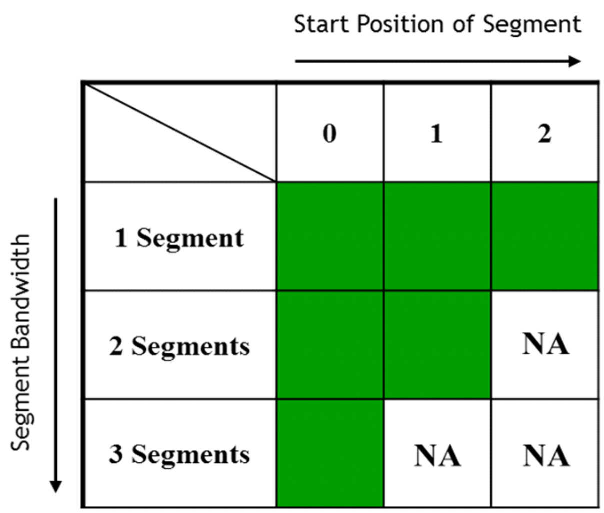


Figure 13g—Combination of segment start position and segment bandwidth

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

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.

— 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.

- 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.

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*

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.

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.

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.

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.

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

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.

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
}		
}		

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.

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.

Change Table 9 as follows:

Table 9—CBP IEs

Element ID	Name
0x00	Backup_and_Candidate_Channel_List_IE
0x01	FC_REQ_IE
0x02	FC_RSP_IE
0x03	FC_ACK_IE
0x04	FC_REL_IE
0x05	CBP_Identificate_IE
0x06	Signature_IE
0x07	CERT-REQ_IE
0x08	CERT-RSP_IE
0x09	CBP_Local_Cell_ID_IE

7.6.1.3.1.7 CBP Protection IEs

Insert the following subclause (7.6.1.3.1.7.4 and its table) after 7.6.1.3.1.7.3:

7.6.1.3.1.7.4 CBP Local Cell ID IE

The CBP Local Cell ID IE shown in Table 18a may be added to CBP MAC PDUs that are to be forwarded by a distributed scheduling A-CPE or S-CPEs attached to the distributed scheduling A-CPE. This IE allows the recipient of the CBP MAC PDU containing this IE to distinguish the presence of a local cell from that of CBP MAC PDUs emitted by the A-BS and S-CPEs operating within the serving cell.

Table 18a—CBP Local Cell ID IE

Syntax	Size	Description
CBP_Local_Cell_ID_IE_format (){		
Element ID	8 bits	0x09 (see Table 9)
Local Cell MAC ID	48 bits	IEEE 48-bit MAC address of the distributed A-CPE that manages the local cell
}		

7.7 Management messages

Insert the following rows at the end of Table 19:

Table 19—Management messages

Type	Message	Description	Reference	Class of connection
41	LCU-REQ	Local Cell Update Request	7.7.25.1	Primary Management
42	LCU-RSP	Local Cell Update Response	7.7.25.2	Primary Management
43	Container	Container	7.7.26	Primary Management
44	Container ACK	Container acknowledgment	7.7.26.2	Primary Management
45	DTT-REQ	Downstream Transit Test Request	7.7.27.1	Primary Management
46	DTT-RSP	Downstream Transit Test Response	7.7.27.2	Primary Management
47	DTT-RPT	Downstream Transit Test Report	7.7.27.3	Primary Management
48	DTT-CFM	Downstream Transit Test Confirmation	7.7.27.4	Primary Management
49	Relay-SCHE	Relay Schedule	7.7.28	Primary Management
50	CAM-ADD	Add new operating channel	7.7.29.2	Primary Management
51	CAM-STP	Stop operating channel	7.7.29.3	Primary Management
52	CAM-STP-ACK	Stop operating channel acknowledgment	7.7.29.4	Primary Management
53	CAM-SWH	Switch operating channel	7.7.29.5	Primary Management
54	CAM-SWH-ACK	Switch operating channel acknowledgment	7.7.29.6	Primary Management
55	GRA-CFG	Group Resource Allocation Configuration	7.7.30.1	Primary Management
56	GRA-UPD	Group Resource Allocation Update	7.7.30.2	Primary Management
57	RNG-RPT	Ranging Report	7.7.31	Primary Management

7.7.1 Downstream Channel Descriptor (DCD)

Change the text of 7.7.1 as follows:

The format of a DCD message is shown in Table 20. This message shall be transmitted by the BS/A-BS or the distributed scheduling A-CPE at a periodic interval (Table 273) to define the characteristics of a downstream physical channel.

Change Table 20 as follows:

Table 20 — DCD message format

Syntax	Size	Note
DCD_Message_Format() {		
Management Message Type = 0	8 bits	
Configuration Change Count	8 bits	Incremented by one (modulo 256) by the BS/A-BS or the distributed scheduling A-CPE whenever any of the values of this channel descriptor change. If the value of this count in a subsequent DCD remains the same, the CPE can quickly decide that the remaining fields have not changed and may be able to disregard the remainder of the message. This value is also referenced from the DS-MAP messages (see Table 25).
DCD Channel Information Elements (IEs)	Variable in integer number of bytes	Table 21
Begin PHY Specific Section {		
Number of downstream burst profiles: n	~~6~~7 bits	Number of burst profiles described in the current DCD message. Its maximum size corresponds to the maximum number of DIUC burst profiles contained in Table 27 and Table 27a.
Reserved	~~2~~1 bit	All bits shall be set to zero.
for (i = 1; $i \leq$ n; i++) {		"n" is defined as the "Number of downstream burst profiles" to be described in the current DCD message.
Downstream_Burst_Profile	Variable	PHY specific (Table 23).
}		
}		
}		

7.7.1.1 DCD Channel information elements

Change Table 21 as follows:

Table 21 — DCD channel information elements

Name	Element ID (1 byte)	Length (bits)	Description
Downstream_Burst_Profile	1	Variable	Value reserved for the burst profile (see Table 23)
$EIRP_{BS}$	2	8	Signed in units of dBm in 0.5 dB steps with a range from –64 dBm (encoded 0x00) to +63.5 dBm (encoded 0xFF). Values outside this range shall be assigned the closest extreme.
TTG	3	8	0x00–0xFF: range of TTG in 2.75 µs increments. Default set to 0x4D to allow for 210 µs for 30 km propagation.
$RSS_{IR\_BS\_nom}$	4	8	Initial ranging nominal signal strength per subcarrier to be received at the BS by a 0 dBi antenna gain, i.e., corrected for the gain of the BS receive antenna in the direction of the CPE and for 0 coupling and cable loss (see 7.14.2.8.1). Signed in units of dBm in 0.5 dB steps ranging from –104 dBm (encoded 0x00) to +23.5 dBm (encoded 0xFF). Values outside this range shall be assigned the closest extreme.
Channel Action	5	3	Action to be taken by all CPEs in a cell. 000: None 001: Switch 010–111: *Reserved*
Action Mode	6	1	This is valid only for channel switch (Action = 001). Indicates a restriction on transmission until the specified Channel Action is performed. The BS shall set the Action Mode field to either 0 or 1 on transmission. A value of 1 means that the CPE to which the frame containing this element is addressed shall transmit no further frames until the scheduled Channel Action is performed. An Action Mode set to 0 does not impose any requirement on the receiving CPE.
Action Superframe Number	7	8	The superframe number (modulo 256) at which Channel Action shall be performed.
Action Frame Number	8	~~4~~8	Integer value greater than or equal to zero that indicates the starting frame number, within the Action Superframe Number, at which the Channel Action shall be performed by all CPEs.
Number of Backup channels	9	4	Number of backup channels in the backup and candidate channel list IE (see Table 22).
Backup and Candidate channel list.	10	Variable	See Table 22 for specification.

Table 21 — DCD channel information elements *(continued)*

Name	Element ID (1 byte)	Length (bits)	Description
MAC version	11	8	IEEE 802.22 MAC version to which the message originator conforms. 0x01: IEEE Std 802.22 0x02: IEEE Std 802.22b 0x03–0xFF: *Reserved*
Relay-RTG (RRTG)	12	8	0x00–0xFF: range of Relay RTG in 2.75 µs increments. Default set to 0x4D to allow for 210 µs for 30 km propagation.
$EIRP_{A\text{-}CPE}$	13	8	Signed in units of dBm in 0.5 dB steps with a range from –64 dBm (encoded 0x00) to +63.5 dBm (encoded 0xFF). Values outside this range shall be assigned the closest extreme.
$RSS_{IR\_A\text{-}CPE\_nom}$	14	8	Initial ranging nominal signal strength per subcarrier to be received at the BS by a 0 dBi antenna gain, i.e., corrected for the gain of the BS receive antenna in the direction of the CPE and for 0 coupling and cable loss (see 7.14.2.8.1). Signed in units of dBm in 0.5 dB steps ranging from –104 dBm (encoded 0x00) to +23.5 dBm (encoded 0xFF). Values outside this range shall be assigned the closest extreme.

Change Table 22 as follows:

Table 22—Backup and Candidate channel list

Syntax	Size	Note
Backup_and_candidate_channel_list_IE_Format() {		
Element ID = 10	8 bits	
Length	8 bits	
Number of Channels in the list	8 bits	
For (*i* = 0; *i* < Number of Channels in the list; *i*++) {		List of backup channels in order of priority to be used by CPEs in case of loss of communication with the BS due to incumbents. This list may also include candidate channels, in which case they will follow the backup channels in the list, and will also be included in order of priority. The number of backup channels in the list is indicated in DCD Element ID 9 (see Table 21). The list shall be a disjoint set with the current operating channel.
Channel Number [i]	8 bits	
Group Flag	1 bit	Flag to indicate whether the backup and candidate channels are used globally within a cell or locally within a group 0: Used globally within a cell 1: Used locally within a group

Table 22—Backup and Candidate channel list *(continued)*

Syntax	Size	Note
If (Group Flag=1){		
GID [i]	10 bits	Group ID at which the backup and candidate channels are used locally within a group
}		
}		
}		

7.7.2 Downstream MAP (DS-MAP)

Change Table 25 as follows:

Table 25 — DS-MAP message format

Syntax	Size	Note
DS-MAP_Message_Format () {		
Management Message Type = 1	8 bits	
DCD Count	8 bits	Matches the value of the configuration change count of the DCD, which describes the downstream burst profiles that apply to this map.
If (transmitted by BS, A-BS, or distributed scheduling A-CPE) {		
Begin PHY Specific Section {		
Number of IEs: n	12 bits	Number of IEs in the downstream map
for (i = 1; $i \leq$ n; i++) {		
DS-MAP_IE()	Variable	PHY specific (7.7.2.1)
}		
}		
}		
If (!byte_boundary)		
Padding bits	0–7 bits	Padding to octet alignment—All bits shall be set to 0.
}		

7.7.2.1 DS-MAP IE

Change Table 26 as follows:

Table 26—DS-MAP information elements

Syntax	Size	Description
DS-MAP IE() {		
DIUC	6 bits	7.7.2.1.1
If (DIUC == 12)		
Extended DIUC value	6 bits	
}		
If (DIUC == 62)		
~~Extended DIUC Dependent IE~~ DS-MAP Extended DIUC IE	Variable	7.7.2.1.2
else {		
SID	~~9~~13 bits	Station ID of CPE or multicast group
}		
Length	12 bits	Number of OFDM slots linerly allocated to the DS burst specified by this IE
Boosting	3 bits	111: +9 dB 110: +6 dB 101: +3 dB 100: 0 dB, normal (not boosted) 011: –3 dB 010: –6 dB 001: –9 dB 000: –12 dB
}		
}		

7.7.2.1.1 DIUC allocations

Change the text of 7.7.2.1.1 as follows:

Table 27 illustrates the various DIUC values used in the MAC. Table 27a illustrates the various Extended DIUC values used in the MAC.

Change the following rows in Table 27 as indicated:

Table 27—DIUC values

DIUC	Usage
0-~~12~~11	*Reserved*
12	Extended DIUC values (Table 27a)
62	~~Extended DIUC~~ DS-MAP Extended DIUC IE (Table 28)

Insert the new Table 27a immediately after Table 27 in 7.7.2.1.1 as follows:

Table 27a—Extended DIUC values

DIUC	Usage		
0	Convolutional Code	FEC rate = 1/2	256-QAM
1	Convolutional Code	FEC rate = 2/3	256-QAM
2	Convolutional Code	FEC rate = 3/4	256-QAM
3	Convolutional Code	FEC rate = 5/6	256-QAM
4	Convolutional Code	FEC rate = 7/8	256-QAM
5	Convolutional Code	FEC rate = 10/11 for two 2D symbols	4D-TCM 48QAM
6	Convolutional Code	FEC rate = 14/15 for two 2D symbols	4D-TCM 192QAM
7	CTC	FEC rate = 1/2	256-QAM
8	CTC	FEC rate = 2/3	256-QAM
9	CTC	FEC rate = 3/4	256-QAM
10	CTC	FEC rate = 5/6	256-QAM
11	CTC	FEC rate = 7/8	256-QAM
12	CTC	FEC rate = 10/11 for two 2D symbols	4D-TCM 48QAM
13	CTC	FEC rate = 14/15 for two 2D symbols	4D-TCM 192QAM
14	LDPC	FEC rate = 1/2	256-QAM
15	LDPC	FEC rate = 2/3	256-QAM
16	LDPC	FEC rate = 3/4	256-QAM
17	LDPC	FEC rate = 5/6	256-QAM
18	LDPC	FEC rate = 7/8	256-QAM
19	LDPC	FEC rate = 10/11 for two 2D symbols	4D-TCM 48QAM
20	LDPC	FEC rate = 14/15 for two 2D symbols	4D-TCM 192QAM
21	SBTC	FEC rate = 1/2	256-QAM

Table 27a—Extended DIUC values *(continued)*

DIUC	Usage		
22	SBTC	FEC rate = 2/3	256-QAM
23	SBTC	FEC rate = 3/4	256-QAM
24	SBTC	FEC rate = 5/6	256-QAM
25	SBTC	FEC rate = 7/8	256-QAM
26	SBTC	FEC rate = 10/11 for two 2D symbols	4D-TCM 48QAM
27	SBTC	FEC rate = 14/15 for two 2D symbols	4D-TCM 192QAM
28–63	*Reserved*		

7.7.2.1.2 DS-MAP Extended DIUC IE

Change Table 28 as follows:

Table 28 — DS-MAP Extended DIUC IE general format

Syntax	Size	Note
~~DS_Extended_IE ()~~ DS-MAP Extended DIUC IE() {		
Extended DIUC IE Type	~~6~~8 bits	Table 28a
Length	8 bits	Length of this IE in bits.
Unspecified Data	Variable	
}		

Insert the new Table 28a immediately after Table 28 as follows:

Table 28a — Extended DIUC IE Type code assignment

Extended DIUC	Usage
0x00	DS-MAP Dummy Extended IE
0x01	DS Multi-Zone Configuration IE
0x02	AZDS-MAP IE
0x03	CRZDS-MAP IE
0x04	DRZDS-MAP GRA IE
0x05–0xFF	*Reserved*

7.7.2.1.2.1 DS-MAP Dummy Extended IE

Change Table 29 as follows:

Table 29—DS-MAP Dummy Extended IE format

Syntax	Size	Notes
Dummy_IE() {		
~~Extended~~ DIUC	6 bits	~~0x00~~ DIUC values as defined in Table 27
if (DIUC == 12) {		
Extended DIUC Value	6 bits	See Table 27a
}		
Length	8 bits	Length of this IE in ~~bits~~bytes
Unspecified Data	Variable	
}		

Insert the following subclauses (7.7.2.1.2.2 through 7.7.2.1.2.5 and their tables) after 7.7.2.1.2.1:

7.7.2.1.2.2 DS Multi-Zone Configuration IE

A CPE shall be able to decode the DS Multi-Zone Configuration IE shown in Table 29a. An A-BS shall transmit this IE for multi-hop relay operations.

Table 29a—DS Multi-Zone Configuration IE format

Syntax	Size	Notes
DS Multi-Zone Configuration_IE() {		
Multi-Zone Configuration {		
Number of zones	8 bits	Number of zones including access and relay zones. Number of zones (0) is not available of DS. Number of zone (1) shall be access zone.
For (i = 1; $i \leq$ Number of zones; i++){		
Zone Index	8 bits	Increase the index from 0 to Number of Zones–1
Zone Mode	2 bits	0: access zone 1: centralized relay zone 2: distributed relay zone
Start Position of Segment	2 bits	00: 0 01: 1 10: 2 11: If ‘Zone Mode’ is set to Access or Centralized Relay Zone

Table 29a—DS Multi-Zone Configuration IE format *(continued)*

Syntax	Size	Notes
Segment Bandwidth	2 bits	00: one segment from start position 01: two segments from start position 10: three segments from start position 11: If 'Zone Mode' is set to Access or Centralized Relay Zone
PHY Mode	1 bit	0: PHY-OM1 1: PHY-OM2
}		
}		
for (Zone index = 0; Zone index < Number of zones; Zone index++){		
OFDMA symbol offset	7 bits	The zone starts at the OFDMA symbol offset, counted after the preamble of the frame
Zone duration	5 bits	The zone ends after the zone duration starting from the OFDMA symbol offset. The unit of duration is an OFDMA symbol
if (Zone mode == 2) {		Distributed Relay Zone (DRZ) mode
SID	13 bits	SID of distributed scheduling A-CPE
}		
}		
}		

7.7.2.1.2.3 Access Zone DS-MAP IE (AZ DS-MAP IE)

Encodings of AZ DS-MAP IE for the downstream from the A-BS are provided in Table 29b.

Table 29b—AZDS-MAP IE format

Syntax	Size	Notes
AZDS-MAP_IE(){		
Zone Index	8 bits	See Table 29a
DIUC	6 bits	7.7.2.1.1
if (DIUC == 12)		
Extended DIUC Value	6 bits	See Table 27a
SID	13 bits	Station ID of CPE or centralized scheduling A-CPE.
Length	12 bits	Number of OFDM slots linearly allocated to the DS burst specified by this IE.

Table 29b—AZDS-MAP IE format *(continued)*

Syntax	Size	Notes
Boosting	3 bits	111: +9 dB 110: +6 dB 101: +3 dB 100: 0 dB, normal (not boosted) 011: –3 dB 010: –6 dB 001: –9 dB 000: –12 dB
Relay Mode	1 bit	0: No relay 1: Relay mode on
CRZ DS-MAP Index	16 bits	For relaying through the centralized scheduling A-CPE, it indicates the matched CRZDS-MAP IE. Increase the index from 0 to 65535
}		

7.7.2.1.2.4 Centralized Relay Zone DS-MAP IE (CRZ DS-MAP IE)

Encodings of CRZ DS-MAP IE for the relay DS from the centralized scheduling A-CPE to the S-CPE are provided in Table 29c.

Table 29c—CRZDS-MAP IE format

Syntax	Size	Notes
CRZDS-MAP_IE(){		
Zone Index	8 bits	See Table 29a
CRZ DS-MAP Index	16 bits	See Table 29b
DIUC	6 bits	7.7.2.1.1
if (DIUC == 12)		
Extended DIUC Value	6 bits	See Table 27a
SID	13 bits	Station ID of CPE or multicast group.
CRZ Start Offset	12 bits	Number of OFDMA slots counted after the centralized relay zone mode start
Length	12 bits	Number of OFDM slots linearly allocated to the CRZDS burst specified by this IE.
Boosting	3 bits	111: +9 dB 110: +6 dB 101: +3 dB 100: 0 dB, normal (not boosted) 011: –3 dB 010: –6 dB 001: –9 dB 000: –12 dB
}		

7.7.2.1.2.5 Distributed Relay Zone DS-MAP Group Resource Allocation IE (DRZ DS-MAP GRA IE)

The format of the DRZ DS-MAP GRA IE is shown in Table 29d.

Table 29d—DRZ DS-MAP GRA IE format

Syntax	Size	Notes
DRZDS-MAP_GRA_IE() {		
Resource Allocation Bitmap	Variable (1 bit × number of devices in the group)	Indicates whether the resources are allocated to the device in a group. The number of devices in the group is determined by the Device Bitmap Size in GRA Configuration Message. 0: not allocated in the frame 1: allocated in the frame
Resource Starting Index	11 bits	Indicates the starting index of resource in the unit of OFDMA slot. In the DS subframe, the index starts right after the frame preamble from 0. In the US subframe, the index 0 starts from the ranging/BW request/UCS notification contention windows (not including SCW) if it exists.
Resource Size Bitmap	Variable (3 bits × number of devices in the group)	Indicates the resource allocation size for the device in the unit of OFDMA slot. 000: 1 001: 2 010: 4 011: 8 100: 16 101: 32 110: 64 111: 128
Group DIUC Flag	1 bit	Indicates whether the DIUC is fixed within group. 0: not fixed within group 1: fixed within group
Group Boosting Flag	1 bit	Indicates whether the Boosting is fixed within group. 0: not fixed within group 1: fixed within group
If (Group DIUC Flag = 0) {		
Group DIUC Bitmap	Variable (6 bits × number of devices in the group)	Specifies the DIUC of each device in a group
}		
Else{		
DIUC	6 bits	Same DIUC is used by all device in a group
if (DIUC == 12)		
Extended DIUC Value	6 bits	See Table 27a
}		

Table 29d—DRZ DS-MAP GRA IE format *(continued)*

Syntax	Size	Notes
If (Group Boosting Flag = 0) {		
Group Boosting Bitmap	Variable (3 bits × number of devices in the group)	Specifies the Boosting of each device in a group
}		
Else{		
Boosting	3 bits	Same Boosting is used by all device in a group
}		
}		

7.7.3 Upstream Channel Descriptor (UCD)

Change the text of 7.7.3 as follows:

The format of a UCD message is shown in Table 30. This message shall be transmitted by the BS/A-BS or the distributed scheduling A-CPE at a periodic interval (Table 272) to define the characteristics of an upstream physical channel.

Change Table 30 as follows:

Table 30—UCD message format

Syntax	Size	Notes
UCD_Message_Format() {		
Management Message Type = 2	8 bits	
Configuration Change Count	8 bits	Incremented by one (modulo 256) by the BS whenever any of the values of this channel descriptor change. If the value of this count in a subsequent UCD remains the same, the CPE can quickly decide that the remaining fields have not changed and may be able to disregard the remainder of the message. This value is also referenced from the US-MAP messages (see Table 34).
BW Request Backoff Start	4 bits	Initial backoff window size in units of BW Request opportunity or DRZ BW Request (see Table 31) used by CPEs to contend to send BW requests to the BS or to send DRZ BW request to the distributed scheduling A-CPE, expressed as a power of 2. Values of *n* range 0–15. Refer in the note to 6.16 on Contention Resolution. Include a subsection that will describe the size and the content of the BW Request US burst and refer to it in the note.

Table 30—UCD message format *(continued)*

Syntax	Size	Notes
BW Request Backoff End	4 bits	Final backoff window size in units of BW Request opportunity or DRZ BW Request (see Table 39) to contend to send BW requests to the BS or to send DRZ BW request to the distributed scheduling A-CPE, expressed as a power of 2. Values of *n* range 0–15. All declared opportunities for BW request in subsequent frames are concatenated in this potentially large number.
UCS Notification Backoff Start	4 bits	Initial backoff window size in units of UCS notification opportunity or DRZ UCS notification opportunity (see Table 31) used by CPEs to contend to send UCS notifications to the BS or to send DRZ UCS notifications to the distributed scheduling A-CPE. This is expressed as a power of 2. Values of *n* range 0–15.
UCS Notification Backoff End	4 bits	Final backoff window size in units of UCS notification opportunity or DRZ UCS notification opportunity (see Table 31) used by CPEs to contend to send UCS notifications to the BS or to send DRZ UCS notifications to the distributed scheduling A-CPE. This is expressed as a power of 2. Values of *n* range 0–15. All declared opportunities for UCS Notifications in subsequent frames are concatenated in this potentially large number.
Information elements (IEs) for the overall channel	Variable	See 7.7.3.1.
Begin PHY Specific Section {		
Number of upstream burst profiles: *n*	~~6~~7 bits	Number of upstream burst profiles described in the current UCD message. Its maximum size corresponds to the maximum number of UIUC burst profiles contained in Table 36.
Reserved	1 bit	All bits shall be set to zero.
for (i = 1; $i \leq$ n; i++) {		n = number of upstream burst profiles
Upstream_Burst_Profile	Variable	PHY specific (Table 32)
}		
}		
}		

7.7.3.1 UCD Channel IEs

Change Table 31 as follows:

Table 31—UCD channel information elements

Name	Element ID (1 byte)	Length (bytes)	Description
Upstream_Burst_Profile	1	Variable	Value reserved for the burst profile (see Table 32)
Contention-based reservation timeout	2	1	Number of US-MAPs to receive before contention-based reservation is attempted again for the same connection
Bandwidth request opportunity size	3	1	Size (in OFDM slots) of PHY bursts, mapped horizontally in one subchannel at a time as in the case of normal upstream data, that a CPE may use to format and transmit a bandwidth request message in a contention request opportunity. The value includes all PHY overhead as well as allowance for the BW Request MAC subheader that the message will hold (see Table 5).
UCS Notification request opportunity size	4	1	Size (in OFDM slots) of PHY bursts, mapped horizontally in one subchannel at a time as in the case of normal upstream data, that a CPE may use to transmit a UCS notification. The value includes all PHY overhead for the GMH containing the UCS flag (see Table 3).
CRZ Bandwidth request opportunity size	5	1	Size (in OFDM slots) of PHY bursts, mapped horizontally in one subchannel at a time as for normal upstream data, that a CPE may use to format and transmit a bandwidth request message in a contention request opportunity. The value includes all PHY overhead as well as allowance for the BW Request MAC subheader that the message will hold (see Table 5).
CRZ UCS Notification request opportunity size	6	1	Size (in OFDM slots) of PHY bursts, mapped horizontally in one subchannel at a time as for normal upstream data, that a CPE may use to transmit a UCS notification. The value includes all PHY overhead for the GMH containing the UCS flag (see Table 3).
Initial ranging codes	150	1	Number of initial ranging CDMA codes. Possible values are 0–255.
Periodic ranging codes	151	1	Number of periodic ranging CDM codes. Possible values are 0–255.
Bandwidth request codes	152	1	Number of bandwidth request CDMA codes. Possible values are 0–255.
UCS notification codes	153	1	Number of UCS notification CDMA codes. Possible values are 0–255.

Table 31—UCD channel information elements *(continued)*

Name	Element ID (1 byte)	Length (bytes)	Description
Start of CDMA codes group	154	1	Indicates the starting number, S, of the group of codes used for this upstream. All the ranging codes used on this upstream will be between S and (S+N+M+L+I) mod 256). Where: N is the number of initial-ranging codes M is the number of periodic-ranging codes L is the number of bandwidth-request codes I is the number of UCS notification codes The range of values is $0 \leq S \leq 255$.
CRZ initial ranging codes	155	1	Number of CRZ initial ranging CDMA codes. Possible values are 0–255.
CRZ periodic ranging codes	156	1	Number of CRZ periodic ranging CDMA codes. Possible values are 0–255.
CRZ UCS notification codes	157	1	Number of CRZ UCS notification CDMA codes. Possible values are 0–255.
CRZ bandwidth request code	158	1	Number of CRZ bandwidth request CDMA codes. Possible values are 0–255.

7.7.4 Upstream MAP (US-MAP)

Change Table 34 as follows:

Table 34—US-MAP message format

Syntax	Size	Notes
US-MAP_Message_Format() {		
Management Message Type = 3	8 bits	
UCD Count	8 bits	Matches the value of the Configuration Change Count of the UCD, which describes the upstream burst profiles that apply to this map.
Allocation Start Time	6 bits	Effective start time (in OFDM symbols from the start of the frame including all preambles) of the upstream allocation defined by the US-MAP.
If (transmitted by BS or A-BS or distributed scheduling A-CPE) {		
Begin PHY Specific Section {		
Number of IEs: n	12 bits	Number of IEs in the upstream map
for (i = 1; $i \leq$ n; i++) {		
US-MAP_IE()	Variable	PHY specific (7.7.4.1) Define upstream bandwidth allocations. Each US-MAP message shall contain at least one IE that marks the end of the last allocated burst. (UIUC=63 as defined in Table 36.)

Table 34—US-MAP message format

Syntax	Size	Notes
}		
}		
}		
If(!byte_boundary)		
Padding bits	0–7 bits	Padding to octet alignment—All bits shall be set to 0.
}		

7.7.4.1 US-MAP IE

Change Table 35 as follows:

Table 35—US-MAP information elements

Syntax	Size	Description
US-MAP IE ()		
SID	~~9~~13 bits	Station ID of the CPE
UIUC	6 bits	7.7.4.1.1 (see Table 36)
If ((UIUC ≥ 0) && (UIUC ≤ 1)) {		
CBP Frame Number	4 bits	Frame number where the active or passive CBP action is to take place. If the identified frame falls in the next superframe (e.g., current frame is 9 and the CBP Frame Number is 4), the CPE shall make sure that an SCW is still scheduled for this frame as indicated by the upcoming SCH. If not, the CBP action shall be cancelled.
If (UIUC ==0) {		Active SCW mode (CPE to transmit a CBP burst as requested by the BS).
Timing advance	16 bits	Signed number in TU corresponding to the advance of the transmission of the CBP burst at the CPE. As the CPE starts to transmit the CBP burst as its fourth symbol before the end of the frame, zero advance corresponds to this signal being received by the BS at the beginning of its fourth symbol before the end of the frame when the CPE is co-located with the BS (see Table 44).
EIRP Density Level	8 bits	EIRP per transmitted subcarrier (see 9.9.4.2). Signed in units of 0.5dB, ranging from –104 dBm (encoded 0x00) to +23.5 dBm (encoded 0xFF).
}		
If (UIUC == 1) {		Passive SCW mode (CPE to receive and demodulate the CBP burst and send content to the BS).

Table 35—US-MAP information elements *(continued)*

Syntax	Size	Description
Channel Number	8 bits	Channel number in which the CPE shall listen to the medium for a coexistence beacon.
Synchronization mode	1 bit	0: The CPE will capture the CBP burst using its current synchronization (i.e., locked to its BS) for geolocation purposes. 1: The CPE will resynchronize on the received CBP burst using the preamble symbol and optionally pilot carriers to decode the payload for self-coexistence purposes.
} else if (UIUC ≥ 2) && (UIUC ≤ 3) {		
Number of Subchannels	4 bits	Number of subchannels reserved for the BW Request/ UCS Notification opportunistic window.
} else if (UIUC ≥ 4) && (UIUC ≤ 6) {		
Number of Subchannels	4 bits	Number of subchannels reserved for the CDMA Ranging/BW Request/UCS notification opportunistic window. Note that in case where UIUC=8 and any UIUC in the range 4 to 6 are allocated to a frame, the largest number of subchannel specified shall prevail. Note also that when the CDMA ranging burst is to be used for terrestrially-based geolocation (see 10.5.2), the number of subchannels shall be at least 6.
Number of symbols	5 bits	Number of symbols in the US ranging channel reserved for the opportunistic windows carrying either CDMA Periodic Ranging/BW Request/UCS notification as specified by the respective UIUC. These shall be placed in the ranging channel following the initial ranging window if scheduled and consecutively (see Figure 157).
} else if (UIUC == 7) {		
CDMA_Allocation_IE ()	20 bits	See 7.7.4.1.2
} else if (UIUC == 8) {		The first 5 symbols of the upstream subframe shall be reserved for the opportunistic initial ranging burst.
Number of Subchannels	4 bits	Number of subchannels reserved for the initial ranging burst. Note that in the case where UIUC=8 and any UIUC in the range 4 to 6 are allocated to a frame, the largest number of claimed subchannels specified shall prevail.
} else if (UIUC ==9) {		US-MAP EIRP Control IE
US-MAP EIRP Control IE	Variable	See 7.7.4.1.3.
} else if (UIUC == 12) {		Extended UIUC values
Extended UIUC value	6 bits	
}else if (UIUC == 62){		
~~US_Extended_IE()~~ US-MAP Extended UIUC IE	Variable	See 7.7.4.1.4.

Table 35—US-MAP information elements *(continued)*

Syntax	Size	Description
} else {		
Burst_Type	1 bit	This value specifies the burst type for the burst specified by this US-MAP IE. 0: Bursts are mapped in the time axis over the full width of the upstream subframe before incrementing in the frequency axis. 1: Bursts are mapped in the time axis over segments of 7 symbols before incrementing in the frequency axis and then retracing to the lowest unused subchannel in the next 7 symbol segment. The width of the last segment is to be between 7 and 13 symbols depending on the width of the upstream subframe.
Duration	12 bits	Number of OFDM slots linearly allocated to the US burst specified by this IE. (Up to 60 by 30 slots can be allocated to a US burst.)
MDP	1 bit	Measurement Data Preferred Used by the BS to indicate to the CPE that this upstream allocation is to be preferably used by the CPE for the specific purpose of reporting back any measurement data. The measurement data to be reported is in connection to the specified Transaction ID. In case the CPE does not have anything to report, it can use this allocation for any other data. This is useful, for example, after a quiet period. 0: Measurement data not required (default) 1: Measurement data preferred
MRT	1 bit	Measurement Report Type In case MDP == 1, this field indicates which type of report the BS wants the CPE to send back. 0: Detailed (see 7.7.18.3.1.1 through 7.7.18.3.1.8) 1: Consolidated (see 7.7.18.3.1.9)
CMRP	1 bit	Channel Management Response Preferred Used by the BS to indicate to the CPE that this upstream allocation is to be used for confirming the receipt of the channel management command with the Transaction ID specified. 0: Channel management response not required (default) 1: Channel management response required
}		
}		

7.7.4.1.1 UIUC allocations

Change the following rows in Table 36 as indicated:

Table 36—UIUC values

UIUC	Usage
10~~~12~~11	*Reserved*
12	Extended UIUC value (Table 36a)
62	~~Extended UIUC~~ US-MAP Extended UIUC IE (Table 39)

Insert the new Table 36a immediately after Table 36 as follows:

Table 36a—Extended UIUC values

UIUC	Usage		
0	Convolutional Code	FEC rate = 1/2	256-QAM
1	Convolutional Code	FEC rate = 2/3	256-QAM
2	Convolutional Code	FEC rate = 3/4	256-QAM
3	Convolutional Code	FEC rate = 5/6	256-QAM
4	Convolutional Code	FEC rate = 7/8	256-QAM
5	Convolutional Code	FEC rate = 10/11 for two 2D symbols	4D-TCM 48QAM
6	Convolutional Code	FEC rate = 14/15 for two 2D symbols	4D-TCM 192QAM
7	CTC	FEC rate = 1/2	256-QAM
8	CTC	FEC rate = 2/3	256-QAM
9	CTC	FEC rate = 3/4	256-QAM
10	CTC	FEC rate = 5/6	256-QAM
11	CTC	FEC rate = 7/8	256-QAM
12	CTC	FEC rate = 10/11 for two 2D symbols	4D-TCM 48QAM
13	CTC	FEC rate = 14/15 for two 2D symbols	4D-TCM 192QAM
14	LDPC	FEC rate = 1/2	256-QAM
15	LDPC	FEC rate = 2/3	256-QAM
16	LDPC	FEC rate = 3/4	256-QAM
17	LDPC	FEC rate = 5/6	256-QAM
18	LDPC	FEC rate = 7/8	256-QAM
19	LDPC	FEC rate = 10/11 for two 2D symbols	4D-TCM 48QAM
20	LDPC	FEC rate = 14/15 for two 2D symbols	4D-TCM 192QAM

Table 36a—Extended UIUC values *(continued)*

UIUC	Usage		
21	SBTC	FEC rate = 1/2	256-QAM
22	SBTC	FEC rate = 2/3	256-QAM
23	SBTC	FEC rate = 3/4	256-QAM
24	SBTC	FEC rate = 5/6	256-QAM
25	SBTC	FEC rate = 7/8	256-QAM
26	SBTC	FEC rate = 10/11 for two 2D symbols	4D-TCM 48QAM
27	SBTC	FEC rate = 14/15 for two 2D symbols	4D-TCM 192QAM
28–63	*Reserved*		

7.7.4.1.4 US-MAP Extended UIUC IE

Change Table 39 as follows:

Table 39 — US-MAP Extended UIUC IE general format

Syntax	Size	Note
~~US_Extended_IE()~~ US-MAP Extended UIUC IE (){		
~~Extended UIUC~~ Extended UIUC IE Type	~~6~~ 8 bits	~~Values specific to the Extended IE~~ Type of Extended UIUC IE as specified in Table 39a
Length	8 bits	Length of this IE in bits.
Unspecified Data	Variable	
}		

Insert the new Table 39a immediately after Table 39 as follows:

Table 39a — Extended UIUC IE Type code assignment

Extended UIUC	Usage
0x00	US-MAP Dummy Extended IE
0x01	US Multi-Zone Configuration IE
0x02	AZUS-MAP IE
0x03	CRZUS-MAP IE
0x04	DRZUS-MAP GRA IE
0x05–0xFF	*Reserved*

7.7.4.1.4.1 US-MAP Dummy Extended IE

Change Table 40 as follows:

Table 40—US-MAP Dummy Extended IE format

Syntax	Size	Notes
Dummy_IE () {		
Extended UIUC	6 bits	~~0x00~~UIUC values as defined in Table 36.
If (UIUC == 12) {		
Extended UIUC Value	6 bits	See Table 36a.
}		
Length	8 bits	Length of IE data in ~~bits~~bytes.
Unspecified Data	Variable	
}		

Insert the following subclauses (7.7.4.1.4.2 through 7.7.4.1.4.5) after 7.7.4.1.4.1:

7.7.4.1.4.2 US Multi-Zone Configuration IE

A CPE shall be able to decode the US Multi-Zone Configuration IE shown in Table 40a. An A-BS shall transmit this IE for multi-hop relay operations.

Table 40a—US Multi-Zone Configuration IE format

Syntax	Size	Notes
US Multi-Zone Configuration_IE() {		
Multi-Zone configuration{		
Number of zones	8 bits	Number of zones including access and relay zones. Number of zones (0) is not available of DS. Number of zone (1) shall be access zone.
For (i = 1; $i \le$ Number of zones; i++){		
Zone Index	8 bits	Increase the index from 0 to Number of Zones-1
Zone Mode	2 bits	0: access zone 1: centralized relay zone 2: distributed relay zone
Start Position of Segment	4 bits	00: 0 01: 1 10: 2 11: If 'Zone Mode' is set to Access or Centralized Relay Zone

Table 40a—US Multi-Zone Configuration IE format *(continued)*

Syntax	Size	Notes
Segment Bandwidth	2 bits	00: one segment from start position 01: two segments from start position 10: three segments from start position 11: If ‘Zone Mode’ is set to Access or Centralized Relay Zone
PHY Mode	1 bit	0: PHY-OM1 1: PHY-OM2
}		
}		
for (Zone index = 0; Zone index < Number of zones; Zone index++){		
OFDMA symbol offset	7 bits	The zone starts at the OFDMA symbol offset, counted after the preamble of the frame
Zone duration	5 bits	The zone ends after the zone duration starting from the OFDMA symbol offset. The unit of duration is an OFDMA symbol
if (Zone mode == 2) {		Distributed Relay Zone (DRZ) mode
SID	13 bits	SID of distributed scheduling R-CPE
}		
}		
}		

7.7.4.1.4.3 Access Zone US-MAP IE (AZUS-MAP IE)

Encodings of AZ US-MAP IE for the US to the A-BS are provided in Table 40b.

Table 40b—AZ US-MAP IE format

Syntax	Size	Notes
AZ US-MAP_IE() {		
Zone Index	8 bits	See Table 40a
CRZUS-MAP Index	16 bits	For relaying through the centralized scheduling A-CPE, it indicates the matched CRZUS-MAP IE. Increase the index from 0 to 65535
SID	13 bits	Station ID of the CPE or centralized scheduling A-CPE.
UIUC	6 bits	7.7.4.1.1 (see Table 36).
If (UIUC == 12)		
Extended UIUC Value	6 bits	See 7.7.4.1.1.

Table 40b—AZ US-MAP IE format *(continued)*

Syntax	Size	Notes
If ((UIUC ≥ 0) && (UIUC ≤ 1)) {		Frame number where the active or passive CBP action is to take place.
CBP Frame Number	4 bits	Active SCW mode (CPE to transmit a CBP burst as requested by the BS).
If(UIUC==0) {		
Timing advance	16 bits	Signed number in TU corresponding to the advance of the transmission of the CBP burst at the CPE. As the CPE starts to transmit the CBP burst as its fourth symbol before the end of the frame, zero advance corresponds to this signal being received by the BS at the beginning of its fourth symbol before the end of the frame when the CPE is co-located with the BS (see Table 44).
EIRP Density Level	8 bits	EIRP per transmitted subcarrier (see 9.9.4.2). Signed in units of 0.5 dB, ranging from –104 dBm (encoded 0x00) to +23.5 dBm (encoded 0xFF).
}		
If(UIUC==1) {		Passive SCW mode (CPE to receive and demodulate the CBP burst and send content to the BS).
Channel Number	8 bits	Channel number in which the CPE shall listen to the medium for a coexistence beacon.
Synchronization mode	1 bit	0: The CPE will capture the CBP burst using its current synchronization (i.e., locked to its BS) for geolocation purposes. 1: The CPE will resynchronize on the received CBP burst using the preamble symbol and optionally pilot carriers to decode the payload for self-coexistence purposes.
} else if (UIUC ≥ 2) && (UIUC ≤ 3)) {		
Number of Subchannels	4 bits	Number of subchannels reserved for the BW Request/ UCS Notification opportunistic window.
Number of Symbols	5 bits	Number of symbols reserved for the BW Request/ UCS/Notification opportunistic window.
} else if (UIUC ≥ 4) && (UIUC ≤ 6)) {		
Number of Subchannels	4 bits	Number of subchannels reserved for the CDMA Periodic Ranging/BW Request/UCS notification opportunistic window. Note that in case where UIUC=8 and any UIUC in the range 4 to 6 are allocated to a frame, the largest number of subchannel specified shall prevail. Note also that when the CDMA ranging burst is to be used for terrestrially-based geolocation (see 10.5.2), the number of subchannels shall be at least 6.
Number of symbols	5 bits	Number of symbols CDMA Periodic Ranging/BW Request/UCS notification as specified by the respective UIUC. These shall be placed in the ranging channel following the initial ranging window if scheduled and consecutively (see Figure 157).

Table 40b—AZ US-MAP IE format *(continued)*

Syntax	Size	Notes
} else if (UIUC == 7) {		
CDMA_ Allocation_IE ()	20 bits	See 7.7.4.1.2.
} else if (UIUC == 8) {		
Number of Subchannels	4 bits	Number of subchannels reserved for the initial ranging burst. Note that in case where UIUC=8 and any UIUC in the range 4 to 6 are allocated to a frame, the largest number of claimed subchannels specified shall prevail.
Number of Symbols	5 bits	Number of symbols reserved for the initial ranging burst.
} else if (UIUC == 9) {		
US-MAP EIRP Control IE	Variable	See 7.7.4.1.3.
} else {		
Burst_Type	1 bit	This value specifies the burst type for the burst specified by this US-MAP IE. 0: Bursts are mapped in the time axis over the full width of the US subframe before incrementing in the frequency axis. 1: Bursts are mapped in the time axis over segments of 7 symbols before incrementing in the frequency axis and then retracing to the lowest unused subchannel in the next 7 symbol segment. The width of the last segment is to be between 7 and 13 symbols depending on the width of the US subframe.
Duration	12 bits	Number of OFDM slots linearly allocated to the US burst specified by this IE. (Up to 60 by 30 slots can be allocated to a US burst.)
MDP	1 bit	Measurement Data Preferred Used by the BS to indicate to the CPE that this US allocation is to be preferably used by the CPE for the specific purpose of reporting back any measurement data. The measurement data to be reported is in connection to the specified Transaction ID. In case the CPE does not have anything to report, it can use this allocation for any other data. This is useful, for example, after a quiet period. 0: Measurement data not required (default) 1: Measurement data preferred
MRT	1 bit	Measurement Report Type In case MDP == 1, this field indicates which type of report the BS wants the CPE to send back. 0: Detailed (see 7.7.18.3.1.1 through 7.7.18.3.1.8) 1: Consolidated (see 7.7.18.3.1.9)

Table 40b—AZ US-MAP IE format *(continued)*

Syntax	Size	Notes
CMRP	1 bit	Channel Management Response Preferred Used by the BS to indicate to the CPE that this US allocation is to be used for confirming or not the receipt of the channel management command with the Transaction ID specified. 0: Channel management response not required (default) 1: Channel management response required
}		
}		
}		

7.7.4.1.4.4 Centralized Relay Zone US-MAP IE (CRZ US-MAP IE)

Encodings of CRZ US-MA IE for the relay US to the centralized scheduling A-CPE from the S-CPE are provided in Table 40c.

Table 40c—CRZUS-MAP IE format

Syntax	Size	Notes
CRZ US-MAP_IE() {		
Zone Index	8 bits	See Table 40a
CRZ US-MAP Index	16 bits	See Table 40a
SID	13 bits	Station ID of the CPE.
UIUC	6 bits	7.7.4.1.1 (see Table 36).
If (UIUC == 12)		
Extended UIUC Value	6 bits	See 7.7.4.1.1.
If ((UIUC ≥ 0) && (UIUC ≤ 1)) {		Frame number where the active or passive CBP action is to take place.
CBP Frame Number	4 bits	Active SCW mode (CPE to transmit a CBP burst as requested by the BS).
If(UIUC==0) {		
Timing advance	16 bits	Signed number in TU corresponding to the advance of the transmission of the CBP burst at the CPE. As the CPE starts to transmit the CBP burst as its fourth symbol before the end of the frame, zero advance corresponds to this signal being received by the BS at the beginning of its fourth symbol before the end of the frame when the CPE is co-located with the BS (see Table 44).

Table 40c—CRZUS-MAP IE format *(continued)*

Syntax	Size	Notes
EIRP Density Level	8 bits	EIRP per transmitted subcarrier (see 9.9.4.2). Signed in units of 0.5 dB, ranging from –104 dBm (encoded 0x00) to +23.5 dBm (encoded 0xFF).
}		
If(UIUC==1) {		Passive SCW mode (CPE to receive and demodulate the CBP burst and send content to the BS).
Channel Number	8 bits	Channel number in which the CPE shall listen to the medium for a coexistence beacon.
Synchronization mode	1 bit	0: The CPE will capture the CBP burst using its current synchronization (i.e., locked to its BS) for geolocation purposes. 1: The CPE will resynchronize on the received CBP burst using the preamble symbol and optionally pilot carriers to decode the payload for self-coexistence purposes.
} else if (UIUC ≥ 2) && (UIUC ≤ 3)) {		
Number of Subchannels	4 bits	Number of subchannels reserved for the Relay BW Request/UCS Notification opportunistic window.
Number of Symbols	5 bits	Number of symbols reserved for the Relay BW Request/UCS/Notification opportunistic window.
} else if (UIUC ≥ 4) && (UIUC ≤ 6)) {		
Number of Subchannels	4 bits	Number of subchannels reserved for the Relay CDMA Periodic Ranging/BW Request/UCS notification opportunistic window. Note that in case where UIUC=8 and any UIUC in the range 4 to 6 are allocated to a frame, the largest number of subchannel specified shall prevail. Note also that when the CDMA ranging burst is to be used for terrestrially-based geolocation (see 10.5.2), the number of subchannels shall be at least 6.
Number of symbols	5 bits	Number of symbols Relay CDMA Periodic Ranging/ BW Request/UCS notification as specified by the respective UIUC. These shall be placed in the ranging channel following the initial ranging window if scheduled and consecutively (see Figure 157).
} else if (UIUC == 7) {		
CDMA_ Allocation_IE ()	20 bits	See 7.7.4.1.2.
} else if (UIUC == 8) {		
Number of Subchannels	4 bits	Number of subchannels reserved for the Relay initial ranging burst. Note that in case where UIUC=8 and any UIUC in the range 4 to 6 are allocated to a frame, the largest number of claimed subchannels specified shall prevail.
Number of Symbols	5 bits	Number of symbols reserved for the Relay initial ranging burst.
} else if (UIUC == 9) {		

Table 40c—CRZUS-MAP IE format *(continued)*

Syntax	Size	Notes
US-MAP EIRP Control IE	Variable	See 7.7.4.1.3.
} else {		
Burst_Type	1 bit	This value specifies the burst type for the burst specified by this US-MAP IE. 0: Bursts are mapped in the time axis over the full width of the US subframe before incrementing in the frequency axis. 1: Bursts are mapped in the time axis over segments of 7 symbols before incrementing in the frequency axis and then retracing to the lowest unused subchannel in the next 7 symbol segment. The width of the last segment is to be between 7 and 13 symbols depending on the width of the US subframe.
Duration	12 bits	Number of OFDM slots linearly allocated to the US burst specified by this IE. (Up to 60 by 30 slots can be allocated to a US burst.)
MDP	1 bit	Measurement Data Preferred Used by the BS to indicate to the CPE that this US allocation is to be preferably used by the CPE for the specific purpose of reporting back any measurement data. The measurement data to be reported is in connection to the specified Transaction ID. In case the CPE does not have anything to report, it can use this allocation for any other data. This is useful, for example, after a quiet period. 0: Measurement data not required (default) 1: Measurement data preferred
MRT	1 bit	Measurement Report Type In case MDP == 1, this field indicates which type of report the BS wants the CPE to send back. 0: Detailed (see 7.7.18.3.1.1 through 7.7.18.3.1.8) 1: Consolidated (see 7.7.18.3.1.9)
CMRP	1 bit	Channel Management Response Preferred Used by the BS to indicate to the CPE that this US allocation is to be used for confirming or not the receipt of the channel management command with the Transaction ID specified. 0: Channel management response not required (default) 1: Channel management response required
}		
}		
}		

7.7.4.1.4.5 Distributed Relay Zone US-MAP Group Resource Allocation IE (DRZUS-MAP GRA IE)

The format of the DRZ US-MAP GRA IE is shown in Table 40d.

Table 40d—DRZUS-MAP GRA information element

Syntax	Size	Notes
DRZUS-MAP_GRA_IE() {		
Resource Allocation Bitmap	Variable (1 bit × number of devices in the group)	Indicates whether the resources are allocated to the device in a group. The number of devices in the group is determined by the Device Bitmap Size in GRA Configuration Message. 0: not allocated in the frame 1: allocated in the frame
Resource Starting Index	11 bits	Indicates the starting index of resource in the unit of OFDMA slot. In the DS subframe, the index starts right after the frame preamble from 0. In the US subframe, the index 0 starts from the ranging/BW request/UCS notification contention windows (not including SCW) if it exists.
Resource Size Bitmap	Variable (3 bits × number of devices in the group)	Indicates the resource allocation size for the device in the unit of OFDMA slot. 000: 1 001: 2 010: 4 011: 8 100: 16 101: 32 110: 64 111: 128
Group UIUC Flag	1 bit	Indicates whether the UIUC is fixed within group. 0: not fixed within group 1: fixed within group
Group Burst_Type Flag	1 bit	Indicates whether the Burst_Type is fixed within group. 0: not fixed within group 1: fixed within group
Group MDP Flag	1 bit	Indicates whether the MDP is fixed within group. 0: not fixed within group 1: fixed within group
Group MRT Flag	1 bit	Indicates whether the MRT is fixed within group. 0: not fixed within group 1: fixed within group
Group CMRP Flag	1 bit	Indicates whether the CMRP is fixed within group. 0: not fixed within group 1: fixed within group
If (Group UIUC Flag = 0) {		
Group UIUC Bitmap	Variable (6 bits × number of devices in the group)	Specifies the UIUC of each device in a group
}		
Else {		
UIUC	6 bits	Same UIUC is used by all device in a group

Table 40d—DRZUS-MAP GRA information element *(continued)*

Syntax	Size	Notes
If (UIUC == 12)		
Extended UIUC Value	6 bits	See 7.7.4.1.1.
}		
If (Group Burst_Type Flag = 0) {		
Group Burst_Type Bitmap	Variable (1 bit × number of devices in the group)	Specifies the Burst_Type of each device in a group
}		
Else{		
Burst_Type	1 bit	Same Burst_Type is used by all device in a group
}		
If (Group MDP Flag = 0) {		
Group MDP Bitmap	Variable (1 bit × number of devices in the group)	Specifies the MDP of each device in a group
}		
Else{		
MDP	1 bit	Same MDP is used by all device in a group
}		
If (Group MRT Flag = 0) {		
Group MRT Bitmap	Variable (1 bit × number of devices in the group)	Specifies the MRT of each device in a group
}		
Else{		
MRT	1 bit	Same MRT is used by all device in a group
}		
If (Group CMRP Flag = 0) {		
Group CMRP Bitmap	Variable (1 bit × number of devices in the group)	Specifies the CMRP of each device in a group
}		

Table 40d—DRZUS-MAP GRA information element *(continued)*

Syntax	Size	Notes
Else{		
CMRP	1 bit	Same CMRP is used by all device in a group
}		
}		

7.7.7 REG-REQ/RSP

7.7.7.3 REG-REQ/RSP information elements

7.7.7.3.4 CPE capability

7.7.7.3.4.12 Permanent Station ID

Change Table 61 as follows:

Table 61—Permanent Station ID information element

Element ID	Length (bytes)	Value	Scope
15	2	Permanent SID (Bit ~~0000 000b bbbb bbbb~~ 000b bbbb bbbb bbbb)	REG-REQ/RSP

7.7.7.3.4.13 CPE Operational Capability

Change Table 62 as follows:

Table 62—CPE Operational Capability information element

Element ID	Length (bytes)	Value	Scope
16	1	0x00: Fixed (no relay) 0x01: Portable (no relay) 0x02: Centralized scheduling A-CPE (fixed only) 0x03: Distributed scheduling A-CPE (fixed) 0x04: Distributed scheduling A-CPE (portable) 0x05: Fixed Multi-channel Bulk Transmission 0x06: Fixed Multi-channel Transmit Diversity 0x07: Portable Multi-channel Bulk Transmission 0x08: Portable Multi-channel Transmit Diversity 0x09–0xFF: *Reserved*	REG-REQ/RSP

Insert the following subclause (7.7.7.3.6 and its table) after 7.7.7.3.5:

7.7.7.3.6 Local SID Group

The format of a Local SID IE is shown in Table 63a. This IE shall be transmitted by the A-BS to the distributed scheduling A-CPE at registration. Instead of the A-BS, the distributed scheduling A-CPE allocates a Local SID to the S-CPE at initialization.

Table 63a—Local SID Group Information element

Syntax	Size	Notes	Scope
Local SID Group_IE(){			REG-RSP
Element ID = 18	8 bits		
Number of SIDs	13 bits	Total number of SIDs assigned for a distributed scheduling A-CPE	
SIDs	13 bits	Start SID; A group of SIDs will be allocated from SID.	

7.7.8.9 Service Flow encodings

Insert the following subclause (7.7.8.9.19 and its tables) after 7.7.8.9.18.3.14:

7.7.8.9.19 Per-RS QoS

The format of a Per-RS QoS IE is shown in Table 101a.

Table 101a—Per-RS QoS information elements

Name	Element ID	Length	Value	Scope
Per-RS QoS	21	Variable	Compound	DSA-REQ/RSP DSC-REQ/RSP

Per-RS QoS value is shown in Table 101b as following.

Table 101b—Per-RS QoS value

Name	Length (1 byte)	Value
RS_Basic_CID	2	RS Basic CID
Maximum Latency for the RS	4	Milliseconds

The value of Maximum Latency for the A-CPE specifies the maximum interval between the reception of an MAC PDU at the A-CPE's air interface that is receiving the MAC PDU and the air interface that is forwarding the MAC PDU.

7.7.11 CPE Basic Capability Request/Response (CBC-REQ/RSP)

7.7.11.3 CBC-REQ/RSP information elements

7.7.11.3.2 Physical parameters supported

7.7.11.3.2.2 PHY-specific parameters

7.7.11.3.2.2.1 CPE Demodulator

Change Table 109 as follows:

Table 109—CPE Demodulator information element

Element ID	Length (bytes)	Value	Scope
3	~~1~~2	For a particular mode being represented, see the corresponding index in Table 27 (DIUC values) bit 0–bit 7: Supported modulation (see Table 109a) bit 8–bit 15: Supported coding rates (see Table 109b)	CBC-REQ, CBC-RSP

Insert new Table 109a and Table 109b immediately after Table 109 in 7.7.11.3.2.2.1:

Table 109a—Supported modulation

b0	b1	b2	b3	b4	b5	b6	b7
QPSK	16-QAM	64-QAM	256-QAM	MD-TCM	*Reserved*		

Table 109b—Supported coding rates

b8	b9	b10	b11	b12	b13	b14	b15
1/2	2/3	3/4	5/6	7/8	10/11	14/15	*Reserved*

Insert the following subclauses (7.7.11.3.2.2.3 and 7.7.11.3.2.2.4 and their tables) after 7.7.11.3.2.2.2:

7.7.11.3.2.2.3 Centralized Scheduling A-CPE Demodulator

The format of a Centralized Scheduling A-CPE Demodulator IE is shown in Table 110a. This field indicates the different demodulator options supported by a centralized scheduling A-CPE for the DS reception.

Table 110a—Centralized Scheduling A-CPE Demodulator

Element ID	Length (bytes)	Value	Scope
3.1	2	For a particular mode being represented, see the corresponding index in Table 27 (DIUC values) bit 0–bit 7: supported modulation (Table 109a) bit 8–bit 15: supported coding rates (Table 109b)	CBC-RSP

7.7.11.3.2.2.4 Centralized Scheduling A-CPE Modulator

The format of a Centralized Scheduling A-CPE modulator IE is shown in Table 110b. This field indicates the different modulator options supported by a centralized scheduling A-CPE for US transmission.

Table 110b—Centralized Scheduling A-CPE Modulator

Element ID	Length (bytes)	Value	Scope
4.1	2	For a particular mode being represented, see the corresponding index in Table 36 (UIUC values) bit 0–bit 7: supported modulation (Table 109a) bit 8–bit 15: supported coding rates (Table 109b)	CBC-RSP

Insert the following subclauses (7.7.11.3.4 and 7.7.11.3.5 and their tables) after 7.7.11.3.3.3:

7.7.11.3.4 Relay CPE Mode

The format of a Relay CPE Mode IE is shown in Table 113a. This IE defines a relay operation mode for the CPEs.

Table 113a—Relay CPE Mode information element

Element ID	Length (bytes)	Value	Scope
8	1	0: No support Relay 1: Centralized Scheduling A-CPE Support 2: Distributed Scheduling A-CPE Support	CBC-REQ

7.7.11.3.5 Multi-channel operation supported

This information element indicates the capability of the CPE shown in Table 113b whether the multi-channel operation is supported or not supported.

Table 113b—Multi-channel operation supported information element

Element ID	Length (bytes)	Value	Scope
9	1	0x00: Multi-channel operation not supported. 0x01: Multi-channel operation supported. 0x02–0xFF: *Reserved*.	CBC-REQ, CBC-RSP

7.7.24 Confirmation codes

Insert the following rows in Table 173, and change the reserved row as indicated:

Table 173—Confirmation codes

CC	Status
0x13	reject-A-CPE-not-supported-parameter-value
0x14	reject-unknown-sid
0x15	reject-invalid-container-pdu-length
0x16	reject-invalid-container-pdu-type
0x17	reject-dtt-not-allowed
0x18	reject-dtt-rpt-not-allowed-to-transmit
0x19	reject-dtt-rpt-need-to-retest
0x20	reject-failed-cam-stp
0x21	reject-failed-cam-swh
~~0x13~~0x22–0xFF	*Reserved*

Insert the following subclauses (7.7.25 through 7.7.31 and their subclauses and tables) after 7.7.24:

7.7.25 Local Cell Update messages

7.7.25.1 Local Cell Update Indication (LCU-IND) message

The format of an LCU-IND message is shown in Table 173a. This message shall be transmitted by a distributed scheduling A-CPEs to the A-BS at the update of local cell information.

Table 173a—LCU-IND message format

Syntax	Size	Note
LCU_IND_Message_Format() {		
Management Message Type = 41	8 bits	Local Cell Update IND
Transaction ID	16 bits	
Number of CPEs: n	8 bits	The number of CPEs, which are attached by a distributed scheduling A-CPE
For (i = 1; $i \leq$ n; i++){	Variable	
SID	13 bits	SID of CPE, which require local cell update that are attached by a distributed scheduling A-CPE
}		
}		

7.7.25.2 Local Cell Update Acknowledgment (LCU-ACK) message

The format of an LCU-ACK message is shown in Table 173b. This message shall be transmitted by an A-BS to a distributed scheduling A-CPEs for the acknowledgment of reception of local cell update indication.

Table 173b—LCU-ACK message format

Syntax	Size	Note
LCU_ACK_Format() {		
Management Message Type = 42	8 bits	
Transaction ID	16 bits	
Confirmation Code	8 bits	See 7.7.24
}		

7.7.26 Container message

7.7.26.1 Message format

The format of a Container message is shown in Table 173c. A container message is used to convey MAC PDUs between the A-CPE to the A-BS.

Table 173c—Container message format

Syntax	Size	Note
Container_Message_Format() {		
Management Message Type = 43	8 bits	
Transaction ID	16 bits	
Number of Contained MAC PDUs: n	8 bits	The number of contained MAC PDUs
For (i = 1; $i \le$ n; i++){	Variable	
SID	13 bits	SID of A-CPE, which sends this messages
MAC PDU Type	3 bits	000: REG-RSP 001: DREG-CMD with Action Code = 0x04 or 0x05] 010: DREG-CMD with Action Code = 0x01, 0x02, or 0x03 011: Any other PDU 100–111: *Reserved*
MAC PDU Length	11 bits	The length in bytes of the contained MAC PDU including the MAC header and the CRC.
MAC PDU	Variable	
}		
}		

7.7.26.2 Container ACK message

The format of a Container ACK message is shown in Table 173d. A container ACK message is used to acknowledgment for a container message.

Table 173d—Container ACK message format

Syntax	Size	Note
Container_ACK_Message_Format() {		
Management Message Type = 44	8 bits	
Transaction ID	16 bits	
Confirmation Code	8 bits	See 7.7.24
}		

7.7.27 Downstream Transmit Test (DTT) messages

7.7.27.1 DTT Request (DTT-REQ) message

7.7.27.1.1 Message format

The format of a DTT-REQ message is shown in Table 173e.

Table 173e—DTT-REQ message format

Syntax	Size	Note
DTT-REQ_Message_Format() {		
Management Message Type = 45	8 bits	
Transaction ID	16 bits	
Information elements (IEs)	Variable	see Table 173f
}		

7.7.27.1.2 DTT-REQ information element

The format of a DTT-REQ IE is shown in Table 173f.

Table 173f—DTT-REQ information element

Name	Element ID (1 byte)	Length	Scope
SID	1	13 bits	Selected a centralized scheduling A-CPE to test a relay burst profile

7.7.27.2 DTT Response (DTT-RSP) message

7.7.27.2.1 Message format

The format of a DTT-RSP message is shown in Table 173g.

Table 173g—DTT-RSP message format

Syntax	Size	Note
DTT-RSP_Message_Format() {		
Management Message Type = 46	8 bits	
Transaction ID	16 bits	
Information elements (IEs)	Variable	see Table 173h
}		

7.7.27.2.2 DTT-RSP information element

The format of a DTT-RSP IE is shown in Table 173h.

Table 173h—DTT-RSP information element

Name	Element ID (1 byte)	Length	Scope
Action Frame Number Offset	1	4 bits	Integer value greater than zero that indicates the starting frame number for a relay burst profile test
Status	2	8 bits	See 7.7.24

7.7.27.3 DTT Report (DTT-RPT) message

7.7.27.3.1 Message format

The format of a DTT-RPT message is shown in Table 173i.

Table 173i—DTT-RPT message format

Syntax	Size	Note
DTT-RPT_Message_Format() {		
Management Message Type = 47	8 bits	
Transaction ID	16 bits	
Information elements (IEs)	Variable	see Table 173j
}		

7.7.27.3.2 DTT-RPT information element

The format of a DTT-RPT IE is shown in Table 173j.

Table 173j—DTT-RPT information element

Name	Element ID (1 byte)	Length	Scope
Downstream burst profile	1	6 bits	Burst profile that can be received by the CPE

7.7.27.4 DTT Confirmation (DTT-CFM) message

7.7.27.4.1 Message format

The format of a DTT-CFM message is shown in Table 173k.

Table 173k—DTT-CFM message format

Syntax	Size	Note
DTT-CFM_Message_Format() {		
Management Message Type = 48	8 bits	
Transaction ID	16 bits	
Information elements (IEs)	Variable	See Table 173l
}		

7.7.27.4.2 DTT-CFM information element

The format of a DTT-CFM IE is shown in Table 173l.

Table 173l—DTT-CFM information element

Name	Element ID (1 byte)	Length	Scope
Confirmation Code	1	8 bits	See 7.7.24
Action Frame Number Offset	2	4 bits	Integer value greater than zero that indicates the starting frame number for a relay burst profile test

7.7.28 Relay-Schedule (Relay-SCHE) message

The format of a Relay-SCHE message is shown in Table 173m. This message may be used for the coordination of the US allocation. It is sent by an A-BS to an A-CPE or sent by an A-CPE to an S-CPE.

Table 173m—Relay-SCHE message format

Syntax	Size	Note
Relay-SCHE_Message_Format() {		
Management Message Type = 49	8 bits	
Transaction ID	16 bits	
N_FID	8 bits	The number of FIDs included
For (i = 0; i < N_FID; i++) {		
FID	8 bits	The FID for the CPE

Table 173m—Relay-SCHE message format *(continued)*

Syntax	Size	Note
Allocation Frame Offset	8 bits	In terms of number of frames
Bandwidth	8 bits	In number of bytes
}		
}		

7.7.29 Channel Allocation Manager management messages

7.7.29.1 Overview

This subclause (7.7.29) describes the channel allocation manager management messages for the basic multi-channel operations such as add new operating channel operation (CAM-ADD), stop operating channel (CAM-STP and CAM-STP-ACK) and switch operating channel (CAM-SWH and CAM-SWH-ACK).

7.7.29.2 Add new operating channel (CAM-ADD) message

The format of the CAM-ADD message is shown in Table 173n. This message is used to configure add new operating channel procedure during the multichannel operation. The aggregation information is needed by the CPE-CAM in order to identify the aggregation information transmitted from the BS-CAM. This message includes the number of maximum aggregation channel allowed and the channel aggregation information for CPE.

Table 173n—CAM-ADD message format

Syntax	Size	Note
CAM-ADD_Message_Format() {		
Management Message Type = 50	8 bits	
Transaction ID	16 bits	
Aggregation Information	1 bit	0: Aggregation on 1: Aggregation off
Maximum Aggregation Channels	6 bits	The number of maximum aggregation channels allowed in CPE.
For (*i* = 0; *i* < Maximum Aggregation Channels; *i*++){		List of the channel informations that are available for channel aggregation in CPE.
Channel Number [i]	8 bits	
}		
reserved	1 bit	This bit shall be set to zero.
}		

7.7.29.3 Stop operating channel (CAM-STP) message

The format of the CAM-STP message is shown in Table 173o. This message is used to configure stop operating channel procedure during the multichannel operation. This message is sent by BS-CHU to the CPE-CHU in order to stop the operating channel in CPE-CHU. Transmission of this message may result from various conditions such as protection of incumbent services (BS incumbent sensing report, CPE incumbent sensing report), channel availability in database and BS channel scheduling.

Table 173o—CAM-STP message format

Syntax	Size	Note
CAM-STP_Message_Format() {		
Management Message Type = 51	8 bits	
Transaction ID	16 bits	
Confirmation Needed	1 bit	0: No confirmation needed 1: Confirmation needed
Stop Channel Number	8 bits	Specified destination for channel stop operation request.
}		

7.7.29.4 Stop operating channel acknowledgment (CAM-STP-ACK) message

The format of the CAM-STP-ACK message is shown in Table 173p. This message shall be sent by CPE-CHU to the BS-CHU in response to a received CAM-STP. This message serves to confirm to the BS-CHU the reception of the CAM-STP message by the CPE-CHU.

Table 173p—CAM-STP-ACK message format

Syntax	Size	Note
CAM-STP-ACK_Message_Format() {		
Management Message Type = 52	8 bits	
Transaction ID	16 bits	
Confirmation Code	8 bits	See 7.7.24
}		

7.7.29.5 Switch operating channel (CAM-SWH) message

The format of the CAM-SWH message is shown in Table 173q. This message is used to configure switch operating channel procedure during the multichannel operation. This message is sent by BS-CHU to the CPE-CHU in order to switch the operating channel in CPE-CHU. Transmission of this message may result from various conditions such as protection of incumbent services (BS incumbent sensing report, CPE incumbent sensing report), channel availability in database and BS channel scheduling.

Table 173q—CAM-SWH message format

Syntax	Size	Note
CAM-SWH_Message_Format() {		
Management Message Type = 53	8 bits	
Transaction ID	16 bits	
Confirmation Needed	1 bit	0: No confirmation needed 1: Confirmation needed
Switch Mode	1 bit	0: no restriction on transmission until the scheduled channel switch 1: addressed CPE shall transmit no further frames until the schedules channel switch.
Switch Count	8 bits	The number of frames until the BS sending the switching operating channel message switches to the new operating channel.
Switch Channel Number	8 bits	Specified destination for channel switch request.
}		

7.7.29.6 Switch operating channel acknowledgment (CAM-SWH-ACK) message

The format of the CAM-SWH-ACK message is shown in Table 173r. This message shall be sent by CPE-CHU to the BS-CHU in response to a received CAM-SWH. This message serves to confirm to the BS-CHU the reception of the CAM-SWH message by the CPE-CHU.

Table 173r—CAM-SWH-ACK message format

Syntax	Size	Note
CAM-SWH-ACK_Message_Format() {		
Management Message Type = 54	8 bits	
Transaction ID	16 bits	
Confirmation Code	8 bits	See 7.7.24
}		

7.7.30 Group Resource Allocation management messages

7.7.30.1 Group Resource Allocation Configuration (GRA-CFG) message

The format of the GRA-CFG message is shown in Table 173s. This message is used to configure the group resource allocation. The BS uses this message to create a new group and identify the devices that belong to the group.

The A-BS uses bitmaps to allocate the resources on a group basis. The device bitmap size specifies the maximum number of devices that can be supported by a new group. The SID bitmap is used to indicate the device belonging to the group. The total size of the SID bitmap is the number of devices multiplied by the

13-bit station ID. Each group is identified by a unique 10-bit group ID. The group is classified into two types, fixed group and portable or mobile group. The type of group is determined according to the mobility of A-CPE. The location of group is represented by the latitude and longitude of A-CPE.

Table 173s—GRA-CFG message format

Syntax	Size	Note
GRA-CFG_Message_Format() {		
Management Message Type = 55	8 bits	
Transaction ID	16 bits	
Device Bitmap Size	4 bits	Maximum number of devices that can be included to a new group 0000: 1 0001: 2 0010: 4 0011: 8 0100: 16 0101: 32 0110: 64 0111: 128 1000~1111: *Reserved*
SID Bitmap	Variable (13 bits × number of devices)	The bitmap of station ID that is belonging to a new group
GID	10 bits	ID of the group to which the device is included
Group Type	1 bit	0: Fixed Group 1: Portable or Mobile Group
Group Location	48 bits	Latitude and longitude of a new group
}		

7.7.30.2 Group Resource Allocation Update (GRA-UPD) message

The format of the GRA-UPD message is shown in Table 173t. This message is used to update the group resource allocation configuration. The device can be added to or deleted from a group. This message is also used to update the location of group.

Table 173t—GRA-UPD message format

Syntax	Size	Note
GRA-UPD_Message_Format() {		
Management Message Type = 56	8 bits	
Transaction ID	16 bits	

Table 173t—GRA-UPD message format *(continued)*

Syntax	Size	Note
Device Flag {	1 bit	Flag to indicate whether the device information is changed 0: Device information is not changed 1: Device information is changed
Group Flag	1 bit	Flag to indicate whether the group information is changed 0: Group information is not changed 1: Group information is changed
If(Device Flag = 1) {		Indicate that device information is changed
GID	10 bits	Group ID to which the device(s) is added to or deleted from a group.
Number of Added Devices	7 bits	
Number of Deleted Devices	7 bits	
For (*i* = 0; *i* < Number of Added Devices; *i*++) {		
SID [i]	13 bits	Station ID that is added to a group.
Device Bitmap Index	7 bits	New index of the device in a group's device bitmap.
}		
For (*i* = 0; *i* < Number of Deleted Devices; *i*++) {		
SID [i]	13 bits	Station ID that is deleted from a group.
}		
}		
if (Group Flag = 1){	1 bit	Indicate that group information is changed
Group Location	48 bits	New latitude and longitude of a group
}		
}		

7.7.31 Ranging Report (RNG-RPT) message

The format of the RNG-RPT message is shown in Table 173u. This message is sent by a centralized scheduling A-CPE to A-BS and is used to inform ranging status of S-CPEs.

Table 173u—RNG-RPT message format

Syntax	Size	Note
RNG-RPT_Message_Format() {		
Management Message Type = 57	8 bits	
Transaction ID	16 bits	
Information element (IEs)	Variable	See Table 173v
}		

Table 173v—RNG-RPT information elements

Name	Element ID (1 byte)	Length (bits)	Description
Ranging Status	1	2	00: require initial ranging adjustment 01: Initial Ranging done 10–11: *Reserved*
EIRP per subcarrier	2	8	See Table 44
CDMA Code	3	8	A unique code assigned to the CPE, to be used for the CRZ initial ranging code set.
Transmission opportunity offset	4	8	A unique transmission opportunity assigned to the CPE, to be used for the CRZ initial ranging in units of symbol duration

7.8 Management of MAC PDUs

7.8.4 Packing

7.8.4.3 ARQ Feedback IEs

Insert the following paragraph at the end of 7.8.4.3:

When operating in a relay network, ARQ Feedback message shall be processed according to the rules outlined in 7.8.7.3.

Insert the following subclauses (7.8.7 and 7.8.8 and their subclauses) after 7.8.6:

7.8.7 MAC PDU construction for relay

7.8.7.1 General

In the relay network, a centralized scheduling A-CPE will not be doing any additional fragmentation and/or packing of PDUs exchanged between the A-BS and the S-CPE. The procedures defined in 7.8.8 shall be followed by the A-BS and S-CPE when exchanging MAC PDUs in either the DS or US, through a centralized scheduling A-CPE. These procedures are applicable to connections between the S-CPE and A-BS that use ARQ and those connections that do not use ARQ.

Distributed scheduling A-CPEs have the ability to locally make decisions with regard to allocating bandwidth and scheduling resources for S-CPEs that are attached to it. Procedures defined in this clause describe how the distributed scheduling A-CPE processes MAC PDUs being exchanged through it between the A-BS and S-CPE. These procedures take into account the configuration of the security sublayer for the S-CPE, and whether or not ARQ is enabled for FIDs associated with a particular S-CPE. Indication of encryption/authentication being configured for the S-CPE is given when the EC bit in the GMH is set to 1.

7.8.7.2 MAC PDU construction for distributed scheduling A-CPE on non-ARQ connections

7.8.7.2.1 Overview

In this subclause, four procedures for the construction of MAC PDUs that may or may not require further Fragmentation/Packing on non-ARQ connections are defined as follows:

1) Security enabled, no further fragmentation/packing by A-CPE of MAC PDUs.
2) Security enabled, A-CPE will further fragment/pack MAC PDUs.
3) Security disabled, no further fragmentation/packing by A-CPE of MAC PDUs.
4) Security disabled, A-CPE will further fragment/pack MAC PDUs.

7.8.7.2.2 Procedure 1 on non-ARQ connections

The following procedure shall be used when the security sublayer for the S-CPE is configured to provide authentication/encryption of MAC PDUs exchanged between the A-BS and S-CPE and the distributed scheduling A-CPE will not further fragment/pack PDUs:

a) When a distributed scheduling A-CPE receives a MAC PDU from an S-CPE or A-BS, the subheaders attached to the PDU are processed as necessary. In the US, this may include the BR subheader and Grant management subheader (GMSH).
b) The A-CPE forwards the MAC PDU as is, i.e., it does not modify the MAC PDU contents (GMH, subheaders, payload).
c) Upon reception of the MAC PDU at the intended destination, the GMH and non-Fragmentation/ Packing subheaders are processed first:
    1) In the US: When the A-BS receives a MAC PDU that was relayed by A-CPE for an attached S-CPE with the EC bit set to 1 in the GMH and the Type field indicating the presence of the BR and/or GMSH subheaders, the BR/GMSH subheader will be ignored because those subheaders will have been processed by the A-CPE.
    2) In the DS: When the S-CPE receives a MAC PDU that was relayed by A-CPE on behalf of the A-BS with the EC bit set to 1 in the GMH, the PDU will be authenticated/decrypted.
d) A-BS/S-CPE then processes the Fragmentation/Packing subheaders (included by the S-CPE or A-BS that sent the MAC PDU) as necessary:

1) Process the fragmentation subheader before decrypting/authenticating the MAC PDU payload.
2) Decrypt/authenticate the PDU prior to processing each packed SDU.

7.8.7.2.3 Procedure 2 on non-ARQ connections

The following procedure shall be used when the security sublayer for the CPE is configured to provide authentication/encryption of the MAC PDUs exchanged between the A-BS and S-CPE and the A-CPE will further fragment/pack PDUs:

a) When a distributed scheduling A-CPE receives a MAC PDU from an S-CPE or A-BS, the subheaders attached to the PDU are processed as necessary. In the US this may include the BR subheader and/or GMSH.
b) If the A-CPE has to pack multiple PDUs coming from one or more S-CPEs in the US and transmit them to the A-BS:
    1) The A-CPE bundles those PDUs into a Container Message (see 7.7.26) and transmits the burst of MAC PDUs containing the Container Message to the A-BS.
    2) When the A-BS receives the packed PDU, it unpacks each of the S-CPE's MAC PDUs from the Container Message.
    3) Each unpacked MAC PDU will be processed as indicated in Procedure 1 on non-ARQ connections (see 7.8.7.2.2).
c) If the A-BS packs multiple PDUs destined for one or more S-CPEs in the DS:
    1) It bundles those PDUs into a Container Message (see 7.7.26) and sends it to the A-CPE.
    2) The A-CPE processes the Container Message:
        i) For each S-CPE that has >1 MAC PDUs bundled within the Container Message, the S-CPE packs each of those PDUs into one new MAC PDU with a GMH that has the EC bit set to 0 and sends it to the intended S-CPE.
        ii) For CPEs that have only one MAC PDU in the container message, the A-CPE copies it out of the Container Message and forwards it to the destination S-CPE.
    3) Each MAC PDU received at the S-CPE will be processed as indicated in Procedure 1 on non-ARQ connections (see 7.8.7.2.2).
d) If the A-CPE has to fragment a MAC PDU that it is forwarding in the US:
    1) It forms a new MAC PDU with a GMH that has the EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, and attaches a CRC.
    2) The A-CPE bundles fragments from multiple S-CPEs into a Container Message and forwards the Container Message to A-BS.
    3) When the A-BS receives the Container Message, it unpacks and stores the PDU fragment for each S-CPE indicated in the Container Message.
    4) It continues to do this until it receives all fragments from the A-CPE.
    5) Once it receives all the fragments of the S-CPE's PDU, the A-BS processes the MAC PDU and subheaders as defined in Procedure 1 for non-ARQ connections (see 7.8.7.2.2).
e) If the A-CPE has to fragment a MAC PDU that it is forwarding in the DS:
    1) It forms a new MAC PDU with a GMH that has the EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, and attaches a CRC.
    2) The A-CPE sends each S-CPE's MAC PDU fragments to the S-CPE.
    3) The S-CPE continues to receive all the fragments.
    4) Once it receives all the fragments sent by the A-CPE PDU, the S-CPE processes the MAC PDU and subheaders as defined in Procedure 1 for non-ARQ connections (see 7.8.7.2.2).

7.8.7.2.4 Procedure 3 on non-ARQ connections

The following procedure shall be used when S-CPE encryption/authentication is disabled and the A-CPE will not further fragment/pack PDUs:

a) When a distributed scheduling A-CPE receives a MAC PDU from an S-CPE or A-BS, the subheaders attached to the PDU are processed as necessary. In the US this may include the BR subheader and/or GMSH.
b) If the A-CPE receives a MAC PDU from one or more S-CPEs in the US:
    1) The A-CPE processes subheaders as necessary.
    2) After processing the subheaders, the A-CPE generates a new MAC PDU:
        i) Strip out the BR and/or GMSH subheader if present, and strip out the CRC.
        ii) Create a new MAC PDU that has a GMH with the BR/GMSH indicators in the Type field set to 0 and a packing/fragmentation subheader, and recalculate the HCS of the GMH.
        iii) Append a new CRC to the payload.
    3) The A-CPE forwards the new MAC PDU as currently defined. If transmission of PDUs from >1 S-CPEs is occurring, repeat step b) of this procedure, and bundle the MAC PDU of each S-CPE into a Container Message to forward to A-BS.
c) If the A-CPE receives a MAC PDU or Container Message in the DS it unpacks each PDU from the Container Message and forwards it to the intended S-CPE.
d) In the US, when A-BS receives the Container Message, it unpacks each S-CPE's MAC PDU from the Container Message and processes the Fragmentation/Packing subheaders that are part of the original MAC PDU originated by S-CPE.
e) In the DS, when the S-CPE receives a PDU transmission from the A-CPE, it processes the Fragmentation/Packing subheaders that are part of the original MAC PDU originated by A-BS

7.8.7.2.5 Procedure 4 on non-ARQ connections

The following procedure shall be used when S-CPE encryption/authentication is disabled and the A-CPE will further fragment/pack PDUs:

a) When a distributed scheduling A-CPE receives a MAC PDU from an S-CPE or A-BS, the subheaders attached to the PDU are processed as necessary. In the US this includes the BR subheader and/or GMSH.
b) In the US, for each S-CPE's PDU that is received at the A-CPE when packing is to be used:
    1) Each PDU is first transformed by the procedure defined in step b) of Procedure 3 for non-ARQ connections (see 7.8.7.2.4).
    2) It then forms a new MAC PDU with a GMH that has the EC bit set to 0, indicating packing subheader for each packed PDU from an S-CPE, and attaches a CRC. The A-CPE forwards the new MAC PDU as currently defined.
        i) This step is repeated for each S-CPE that has one or more PDUs that can be packed.
    3) It the bundles the new PDUs from one or more S-CPEs in a Container Message and forwards the Container Message to A-BS.
    4) When the A-BS receives the Container Message, it unpacks each S-CPEs burst and processes it according to step d) of Procedure 3 for non-ARQ connections (see 7.8.7.2.4).
c) In the DS, when the A-CPE receives the Container Message with one or more bursts associated with a particular S-CPE:
    1) Each PDU associated with a particular S-CPE is first transformed by the procedure defined in steps b)1) and b)2) of Procedure 3 for non-ARQ connections (see 7.8.7.2.4).

  2) A-CPE then forms a new MAC PDU with a GMH that has the EC bit set to 0, indicating packing subheader for each packed PDU from an S-CPE, and attaches a CRC. The A-CPE forwards the new MAC PDU to the S-CPE.

d) If the A-CPE has to fragment a MAC PDU that it is forwarding in the US:
  1) It forms a new MAC PDU with a GMH that has the EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, and attaches a CRC.
  2) The A-CPE bundles fragments from multiple S-CPEs into a Container Message and forwards the Container Message to A-BS.
  3) When the A-BS receives the Container Message, it unpacks and stores the PDU fragment for each S-CPE indicated in the Container Message.
  4) It continues to do this until it receives all fragments from the A-CPE.
  5) Once it receives all the fragments of the S-CPE's PDU, A-BS processes the MAC PDU and subheaders of the constituted/complete MAC PDU originated by the S-CPE associated with the burst in the Container Message.

e) If the A-CPE has to fragment a MAC PDU that it is forwarding in the DS:
  1) It forms a new MAC PDU with a GMH that has the EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, and attaches a CRC.
  2) The A-CPE sends each S-CPE's MAC PDU fragments to the S-CPE.
  3) The S-CPE continues to receive all the fragments.
  4) Once it receives all the fragments sent by the A-CPE PDU, the S-CPE processes the MAC PDU and subheaders as defined in step e) of Procedure 3 for non-ARQ connections (see 7.8.7.2.4).

7.8.7.3 MAC PDU construction for distributed scheduling A-CPE on ARQ connections

7.8.7.3.1 Overview

Procedures 1 to 4 outlined in 7.8.7.2 are applicable to the exchange of MAC PDUs on ARQ connections between the A-BS and S-CPEs through a distributed scheduling A-CPE, as defined by the conditions in this subclause.

7.8.7.3.2 Procedure 1 for ARQ connections

The following procedure shall be used when the security sublayer for the S-CPE is configured to provide authentication/encryption of MAC PDUs exchanged between the A-BS and S-CPE and the distributed scheduling A-CPE will not further fragment/pack PDUs:

a) In the US and DS the ARQ Feedback subheader can be attached to MAC PDUs.

b) Follow Procedure 1 for non-ARQ connections (see 7.8.7.2.2) using the adjustments for ARQ connections in the US and DS as listed in steps c) and d) of this procedure.

c) In the US:
  1) If end-to-end ARQ is used:
    i) The A-CPE ignores the ARQ feedback subheader (attached to MAC PDU received from S-CPE) and forwards the MAC PDU to the A-BS as is (i.e., forwarding the MAC PDU without altering the GMH, the ARQ Feedback IE, or the contents).
    ii) When the A-BS receives the MAC PDU, it processes the ARQ Feedback IE attached to the MAC PDU.
  2) If two-link ARQ is used:
    i) The A-CPE processes the ARQ feedback subheader (attached to MAC PDU received from the S-CPE).

ii) The A-CPE then wraps the MAC PDU (i.e., without altering the GMH, the ARQ Feedback IE, or the payload) in a new MAC PDU and attaches an ARQ Feedback IE to represent the ARQ process on the A-CPE/A-BS link.

iii) The A-CPE then forwards the MAC PDU to the A-BS.

iv) When the A-BS receives the MAC PDU, it first processes the outer MAC PDU and ARQ Feedback IE, but ignores the ARQ Feedback IE attached to the original MAC PDU

d) In the DS:

1) If end-to-end ARQ is used:

i) The A-CPE ignores the ARQ feedback subheader (attached to MAC PDU received from A-BS) and forwards the MAC PDU to the S-CPE as is (i.e., forwarding the MAC PDU without altering the GMH, the ARQ Feedback IE, or the payload).

ii) When the S-CPE receives the MAC PDU, it processes the ARQ Feedback IE attached to the MAC PDU.

2) If two-link ARQ is used:

i) The A-CPE processes the ARQ feedback subheader (attached to MAC PDU received from the A-BS).

ii) The A-CPE then wraps the MAC PDU (i.e., without altering the GMH, the ARQ Feedback IE, or the payload) in a new MAC PDU and attaches an ARQ Feedback IE to represent the ARQ process on the A-CPE/S-CPE link.

iii) The A-CPE then forwards the MAC PDU to the S-CPE.

iv) When the S-CPE receives the MAC PDU, it first processes the outer MAC PDU and ARQ Feedback IE, but ignores the ARQ Feedback IE attached to the original MAC PDU.

7.8.7.3.3 Procedure 2 for ARQ connections

The following procedure shall be used when the security sublayer for the CPE is configured to provide authentication/encryption of the MAC PDUs exchanged between the A-BS and S-CPE and the A-CPE will further fragment/pack PDUs:

a) In the US and DS the ARQ Feedback subheader can be attached to MAC PDUs.

b) Follow Procedure 2 for non-ARQ connections (see 7.8.7.2.3) using the adjustments for ARQ connections in the US and DS as listed in steps c) and d) of this procedure.

c) In the US:

1) If the A-CPE must pack multiple MAC PDUs when end-to-end ARQ is used:

i) The A-CPE ignores the ARQ feedback subheader (attached to MAC PDU received from S-CPE).

ii) It then bundles the MAC PDUs as is (i.e., forwarding the MAC PDU without altering the GMH, the ARQ Feedback IE, or the contents) from one or more S-CPEs into a Container Message.

iii) The A-CPE forwards the Container Message to the A-BS.

iv) When the A-BS receives the Container Message, it unbundles each S-CPE's MAC PDU and processes the ARQ Feedback IE attached to each MAC PDU.

2) If the A-CPE must pack multiple MAC PDUs when two-link ARQ is used:

i) The A-CPE processes the ARQ feedback header attached to a MAC PDU received from each S-CPE.

ii) It then bundles the MAC PDUs as is (i.e., without altering the GMH, the ARQ Feedback IE, or the payload) from one or more S-CPEs into a Container Message. The MAC PDU that encapsulates the Container Message shall have a ARQ Feedback IE added to it to indicate the ARQ process for the A-BS/A-CPE link.

iii) Successful delivery of the MAC PDU that encapsulates the Container Message depends on the ARQ process on the A-BS/A-CPE link. When the A-BS receives the Container Message, it processes the ARQ Feedback IE attached to the Container Message.

iv) The A-BS processes the Container Message and unbundles each S-CPEs MAC PDU.

v) For each received S-CPE MAC PDU, the A-BS ignores the ARQ Feedback IE attached to the original MAC PDU.

3) If the A-CPE must fragment MAC PDUs when end-to-end ARQ is used:

i) The A-CPE ignores the ARQ Feedback IE attached to MAC PDU by the S-CPE.

ii) If fragmentation is necessary, the A-CPE forms a new MAC PDU with a GMH that has the EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, and attaches a CRC. When creating the fragments, it will not alter the contents (e.g., GMH, subheaders, payload) of the original MAC PDU.

iii) The A-CPE bundles fragments from multiple S-CPEs into a Container Message and forwards the Container Message to A-BS.

iv) When the A-BS receives the Container Message, it unpacks and stores the PDU fragment for each S-CPE indicated in the Container Message.

v) It continues to do this until it receives all fragments from the A-CPE.

vi) Once it receives all the fragments of the S-CPE's PDU, A-BS processes the MAC PDU and the ARQ Feedback subheader of the original MAC PDU.

4) If the A-CPE must fragment MAC PDUs when two-link ARQ is used:

i) The A-CPE processes the ARQ Feedback IE attached to MAC PDU by the S-CPE.

ii) If necessary, the A-CPE forms a new MAC PDU with a GMH that has the EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, and attaches a CRC. When doing this, it will not alter the original contents (e.g., GMH, subheaders, payload) of the MAC PDU.

iii) It then bundles the MAC PDU fragments from one or more S-CPEs into a Container Message. The MAC PDU that encapsulates the Container Message shall have an ARQ Feedback IE added to it to indicate the ARQ process for the A-BS/A-CPE link.

iv) Successful delivery of the MAC PDU that encapsulates the Container Message depends on the ARQ process on the A-BS/A-CPE link.

v) When the A-BS receives the Container Message, it first processes the ARQ Feedback IE attached to the MAC PDU encapsulating the Container Message and then unpacks and stores the PDU fragment for each S-CPE indicated in the Container Message.

vi) It continues to do this until it receives all fragments from the A-CPE.

vii) Once A-BS receives all the fragments of the S-CPE's PDU, the A-BS processes the MAC PDU, and the A-BS shall ignore the ARQ Feedback subheader of the original MAC PDU that it reassembles for each S-CPE.

d) In the DS:

1) If the A-BS must pack multiple MAC PDUs destined for one or more S-CPEs in the DS when end-to-end ARQ is used:

i) The A-BS bundles packed PDUs for each S-CPE into its own MAC PDU and adds the ARQ feedback subheader.

ii) The A-BS inserts the generated MAC PDUs into a Container Message and sends it to the A-CPE.

iii) The A-CPE receives the Container Message and processes it by unbundling each PDU destined for the S-CPE and forwarding the PDU to the S-CPE as is (i.e., the A-CPE shall ignore the ARQ Feedback IE). This step is repeated until all PDUs in Container Message have been forwarded.

iv) When the S-CPE receives the MAC PDU, it processes the attached ARQ feedback subheader.

2) If the A-BS must pack multiple MAC PDUs destined for one or more S-CPEs in the DS when two-link ARQ is used:

i) The A-BS bundles packed PDUs for each S-CPE into its own MAC PDU.

ii) The A-BS inserts the generated MAC PDUs into a Container Message and sends it to the A-CPE. The MAC PDU that encapsulates the Container Message shall have a ARQ Feedback IE added to it to indicate the ARQ process for the A-BS/A-CPE link.

iii) Successful delivery of the MAC PDU that encapsulates the Container Message depends on the ARQ process on the A-BS/A-CPE link. When receiving the Container Message, the A-CPE first processes the ARQ Feedback IE attached to MAC PDU that encapsulates the Container Message.

iv) The A-CPE receives the Container Message and processes it by unbundling each PDU destined for the S-CPE and encapsulating the unbundled PDU in a new MAC PDU (with the EC bit set to 0 in the GMH) with an ARQ feedback subheader (this represents the ARQ process on the S-CPE/A-CPE link). This step is repeated until all PDUs in Container Message have been forwarded.

v) When S-CPE receives the MAC PDU, it shall process the attached ARQ feedback subheader as defined and then unbundle the original (packed) PDU.

vi) The ARQ Feedback IE attached to the original (packed) PDU shall be ignored by the S-CPE.

3) If the A-BS has PDUs to send to S-CPEs attached to an A-CPE and the A-CPE must fragment MAC PDUs when end-to-end ARQ is used:

i) The A-BS creates the MAC PDU and adds the ARQ feedback subheader.

ii) Then the A-BS bundles MAC PDUs for multiple S-CPEs into a Container Message and sends it to the A-CPE.

iii) The A-CPE processes each contained MAC PDU in the Container Message by unbundling the MAC PDU from the Container Message and if necessary, fragmenting the PDU by forming a new MAC PDU with a GMH that has the EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, and attaching a CRC. When this is done, the contents of the original MAC PDU will not be altered. The A-CPE then sends each fragment to the destination S-CPE.

iv) Each S-CPE collects those fragments and processes the new fragmentation subheader.

v) Once an S-CPE has collected all of the fragments and has reassembled the original MAC PDU, it processes the ARQ feedback subheader of the original MAC PDU.

4) If the A-BS has PDUs to send to S-CPEs attached to an A-CPE and the A-CPE must fragment MAC PDUs when two-link ARQ is used:

i) The A-BS shall not add an ARQ feedback subheader to the MAC PDUs it is transmitting in the DS.

ii) The A-BS creates a Container Message to bundle MAC PDUs to be transmitted to S-CPEs that are attached to an A-CPE. The MAC PDU encapsulating the Container Message shall have an ARQ feedback subheader (related to the A-BS/A-CPE ARQ process).

iii) The A-BS then sends the Container Message to the A-CPE.

iv) Successful delivery of the MAC PDU that encapsulates the Container Message depends on the ARQ process on the A-BS/A-CPE link.

v) The A-CPE processes each contained MAC PDU in the Container Message by unbundling the MAC PDU from the Container Message and if necessary, fragmenting the PDU by forming a new MAC PDU with a GMH that has the EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, and attaching a CRC. When this is done, the contents of the original MAC PDU will not be altered. Each new fragment will have the ARQ feedback subheader attached to it, before being sent to S-CPE.

vi) Each S-CPE collects those fragments and processes the new fragmentation subheader and the attached ARQ feedback subheader.

vii) Once an S-CPE has collected all of the fragments, it reassembles the original MAC PDU.

7.8.7.3.4 Procedure 3 on ARQ connections

The following procedure shall be used when S-CPE encryption/authentication is disabled and the A-CPE will not further fragment/pack PDUs:

a) In the US and DS the ARQ Feedback subheader can be attached to MAC PDUs.
b) Follow Procedure 3 for non-ARQ connections (see 7.8.7.2.4) using the adjustments for ARQ connections in the US and DS as listed in steps c) and d) of this procedure.
c) In the US:
    1) If end-to-end ARQ is used:
        i) The A-CPE ignores the ARQ feedback subheader (attached to MAC PDU received from S-CPE), but processes any other subheaders attached.
        ii) The A-CPE strips out the other subheaders, creates a new MAC PDU, copies the ARQ feedback header, and forwards the MAC PDU to the A-BS.
        iii) When the A-BS receives the MAC PDU, it processes the ARQ Feedback IE attached to the MAC PDU
    2) If two-link ARQ is used:
        i) The A-CPE processes the ARQ feedback header (attached to MAC PDU received from the S-CPE).
        ii) It processes the ARQ feedback header (as received from the S-CPE) as well as any other subheaders.
        iii) It strips out the existing subheaders and creates a new MAC PDU.
        iv) The new MAC PDU will have a new ARQ feedback subheader to indicate the ARQ process between the A-CPE and A-BS.
        v) The A-CPE then forwards the MAC PDU to the A-BS.
        vi) When the A-BS receives the MAC PDU, it processes the ARQ Feedback IE attached to the MAC PDU.
d) In the DS:
    1) If end-to-end ARQ is used:
        i) The A-CPE ignores the ARQ feedback subheader (attached to MAC PDU received from A-CPE), but processes any other subheaders attached.
        ii) The A-CPE strips out the other subheaders, creates a new MAC PDU, copies the ARQ feedback header, and forwards the MAC PDU to the A-BS.
        iii) When the S-CPE receives the MAC PDU, it processes the ARQ Feedback IE attached to the MAC PDU.
    2) If two-link ARQ is used:
        i) The A-CPE processes the ARQ feedback header (attached to MAC PDU received from the A-BS).

ii) It processes the ARQ feedback header (as received from the A-BS) as well as any other subheaders.

iii) It strips out the existing subheaders and creates a new MAC PDU.

iv) The new MAC PDU will have a new ARQ feedback subheader to indicate the ARQ process between the A-CPE and S-CPE.

v) The A-CPE then forwards the MAC PDU to the S-CPE .

vi) When the S-CPE receives the MAC PDU, it processes the ARQ Feedback IE attached to the MAC PDU.

7.8.7.3.5 Procedure 4 on ARQ connections

The following procedure shall be used when S-CPE encryption/authentication is disabled and the A-CPE will further fragment/pack PDUs:

a) In the US and DS the ARQ Feedback subheader can be attached to MAC PDUs

b) Follow Procedure 4 for non-ARQ connections (see 7.8.7.2.5) using the adjustments for ARQ connections in the US and DS as listed in steps c) and d) of this procedure.

c) In the US:

1) If the A-CPE must pack multiple MAC PDUs when end-to-end ARQ is used:

i) The A-CPE ignores the ARQ feedback subheader (attached to MAC PDU received from S-CPE).

ii) It processes any of the other subheaders and strips them out of the MAC PDU.

iii) The A-CPE then creates a new MAC PDU and adds the original ARQ Feedback IE and MAC PDU payload (without modifying them). Do this step for each S-CPE sending a MAC PDU in the US.

iv) It then bundles the MAC PDUs from one or more S-CPEs into a Container Message.

v) The A-CPE forwards the Container Message to the A-BS.

vi) When the A-BS receives the Container Message, it unbundles each S-CPE's MAC PDU and processes the ARQ Feedback IE attached to the MAC PDU.

2) If the A-CPE must pack multiple MAC PDUs when two-link ARQ is used:

i) The A-CPE processes the ARQ feedback header attached to a MAC PDU received from each S-CPE.

ii) It processes any of the other subheaders and strips them out of the MAC PDU.

iii) The A-CPE then creates a new MAC PDU and copies the original and MAC PDU payload. Do this step for each S-CPE sending a MAC PDU in the US.

iv) It then bundles the MAC PDUs into a Container Message. The MAC PDU that encapsulates the Container Message shall have a ARQ Feedback IE added to it to indicate the ARQ process for the A-BS/A-CPE link.

v) Successful delivery of the MAC PDU that encapsulates the Container Message depends on the ARQ process on the A-BS/A-CPE link.

vi) When the A-BS receives the Container Message, it first processes the ARQ Feedback IE attached to the MAC PDU that encapsulates the Container Message and then unbundles each S-CPE's MAC PDU.

3) If the A-CPE must fragment MAC PDUs when end-to-end ARQ is used:

i) The A-CPE processes the ARQ feedback header attached to a MAC PDU received from each S-CPE.

ii) It processes any of the other subheaders and strips them out of the MAC PDU.

iii) If necessary, it fragments the MAC PDU payload and forms a new MAC PDU with a GMH that has the EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, and attaches a CRC. When creating the fragments, it will not alter the contents (e.g., ARQ Feedback IE and payload) of the original MAC PDU.

iv) The A-CPE bundles fragments from multiple S-CPEs into a Container Message and forwards the Container Message to the A-BS.

v) When the A-BS receives the Container Message, it unpacks and stores the PDU fragment for each S-CPE indicated in the Container Message.

vi) It continues to do this until it receives all fragments from the A-CPE.

vii) Once it receives all the fragments of the S-CPE's PDU, A-BS processes the MAC PDU and the ARQ Feedback IE attached to the original MAC PDU.

4) If the A-CPE must fragment MAC PDUs when two-link ARQ is used:

i) The A-CPE processes the ARQ feedback header attached to a MAC PDU received from each S-CPE.

ii) It processes any of the other subheaders and strips them, as well as the ARQ Feedback IE, out of the MAC PDU.

iii) If necessary, it fragments the MAC PDU payload and forms a new MAC PDU with a GMH that has the EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, and attaches a CRC. When doing this, it will not alter the original contents (e.g., payload) of the MAC PDU.

iv) It then bundles the MAC PDU fragments from one or more S-CPEs into a Container Message. The MAC PDU that encapsulates the Container Message shall have a ARQ Feedback IE added to it to indicate the ARQ process for the A-BS/A-CPE link.

v) Successful delivery of the MAC PDU that encapsulates the Container Message depends on the ARQ process on the A-BS/A-CPE link.

vi) When the A-BS receives the Container Message, it first processes the ARQ Feedback IE attached to the MAC PDU that encapsulates the Container Message and then unpacks and stores the PDU fragment for each S-CPE indicated in the Container Message.

vii) It continues to do this until it receives all fragments from the A-CPE.

viii) Once A-BS receives all the fragments of the S-CPE's PDU, the A-BS processes the MAC PDU.

d) In the DS:

1) If the A-BS must pack multiple MAC PDUs destined for one or more S-CPEs in the DS when end-to-end ARQ is used:

i) The A-BS bundles packed PDUs for each S-CPE into its own MAC PDU and adds the ARQ feedback subheader.

ii) The A-BS inserts the generated MAC PDUs into a Container Message and sends it to the A-CPE.

iii) The A-CPE receives the Container Message and processes it by unbundling a PDU destined for the S-CPE and forwarding the PDU to the S-CPE as is (i.e., the A-CPE shall ignore the ARQ Feedback IE). This step is repeated until all PDUs in Container Message have been forwarded.

iv) When the S-CPE receives the MAC PDU, it processes the attached ARQ feedback subheader.

2) If the A-BS must pack multiple MAC PDUs destined for one or more S-CPEs in the DS whenf two-link ARQ is used:

i) The A-BS bundles packed PDUs for each S-CPE into its own MAC PDU.

ii) The A-BS inserts the generated MAC PDUs into a Container Message and sends it to the A-CPE. The MAC PDU that encapsulates the Container Message shall have a ARQ Feedback IE added to it to indicate the ARQ process for the A-BS/A-CPE link.

iii) Successful delivery of the MAC PDU that encapsulates the Container Message depends on the ARQ process on the A-BS/A-CPE link.

iv) The A-CPE receives the Container Message and processes it by unbundling a PDU destined for the S-CPE and encapsulating the unbundled PDU in a new MAC PDU (with the EC bit set to 0 in the GMH) with an ARQ feedback subheader (this represents the ARQ process on the S-CPE/A-CPE link). This step is repeated until all PDUs in Container Message have been forwarded.

v) When S-CPE receives the MAC PDU, it shall process the attached ARQ feedback subheader as defined and then unbundle the original (packed) PDU.

3) If the A-BS has PDUs to send to S-CPEs attached to an A-CPE, and the A-CPE must fragment MAC PDUs when end-to-end ARQ is used:

i) The A-BS creates the MAC PDU and adds the ARQ feedback subheader.

ii) Then the A-BS bundles MAC PDUs for multiple S-CPEs into a Container Message and sends it to the A-CPE.

iii) The A-CPE processes each contained MAC PDU in the Container Message by unbundling the MAC PDU from the Container Message and, if necessary, fragmenting the PDU by forming a new MAC PDU with a GMH that has EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, and attaching a CRC. When this is done, the contents of the original MAC PDU will not be altered. The A-CPE then sends each fragment to the destination S-CPE.

iv) Each S-CPE collects those fragments and processes the new fragmentation subheader.

v) Once an S-CPE has collected all of the fragments and has reassembled the original MAC PDU, it processes the ARQ feedback subheader of the original MAC PDU.

4) If the A-BS has PDUs to send to S-CPEs attached to an A-CPE and the A-CPE must fragment MAC PDUs when two-link ARQ is used:

i) The A-BS shall not add an ARQ feedback subheader to the MAC PDUs it is transmitting in the DS.

ii) The A-BS creates a Container Message to bundle MAC PDUs to be transmitted to S-CPEs that are attached to an A-CPE. The MAC PDU encapsulating the Container Message shall have an ARQ feedback subheader (related to the A-BS/A-CPE ARQ process).

iii) The A-BS then sends the Container Message to the A-CPE.

iv) Successful delivery of the MAC PDU that encapsulates the Container Message depends on the ARQ process on the A-BS/A-CPE link. When the A-CPE first receives the Container Message, it processes the ARQ Feedback IE attached to the MAC PDU that encapsulates the Container Message.

v) The A-CPE processes each contained MAC PDU in the Container Message by unbundling the MAC PDU from the Container Message and, if necessary, fragmenting the PDU by forming a new MAC PDU with a GMH that has the EC bit set to 0, indicating fragmentation subheader for each PDU fragment from an S-CPE, and attaching a CRC. When this is done, the contents of the original MAC PDU will not be altered. Each new fragment will have the ARQ feedback subheader attached to it before being sent to S-CPE.

vi) Each S-CPE collects those fragments and processes the new fragmentation subheader and the attached ARQ feedback subheader.

vii) Once an S-CPE has collected all of the fragments, it reassembles the original MAC PDU.

7.8.8 MAC PDU transmission for relay

7.8.8.1 Overview

MAC PDU transmission for relay is shown in 7.8.8.2 and 7.8.8.4 for US and DS through a distributed scheduling A-CPE and 7.8.8.3 and 7.8.8.5 for US and DS through a centralized scheduling A-CPE.

7.8.8.2 US through a distributed scheduling A-CPE

In the US, the distributed scheduling A-CPE would use the following method to forward bursts from S-CPEs to A-BS:

(1) Distributed scheduling A-CPE determines N = number of US-MAP IEs on distributed relay zone (DRZ)

(2) The A-CPE initializes a empty container message and set # of contained MAC PDUs == N

(3) for $i = 1$; $i \leq$ N; i++

  (4) grab SID from US-MAP IE "i"

  (5) read burst (MAC PDU) contents out of slots assigned in US-MAP IE "i"

  (6) initialize entry "i" in container message

  (7) copy SID value from step (4) into SID of position "i" in container message

  (8) copy burst (MAC PDU contents) out of slots assigned in US-MAP IE "i" into burst (MAC PDU storage) for entry "i" in container message

  (9) repeat from step (3) until all US MAP IEs have been processed

(10) Once container message is finished being constructed, the A-CPE encapsulates it in a MAC PDU and sends it on up to A-BS

(11) A-BS receives the container messages and retrieves the burst for each S-CPE contained within

Legacy CPEs shall only be serviced by distributed A-CPE in US DRZ, if US DRZ is set to PHY-OM1 (see 7.4b.3.4); otherwise, they will connect directly connect to A-BS.

7.8.8.3 US through a centralized scheduling A-CPE

In the US, the centralized scheduling A-CPE would use the following method to forward bursts from S-CPEs to A-BS:

(1) A-BS determines AZ US-MAP IE and CRZ US-MAP IE for relay US from S-CPE through the centralized scheduling A-CPE.

- AZ US-MAP IE contains SID for the centralized scheduling A-CPE and "CRZ US-MAP Index" for mapping CRZ US-MAP IE used for the connection between the centralized scheduling A-CPE and S-CPE.
- CRZ US-MAP IE contains SID for the S-CPE and "CRZ US-MAP Index" matched with CRZ US-MAP Index of AZ US-MAP IE.

(2) In all likelihood, varying channel conditions will prevent the same slots and slot indexing to be used for an S-CPE's transmission in the CRZ and A-CPE's forwarding in AZ. The purpose of the "CRZ US-MAP Index" that is matched between the AZ and CRZ US-MAP IE is to allow the A-BS and centralized A-CPE to relate a set of slots allocated in the CRZ to slots allocated in the AZ.

(3) When the centralized scheduling A-CPE receives bursts from the S-CPE assigned into CRZ US-MAP IE, the A-CPE allocates received bursts into the slot assigned in AZ US-MAP IE with the same CRZ US-MAP Index.

(4) A-BS maintains tuple of centralized A-CPE SID || S-CPE SID || "CRZ Map Index" used to create the AZ and CRZ US-MAP IEs. When the A-BS receives the burst in the AZ, it retrieves the burst for a particular S-CPE SID from the appropriate slots indicated in AZ US-MAP IE using the CRZ Map Index field.

Centralized scheduling A-CPEs shall not be used service and increase throughput for legacy CPEs in the US. Legacy CPEs cannot interpret the AZ/CRZ US-MAP IEs, only the US-MAP IE. Therefore if centralized A-CPEs are used in the A-BS cell, legacy CPEs must receive US grants using the default US-MAP IE transmitted to it directly by the A-BS.

7.8.8.4 DS through a distributed scheduling A-CPE

In the DS, the distributed scheduling A-CPE would use the following method to forward bursts from the A-BS to S-CPEs:

(1) A-BS selects A-CPE, known in this method as "Da-cpe"

(2) Using current local cell topology info, determine

- LDa-cpe = list of SIDs of S-CPEs attached through Da-cpe that MAC PDUs need to sent to
- N = how many S-CPEs attached through Da-cpe, A-BS needs to send MAC PDUs to, e.g., # of SIDs contained in LDa-cpe

(3) A-BS may initialize a empty container message and set # of contained MAC PDUs == N

(4) for $i = 1$; $i \leq N$; i++

(5) initialize entry "i" in container message

(6) form MAC PDU for SID # "i" in LDa-cpe (this includes forming GMH, setting up any sub-heads, and applying encryption if that is configured for S-CPE)

(7) copy SID value of the "i" entry in LDa-cpe into the SID of position "i" in container message

(8) copy burst (MAC PDU contents) formed in step (6) into burst (MAC PDU storage) for entry "i" in container message

(9) repeat from step (3) until all S-CPE (each identified by a SID in LDa-cpe) have been processed

(10) Once container message is finished being constructed, A-BS encapsulates it in a MAC PDU and sends it on up to the distributed scheduling A-CPE

(11) Distributed scheduling A-CPE receives a container message, for each SID+MAC PDU in the container message

(12) it would forms a DS MAP IE and maps the SID in container message entry to SID in MAP IE

(13) assigns slots to contain the burst, indicates the slot allocation in MAP IE

(14) transmits DRZ DS MAP and the burst in the assigned slots

(15) repeat from step (10) until all MAC PDUs in container message have been handled.

Legacy CPEs shall only be serviced by distributed A-CPE in DS DRZ, if DS DRZ is set to PHY-OM1 (see 7.4b.3.4); otherwise, they will connect directly connect to A-BS.

7.8.8.5 DS through a centralized scheduling A-CPE

In the DS, the centralized scheduling A-CPE would use the following method to forward bursts from the A-BS to S-CPEs:

(1) A-BS determines AZ DS-MAP IE and CRZ DS-MAP IE for relay DS to S-CPE through the centralizedscheduling A-CPE.

— AZ DS-MAP IE contains SID for the centralized scheduling A-CPE, “CRZ DS-MAP IE Index” for mapping CRZ DS-MAP IE used for the connection between the centralized scheduling A-CPE and S-CPE, and Relay Mode set to 1. Relay Mode set to 0 indicates that the destination of bursts is the centralized scheduling A-CPE.

— CRZ DS-MAP IE contains SID for the S-CPE and “CRZ DS-MAP Index” matched with CRZ DS-MAP Index of AZ DS-MAP IE.

(2) In all likelihood, varying channel conditions will prevent the same slots and slot indexing to be used for an S-CPE’s transmission in the CRZ and A-CPE’s forwarding in AZ. The purpose of the “CRZ DS-MAP Index” that is matched between the AZ and CRZ DS-MAP IE is to allow the A-BS and centralized A-CPE to relate a set of slots allocated in the CRZ to slots allocated in the AZ.

(3) When the centralized scheduling A-CPE receives bursts from the A-BS assigned into AZ DS-MAP IE, the A-CPE allocates received bursts into the slot assigned in CRZ DS-MAP IE with the same CRZ DS-MAP Index of AZ DS-MAP IE.

(4) When the S-CPE receives the burst in the CRZ it retrieves the burst using the CRZ DS-MAP IE allocation that matches it’s own SID.

Centralized A-CPEs shall not be used service and increase throughput for legacy CPEs in the DS. Legacy CPEs cannot interpret the AZ/CRZ DS-MAP IEs, only the DS-MAP IE. Therefore, if centralized A-CPEs are used in the A-BS cell, legacy CPEs must receive DS allocations using the default DS-MAP IE transmitted to it directly by the A-BS.

7.9 ARQ mechanism

7.9.6 ARQ operation

Insert the following subclause (7.9.6.4 and its subclauses and figures) after 7.9.6.3:

7.9.6.4 ARQ for a relay network

7.9.6.4.1 Overview

In A-WRAN systems, there are two ARQ modes. The first mode is an end-to-end ARQ mode that is performed between an A-BS and an S-CPE; the second mode is a two-link ARQ mode that is performed both between an A-BS and an A-CPE and between an A-CPE and an S-CPE. The support of ARQ mode is performed during the network entry. Two-link ARQ mode is limited for a distributed scheduling mode.

In the end-to-end ARQ mode, the ARQ operation is same as the operations described in 7.9.6.1, 7.9.6.2, and 7.9.6.3. An A-CPE does not have an additional ARQ functionality.

In two-link ARQ mode, the ARQ operation is divided into two links that are a relay link between A-BS and A-CPE and an access link between a distributed scheduling A-CPE and S-CPE. The detailed procedure for two-link ARQ mode is described in the 7.9.6.4.2.

7.9.6.4.2 Two-link ARQ mode

For an access link between a distributed scheduling A-CPE and S-CPE, the ARQ state machine runs between the A-CPE and the S-CPE. For relay link between A-BS and distributed scheduling A-CPE, the ARQ state machine runs between the A-BS and the A-CPE. The A-BS schedules retransmission to the A-CPE when ARQ block is corrupted in the relay link. The distributed scheduling A-CPE schedules retransmission to the S-CPE when ARQ block is corrupted in the access link.

The ARQ Feedback IE described in Table 176 is used by the A-BS and A-CPE to ACK/NAK corresponding data transmitted between A-BS and A-CPE. The ARQ Feedback IE is transported either as a packed payload ("piggybacked") within a packed MAC PDU or as a payload of a standalone MAC PDU defined in 7.6.

In downlink (DL) ARQ operation, when A-BS sends ARQ block to A-CPE, it waits for the ARQ Feedback IE from A-CPE. When ARQ block is corrupted in the relay link, the A-CPE sends NAK to A-BS, and A-BS schedules the retransmission of the corresponding ARQ block to A-CPE as shown in Figure 27a. When A-BS receives ACK from the distributed scheduling A-CPE, it waits for the ACK from the S-CPE relayed by A-CPE. A-CPE may modify the ARQ Feedback IE received from S-CPE to inform only ACK to A-BS. When A-BS receives ACK from S-CPE, it clears the buffer corresponding to ARQ block as shown in Figure 27a. When ARQ block is corrupted in the access link, A-CPE shall not send NAK to A-BS and shall schedule the retransmission of ARQ blocks to S-CPE. A-CPE shall discard the ARQ block when ARQ block transmission failed in the access link after a timeout of the ARQ_BLOCK_LIFETIME. A-BS or A-CPE discards the corresponding ARQ block after the timeout of its ARQ_BLOCK_LIFETIME. A-BS and RS ARQ_BLOCK_LIFETIME are independently operated in A-BS and A-CPE, respectively.

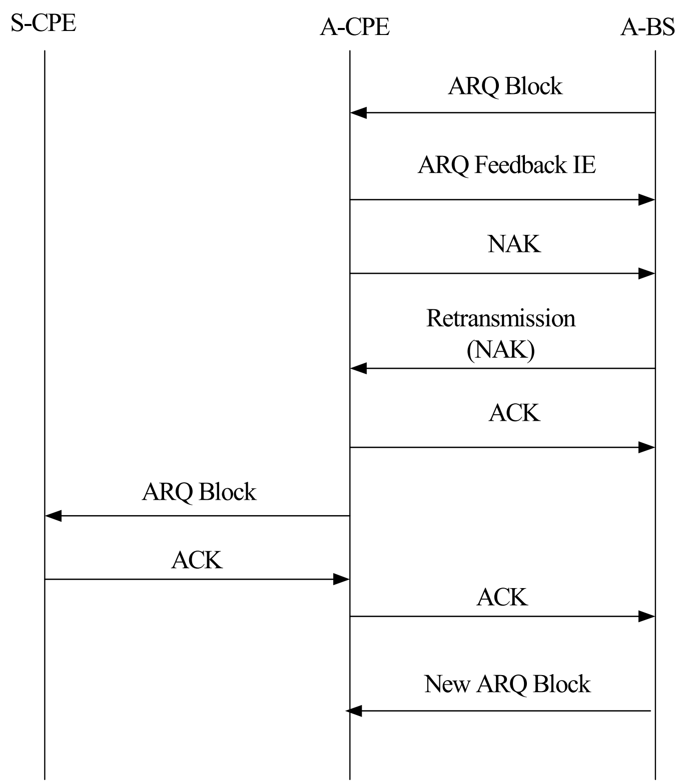


Figure 27a—Example of downlink ARQ for relay

In uplink (UL) ARQ operation, when the distributed scheduling A-CPE receives ARQ block correctly from S-CPE, A-CPE sends ARQ block to A-BS. When A-BS receives ARQ block correctly, A-BS sends ACK to A-CPE and the A-CPE sends ACK to S-CPE. When ARQ block is corrupted in the relay link, the retransmission shall be scheduled from A-CPE to A-BS. A-CPE discards the corresponding ARQ block after a timeout of ARQ_BLOCK_LIFETIME in A-CPE.

7.9.6.4.3 ARQ state machine

The ARQ state machine operation in A-CPE and receiver in A-BS is the same as described in 7.9.6.2 and 7.9.6.3. For the transmitter state machine in A-BS, an ARQ block may be in one of the following five states: not sent, outstanding for R-ACK, outstanding for S-CPE-ACK, waiting for retransmission, and data discard. Outstanding for R-ACK is the state waiting to receive ACK from A-CPE. When R-ACK is received, the state transits to outstanding for S-CPE-ACK. In this state, when the A-BS receives S-CPE-NACK or after ARQ_BLOCK LIFE_TIME, the state transits to discard. If A-BS receives S-CPE-ACK in the state of outstanding for R-ACK or waiting for retransmission, the state transits to done. Other state transition descriptions are the same as for transmitter state machine defined in 7.9.6.2. The ARQ Tx block state sequence in A-BS is shown in Figure 27b.

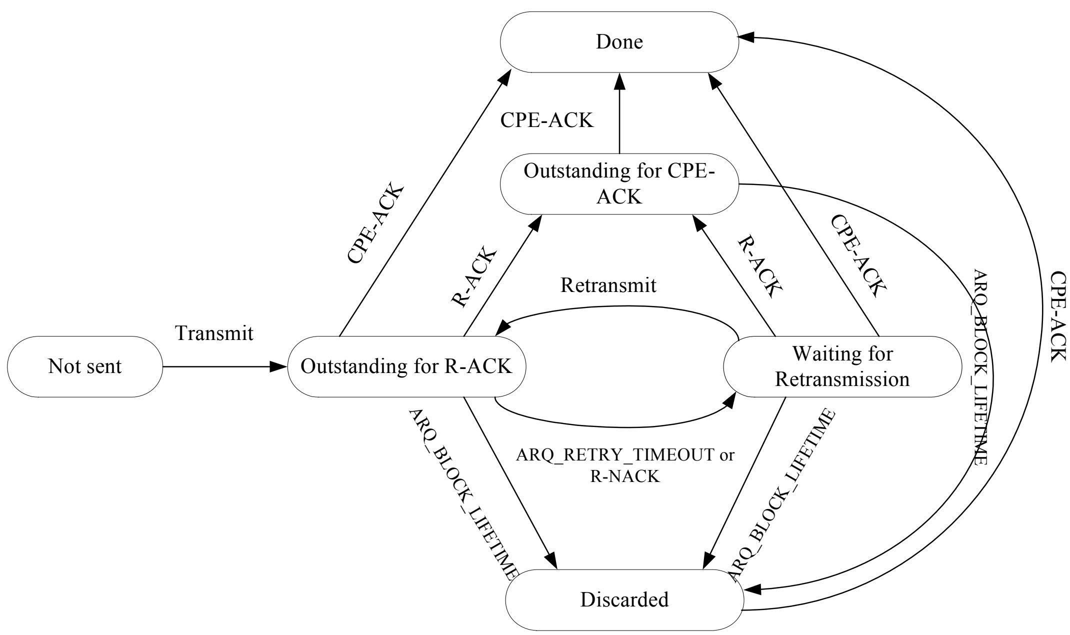


Figure 27b—ARQ Tx block state in A-BS

7.10 Scheduling services

7.10.2 Upstream request/grant scheduling

7.10.2.1 UGS

Insert the following paragraphs at the end of 7.10.2.1:

In A-WRAN systems, to meet a UGS service flow’s need, the A-BS and A-CPE along the path shall grant fixed-size bandwidth to its S-CPE on a real-time periodic basis.

The A-BS or the A-CPE may send RS scheduling information (Relay-SCHE, 7.7.28) in advance to its S-CPE to indicate when and how much bandwidth it will schedule for the service in the future.

7.10.2.2 rtPS

Insert the following paragraphs at the end of 7.10.2.2

In A-WRAN systems, to meet an rtPS service flow's need, the A-BS and A-CPE along the path shall poll its S-CPE or grant dynamic-size bandwidth to its S-CPE on a real-time periodic basis.

The A-BS or the A-CPE may send Relay scheduling information (Relay-SCHE, 7.7.28) to its S-CPE to indicate when it will schedule a poll in the future.

7.11 Bandwidth management

7.11.1 Bandwidth Requests

Insert the following subclause (7.11.1.3 and its subclauses and figure) after 7.11.1.2:

7.11.1.3 Bandwidth Request for a relay network

7.11.1.3.1 Overview

In A-WRAN systems, the bandwidth request message, mechanism, and capability defined for the CPE and A-BS shall be applicable for the A-CPE. Capability of incremental BRs is mandatory only if the A-CPE is a distributed scheduling A-CPE.

7.11.1.3.2 Bandwidth Request by a distributed scheduling A-CPE

A distributed scheduling A-CPE directly handles the bandwidth requests it receives from its S-CPEs.

A distributed scheduling A-CPE may receive bandwidth requests from its S-CPEs via the MAC signaling header, the grant management subheader, or the CDMA bandwidth request code.

To forward US traffic to A-BS, a distributed scheduling A-CPE may request uplink bandwidth via a standalone bandwidth request header. A distributed scheduling A-CPE may combine the bandwidth requests that arrive from S-CPEs together by using a Container message (7.7.26) or with the bandwidth needs of queued packets into one bandwidth request header per QoS class.

The distributed scheduling A-CPE may transmit a BW request header soon after it receives a BW request header from one of its S-CPEs (timed to yield an uplink allocation sequential to the arrival of those packets) instead of waiting for the actual packets to arrive in order to reduce delay in relaying traffic (see Figure 27c).

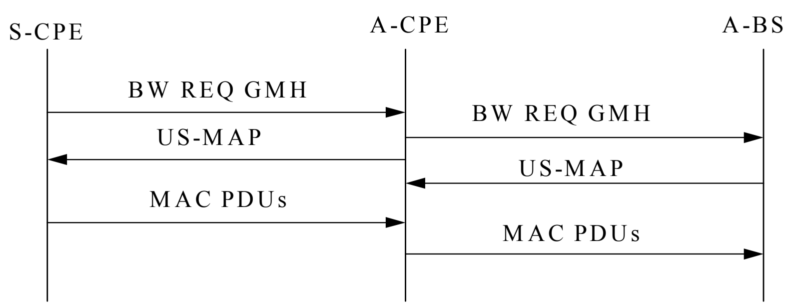


Figure 27c—Reducing latency in relaying traffic by transmitting BW request header before packets arrive

7.11.1.3.3 Bandwidth Request by a centralized scheduling A-CPE

In centralized scheduling mode, the A-BS shall determine the bandwidth allocations (i.e., MAPs) for all links in its cell. As a result, centralized scheduling A-CPEs shall receive the MAPs from the A-BS for the links to/from their CPEs before they can transmit them.

For the same reason, centralized scheduling A-CPEs shall forward all bandwidth request headers and bandwidth request CDMA ranging code information they receive from CPEs to the A-BS. The centralized scheduling A-CPEs may combine bandwidth request by using a Container message (7.7.26).

If the centralized scheduling A-CPE has available uplink bandwidth, it shall simply forward the bandwidth request information by using an Extended BW request subheader (Table 7a) to the A-BS. Otherwise, the centralized scheduling A-CPEs shall request uplink bandwidth from the A-BS using CDMA bandwidth ranging codes or Contention-based bandwidth request.

When the centralized scheduling A-CPE receives a CRZ CDMA bandwidth ranging code from an S-CPE, the Extended BR subheader contains BW request type set to 0 and the received CRZ bandwidth ranging code. Upon receiving an Extended BR subheader from a centralized scheduling A-CPE, the A-BS shall insert CDMA Allocation IEs in CRZUS-MAP IE for which the CPE performs bandwidth request to the centralized scheduling A-CPE.

When the centralized scheduling A-CPE receives a bandwidth request subheader from an S-CPE, the Extended BR subheader contains BW request type set to 1, SID of the S-CPE, Type, and BR. Upon receiving an Extended BR subheader from a centralized scheduling A-CPE, the A-BS shall insert the allocated bandwidth information in CRZUS-MAP IE for which the S-CPE performs US in US CRZ.

7.11.2 Grants

Insert the following subclause (7.11.2.1 and its subclauses and figure) after 7.11.2:

7.11.2.1 Grants for a relay network

7.11.2.1.1 Bandwidth grant for relay with a distributed scheduling A-CPE

If the bandwidth request comes from a distributed scheduling A-CPE, the A-BS shall address the bandwidth grant to the A-CPE's Basic FID. The distributed scheduling A-CPE may schedule a MAC PDU or relay MAC PDU on the bandwidth allocation it receives.

An A-BS may send its distributed scheduling A-CPEs uplink scheduling information ahead of time via an Relay-SCHE management message. This message indicates when a given uplink bandwidth allocation will be granted to the distributed scheduling A-CPE (i.e., in how many frames), the size of the allocation, and the intended CID. The actual bandwidth grant is issued to the distributed scheduling A-CPE using a Data Grant IE in an upcoming US-MAP. For periodic bandwidth grants, the scheduling information need only be sent once (see Figure 27d).

When a distributed scheduling A-CPE receives an Relay-SCHE management message with uplink scheduling information from the A-BS, it shall look up the target CPE of the given FID. Based on this scheduling information and the target CPE of the FID, the distributed scheduling A-CPE can determine the appropriate bandwidth allocations and associated RS UL allocation frame offset on the uplink it controls.

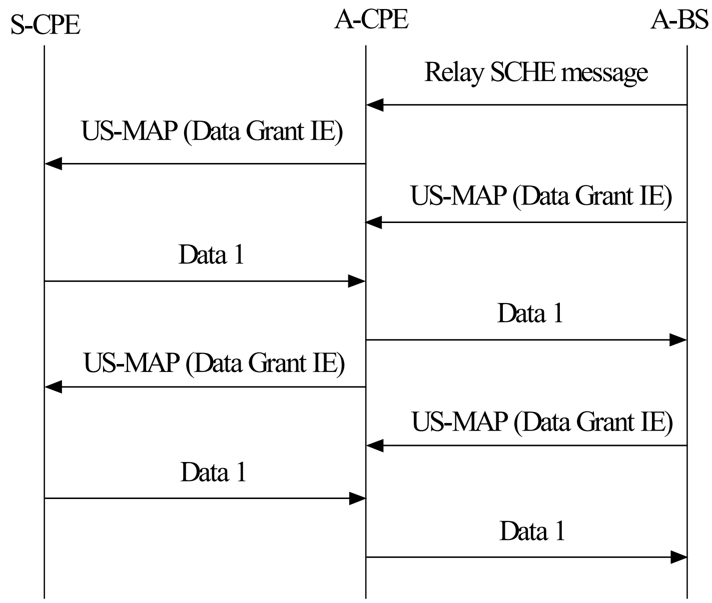


Figure 27d—Periodic bandwidth grant with A-CPE scheduling information

7.11.2.1.2 Bandwidth grant for relay with a centralized scheduling A-CPE

For centralized scheduling, when an A-BS allocates bandwidth to forward a packet to/from a given station, it shall allocate bandwidth on all links (relay and access) that make up the path to/from that station taking into account the processing delay and link qualities at each A-CPE.

7.11.3 Polling

Insert the following subclause (7.11.3.4 and its figures) after 7.11.3.3:

7.11.3.4 Polling for a relay network

The polling procedure defined in 7.11.3 for the CPE and the A-BS may be used between the CPE/A-CPE. If an A-CPE is regularly polled, it can transmit a bandwidth request header to the A-BS as soon as it detects impending uplink traffic in order to reduce delay (see Figure 29a).

An A-BS or a distributed scheduling A-CPE may inform a CPE of upcoming polling via an Relay SCHE management message (see Figure 29b).

For centralized scheduling, only the A-BS may establish a polling process with a CPE or centralized scheduling A-CPE in the MR-cell.

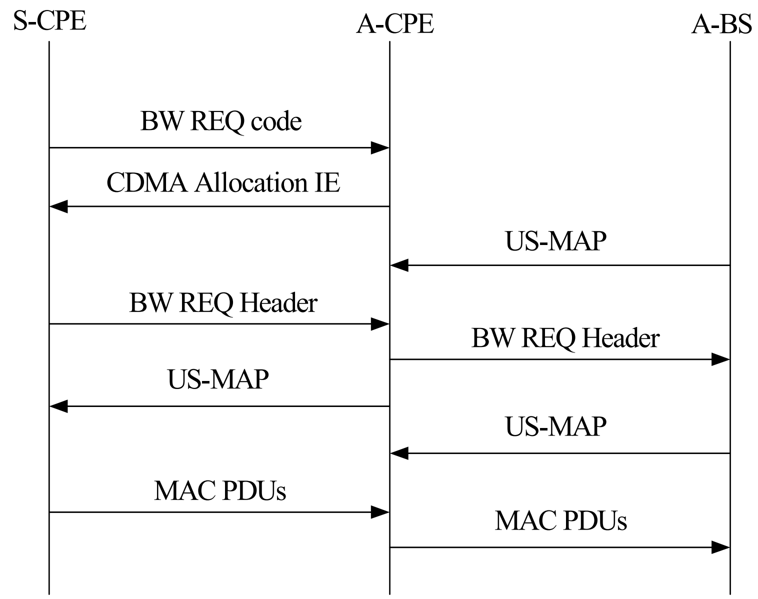


Figure 29a—Reducing latency in relaying traffic via A-CPE polling

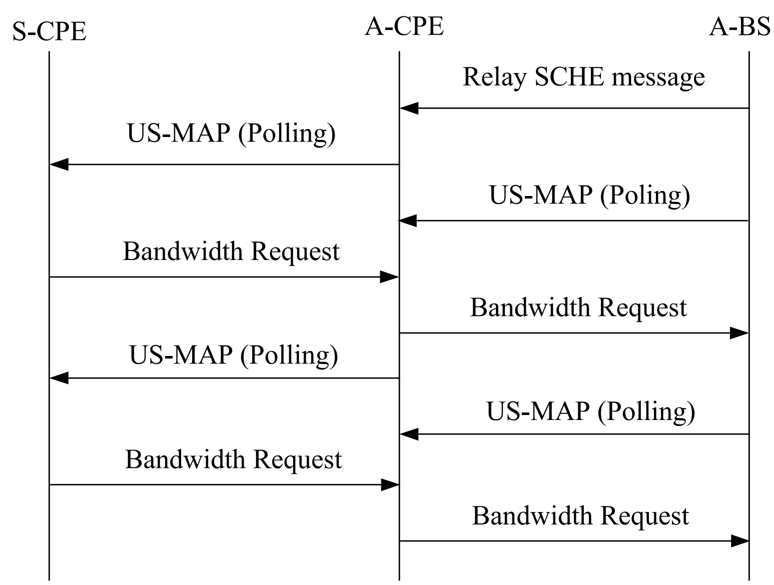


Figure 29b—Periodic polling with A-CPE scheduling information

7.13 Contention resolution

Change the first four paragraphs of the preliminary text of 7.13 as follows:

The BS, A-BS, or distributed scheduling A-CPE controls assignments on the upstream channel through the US-MAP messages and determines which symbol periods are subject to collisions. Collisions may occur during Initial Ranging/Relay Initial Ranging/Local Initial Ranging, Periodic Ranging/Relay Periodic Ranging/Local Periodic Ranging, Bandwidth Request/Relay Bandwidth Request/Local Bandwidth Request, UCS notification/Relay UCS notification/Local UCS notification, and the SCW defined by their respective IEs. The potential occurrence of collisions in the Intervals is dependent upon the number of SIDs whose US-MAP IEs are (simultaneously configures to use an Interval for a specific purpose (e.g., Ranging, UCS notification, BW Request). The CPE has to make a decision in order to resolve collision in the upstream direction for Initial Ranging/Relay Initial Ranging/Local Initial Ranging, Periodic Ranging/Relay Periodic Ranging/Local Periodic Ranging, and BW Request/Relay Bandwidth Request/Local Bandwidth Request. Since in the case of UCS notification/Relay UCS notification/Local UCS notification and SCW (CBP packet transmission in the SCW) no explicit feedback is expected to be received from the BS, A-BS, or distributed scheduling A-CPE, collision resolution does not apply.

In the case of Initial Ranging/Relay Initial Ranging/Local Initial Ranging and Periodic Ranging/Relay Periodic Ranging/Local Periodic Ranging, collision resolution is to be done by a CDMA method (see Table 31 and Table 37). In the case of Bandwidth Request/Relay Bandwidth Request/Local Bandwidth Request and UCS notification/Relay UCS notification/Local UCS notification, both those methods, CDMA as well as exponential time backoff, explained later in this subclause, can be used. In the case of collision resolution in the SCW, a special scheduling scheme, described in 7.20.1.2, shall be used.

Since a CPE may need to service multiple upstream service flows (each with its own FID), it makes these decisions on a per FID or on a QoS (see 7.17) basis. The method of contention resolution that shall be supported for BW Request/Relay Bandwidth Request/Local Bandwidth Request and UCS notification/Relay UCS notification/Local UCS notification is based on a truncated binary exponential backoff, with the initial backoff window and the maximum backoff window controlled by the BS, A-BS, or distributed scheduling A-CPE (see Table 30). The values, expressed in units of opportunity (see Table 31) are specified as part of the UCD message and represent a power-of-two value. For example, a value of 4 indicates a window between 0 and 15 opportunities; a value of 10 indicates a window between 0 and 1023 opportunities. When a CPE has information to send and wants to enter the contention resolution process, it sets its internal backoff window equal to the BW Request/Relay Bandwidth Request/Local Bandwidth Request or UCS Notification/Relay UCS notification/Local UCS notification Backoff Start defined in the UCD message referenced by the UCD Count in the US-MAP message currently in effect (the map currently in effect is the map whose allocation start time has occurred but which includes IEs that have not occurred).

Note that the number of these opportunities per frame depends on the size of the opportunity window in number of subchannels defined by the US-MAP for UIUC 2 or 3 (see Table 35) and the opportunity size for the BW Request/Relay Bandwidth Request/Local Bandwidth Request and UCS notification/Relay UCS notification/Local UCS notification defined in Table 31. These opportunities shall be mapped horizontally in the time domain and fill a subchannel before moving to the next subchannel as is done for the upstream data PDU mapping.

7.13.1 Transmission opportunities

Change the first paragraph of 7.13.1 as follows:

A transmission opportunity is defined as an allocation provided in a US-MAP or part thereof intended for a group of CPEs authorized to transmit initial ranging requests/relay initial ranging requests/local initial ranging requests, periodic ranging requests/relay periodic ranging requests/local periodic ranging requests, bandwidth requests/relay bandwidth requests/local bandwidth requests, or UCS notifications/relay UCS notifications/local UCS notifications. This group may include either all CPEs that have an intention to join the cell or all registered CPEs or a multicast polling group. The number of transmission opportunities associated with a particular IE in a map is dependent on the total size of the allocation as well as the size of an individual transmission.

7.14 Initialization and network association

Insert the following subclauses (7.14.3 and 7.14.4 and their subclauses and figures) after 7.14.2.17:

7.14.3 A-BS initialization

7.14.3.1 General

The A-WRAN A-BS initialization procedure shall consist of the following steps:

a) A-BS is professionally installed.
b) A-BS acquires the antenna gain information
c) Determine the A-BS geographic location.
d) If a database service exists for A-BS area of service, Spectrum Manager at the A-BS receives an initial list of available channels from the database service. If there is no database service, Spectrum Manager initially considers all channels available.
e) Operator disallows channels on the available channel list as needed.
f) Perform incumbent detection in all usable channels and synchronize network to neighboring A-BSs.
g) Present the available channel list to the higher layers for selection of an operating channel or operating channels.
h) Commence single channel operation or multi-channel operation on the selected operating channel(s).

This A-BS initialization procedure is depicted in Figure 49a.

7.14.3.2 Professional installation

The A-BS shall be installed by a professional who will be responsible for assuring that its installation is compliant with local regulations (see Annex A) and the IEEE Std 802.22.2-2012. The professional installer should make sure that the antenna pattern meets the pattern specified in 9.12.1 and that the antenna is directed toward the selected A-BS.

7.14.3.3 A-BS antenna gain information acquisition

The A-BS shall determine if its antenna is integrated or not by querying it using the M-ANTENNA-INTEGRATED primitive structure described in 10.7.6.1and 10.7.6.2. The A-BS shall acquire the antenna information including the maximum antenna gain information for the channels that can be used in the regulatory domain of interest. This information is stored in a MIB, wranIfBsCpeAntennaGainTable. If the antenna is integrated to the A-BS TRU, this MIB object shall be pre-populated by the manufacturer of the A-BS. If the antenna is not integrated into the A-BS TRU, the MIB object shall be populated by querying the antenna unit (AU) through the interface defined in 9.12.2. This information at the antenna shall be pre-populated by the antenna manufacturer.

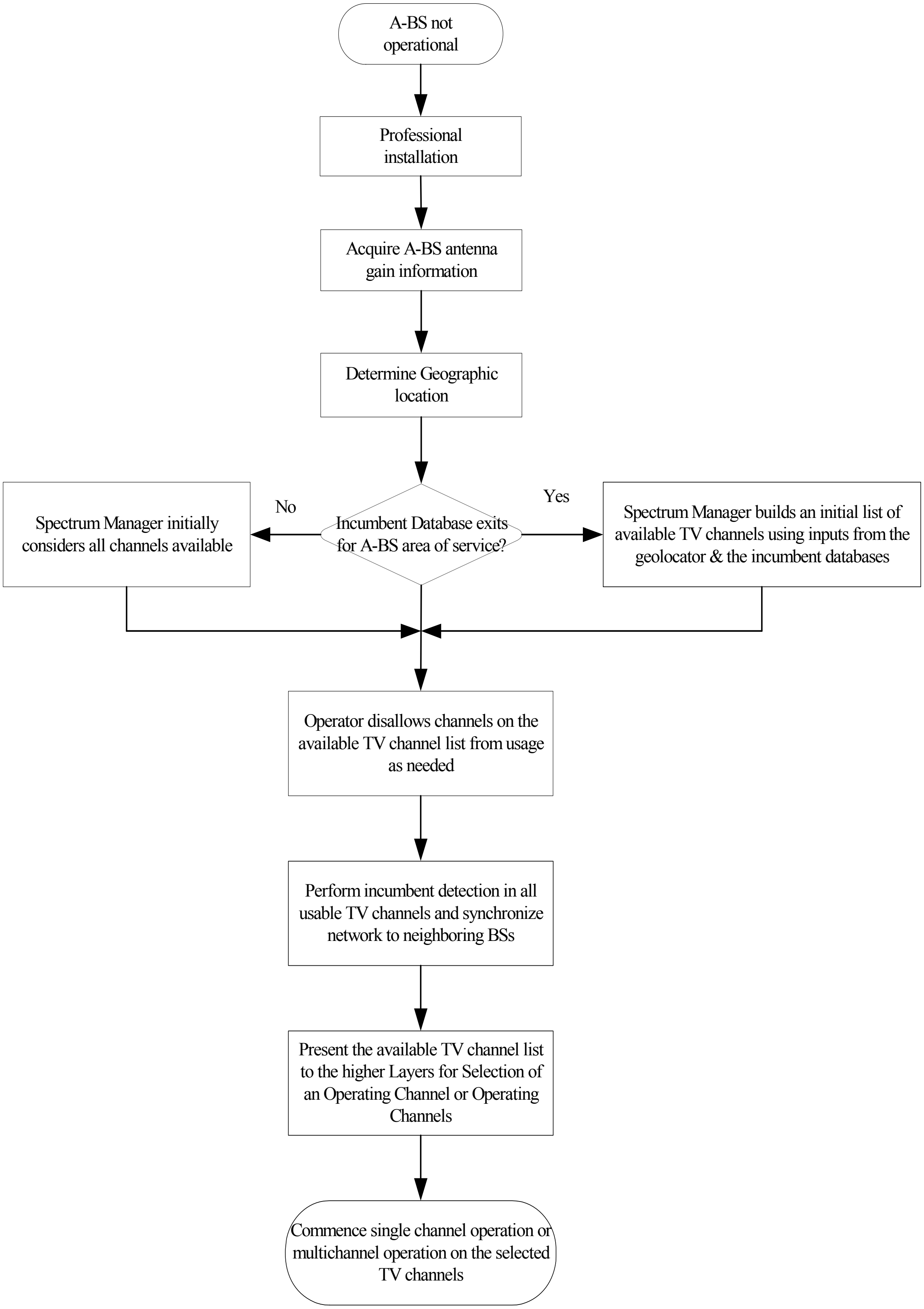


Figure 49a—A-BS initialization procedure

7.14.3.4 Determine geographic location

The geolocation requirement for the A-BS is that the WRAN system shall know the latitude and longitude of the A-BS transmitting antenna within a radius of 15 m and its altitude above mean sea level. The A-BS geographic location information shall be stored in the A-BS memory.

7.14.3.5 Access TV bands database service and receive list of available channels

The A-BS shall access a TV bands database service if one exists.

The A-BS SM communicates with the TV bands database service using the primitives that are defined in 10.7.1. Each WRAN device shall enlist with the TV bands database service by providing information that is required for access to the TV bands. The A-BS SM, which shall act as a proxy for all of its registered client devices, shall perform enlistment using the M-DEVICE-ENLISTMENT primitives. Each instance that a device is required to get a new set of available channels, the A-BS SM shall provide its geographic coordinates or those of one of its registered client devices to the TV bands database service using the MDB-AVAILABLE-CHANNEL-REQUEST primitive. The A-BS shall receive the available channels from the TV bands database service using the M-DB-AVAILABLE-CHANNEL-INDICATION primitive. The SM shall generate the composite available channel list using only those channels that have been indicated as available for every device on the network.

The A-BS shall prohibit WRAN operation on any channel not on this initial list of available channels.

7.14.3.6 Operator disallows channels

Access shall be provided for the operator to disallow channels that are listed on the available channel list from being selected for WRAN operation. The operator shall not have access to channels that are not listed on the available channel list. To further classify channels on the available list, the A-BS SM shall submit an M-AVAIL-TV-CH-REPORT primitive with the mode set equal to 1 to provide the available channel list to the higher layers. Once channels on the available channel list are further classified as disallowed, the SM shall receive an M-DISALLOWED-TV-CHS primitive submitted by the SM.

7.14.3.7 Perform incumbent detection and synchronize network with neighboring networks

The A-BS shall perform incumbent detection in each of the channels listed on the available channel list and each adjacent channel if its EIRP is beyond the limit specified by the regulatory domain classes in Annex A (e.g., 40 mW in the USA) to detect other legitimate incumbent services that do not exist in the database service. The A-BS's SM shall use the output from the A-BS spectrum sensing function to identify occupied channels on the available channel list.

The A-BS shall perform neighboring IEEE 802.22 network discovery on selected channels according to 7.20.1.3. The A-BS shall synchronize with neighboring A-BSs using its installed satellite-based geolocation technology.

7.14.3.8 Present the available channel list to the higher layers

After incumbent detection during which channels may have been identified as protected or occupied, the resulting list shall be presented to the higher layers using an M-AVAIL-TV-CH-REPORT primitive with the mode set equal to 2 for selection of an operating channel or using an M-AVAIL-TV-CH-REPORT primitive with the mode set equal to 3 for selection of operating channels. The required information presented shall be each channel number that is available for the A-BS to commence WRAN service and the maximum allowed EIRP for each channel. Additional information can be provided to the higher layers to help with the selection of an optimal channel or optimal channels, such as a list of channels where other wireless services were detected during the incumbent detection stage. As a result of the selection from the higher layer, the SM shall receive an M-OPERATING-TV-CH or M-OPERATING-TV-CHS primitive from the NCMS.

7.14.3.9 Commence single channel operation or multi-channel operation

The A-BS may now commence single channel operation on any one channel listed on the available channel list or multi-channel operation on any channel listed on the available channel list.

7.14.4 CPE initialization for relay

7.14.4.1 General

Figure 49b illustrates an A-WRAN scenario where the need for the definition of an incumbent safe CPE initialization can be easily seen.

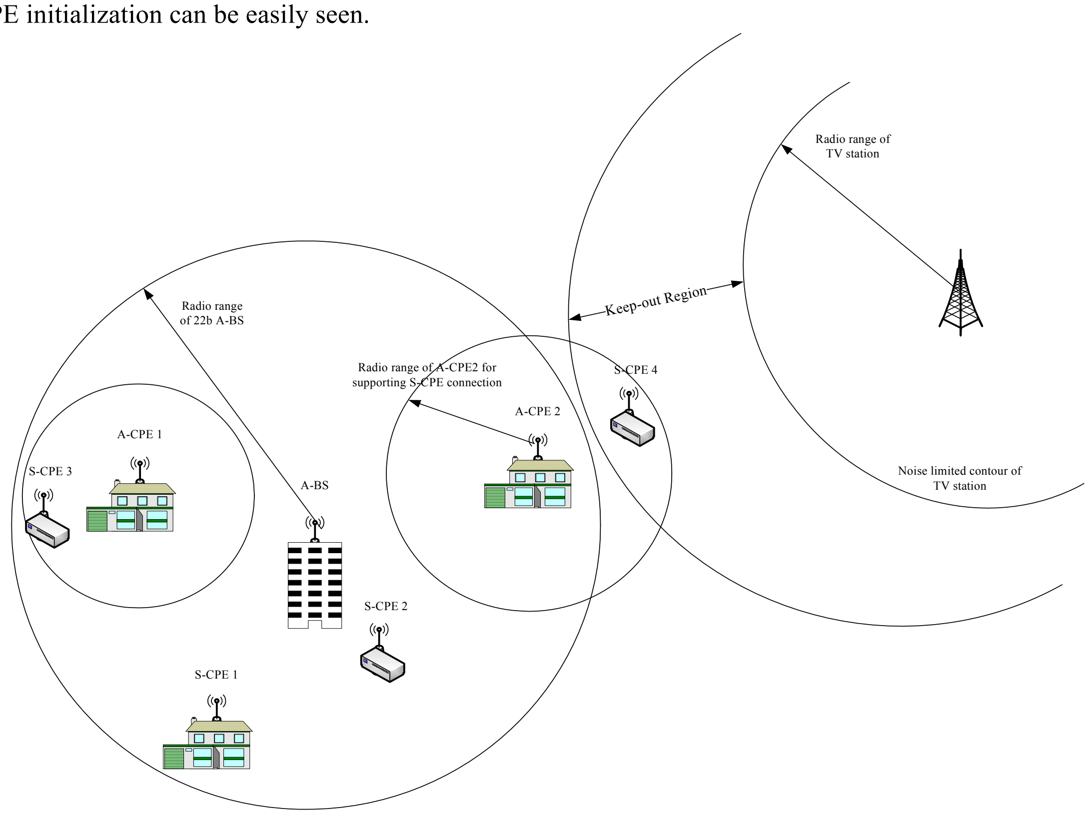


Figure 49b—A-WRAN scenario where a safe bootstrap operation is required to protect incumbents

In this figure, consider that S-CPE 4, which is located outside of an A-BS's cell but located within a distributed scheduling A-CPE 2's local cell, is powered down whereas the A-BS is transmitting in the cell and A-CPE 2 being a member of the A-BS is transmitting in the local cell that is under normal operation. Further, assume that the TV station in Figure 49b is powered up and starts transmitting in the same channel (i.e., channel #N in this example) that is being used by the A-BS and A-CPE 2 for their transmissions in the cell. S-CPE 4 should be capable of detecting that A-CPE 2 is operating in a channel that is occupied by an incumbent service. The A-BS must be capable of determining if S-CPE 4 is located within interference range of the TV station protected contour (i.e., in the keep-out region). If S-CPE 4 is already registered with the network managed by A-CPE 2, it will alert A-CPE 2. If S-CPE 4 is not registered with the network, it shall not transmit. See 10.2.5, policies 5 and 6. In response to the alert from S-CPE 4, the SM at A-CPE 2 attempts to detect the TV station and shall notify the A-BS when it detects the station. In response to the notification from A-CPE 2, the SM at the A-BS may or may not decide to switch channels to accommodate the connected CPEs (see 10.2.6.6). The purpose of the sensing and geolocation capabilities of the WRAN system shall be to prevent harmful interference to the primary TV service by providing the necessary information to the A-BS's SM that generates the list of available channels. The definition of an incumbent safe CPE initialization phase is critical for cognitive radio systems. The SM incorporates algorithms to address this need (see Table 234, policies 5 and 6).

First and foremost, the MAC does not presuppose any preassigned channel where a CPE is able to look for an A-BS or a distributed scheduling A-CPE given the time-varying and unpredictable nature of channel occupancy. Hence, the first task a CPE must perform in attempting to join a network is to scan the set of channels for A-BSs or A-CPEs and incumbent services with which the transmissions of the CPE might interfere. Since the A-BS shall send concentrated OFDM symbols composed of a frame preamble and SCH once every superframe in PHY-OM1, or a frame preamble and an FCH once every frame in PHY-OM2 in its operating channel, and the distributed scheduling A-CPE shall send concentrated OFDM symbols composed of a local frame preamble and a DRZ-FCH in the DS DRZ subframe within a frame, if available, in its operating channel (see 7.3), the CPE will recognize the existence of an A-BS or a distributed scheduling A-CPE transmission and, if appropriate, proceed with the CPE initialization procedure with the corresponding A-BS or distributed scheduling A-CPE. Although a CPE will recognize the existence of an A-BS, in particular, the CPE may not be initialized with the A-BS directly since the transmission of the CPE is not able to reach the A-BS due to the power constraint. In this case, the CPE will make an initialization by relaying on a centralized scheduling A-CPE.

The procedure carried out by the A-BS, the centralized scheduling A-CPE, the distributed scheduling A-CPE, and the CPE to perform CPE network entry and initialization shall be as follows:

a) CPE performs self test.
b) CPE acquires the antenna gain information.
c) CPE senses for and synchronizes to A-WRAN services. The sensing thread also begins during this step to detect broadcasting incumbents.
d) CPE presents sensing results to the higher layers.
e) CPE chooses an A-WRAN service for single channel operation or for multi-channel operation.
f) If CPE is capable of geolocation, CPE acquires valid geolocation data from the satellites. If the data acquisition is unsuccessful, CPE initialization should not continue or may continue to operate as an S-CPE mode. If CPE is not capable of geolocation, CPE initialization should not continue or may continue to operate as an S-CPE mode.
g) CPE acquires the DS and US parameters from the selected A-WRAN service.
h) CPE directional antenna azimuth adjustment.
i) If channels N and N±1 pass the sensing and timing requirements, CPE performs initial ranging (see 7.15.2.3).
j) CPE transmits basic capabilities.
k) If all required basic capabilities are present in the CPE, the AAA authenticates the CPE and key exchange is performed; otherwise, the CPE does not proceed to registration and the A-BS de-registers the CPE.
l) Perform Registration (REG-REQ/RSP).
m) Upon completing registration, A-BS transmits channel sets to CPE.
n) Establish IP connectivity.
o) Establish time of day.
p) Transfer operational parameters.
q) Establish dynamic service flows.
r) CPE reports sensing results and discovered neighboring networks.

Figure 49c summarizes the network entry of the CPE and its initialization procedure in the A-WRAN. Note that these steps taken by the CPE consist of a set of actions and error verification. In the following subclauses, a more detailed description of these steps and their individual responsibilities are provided.

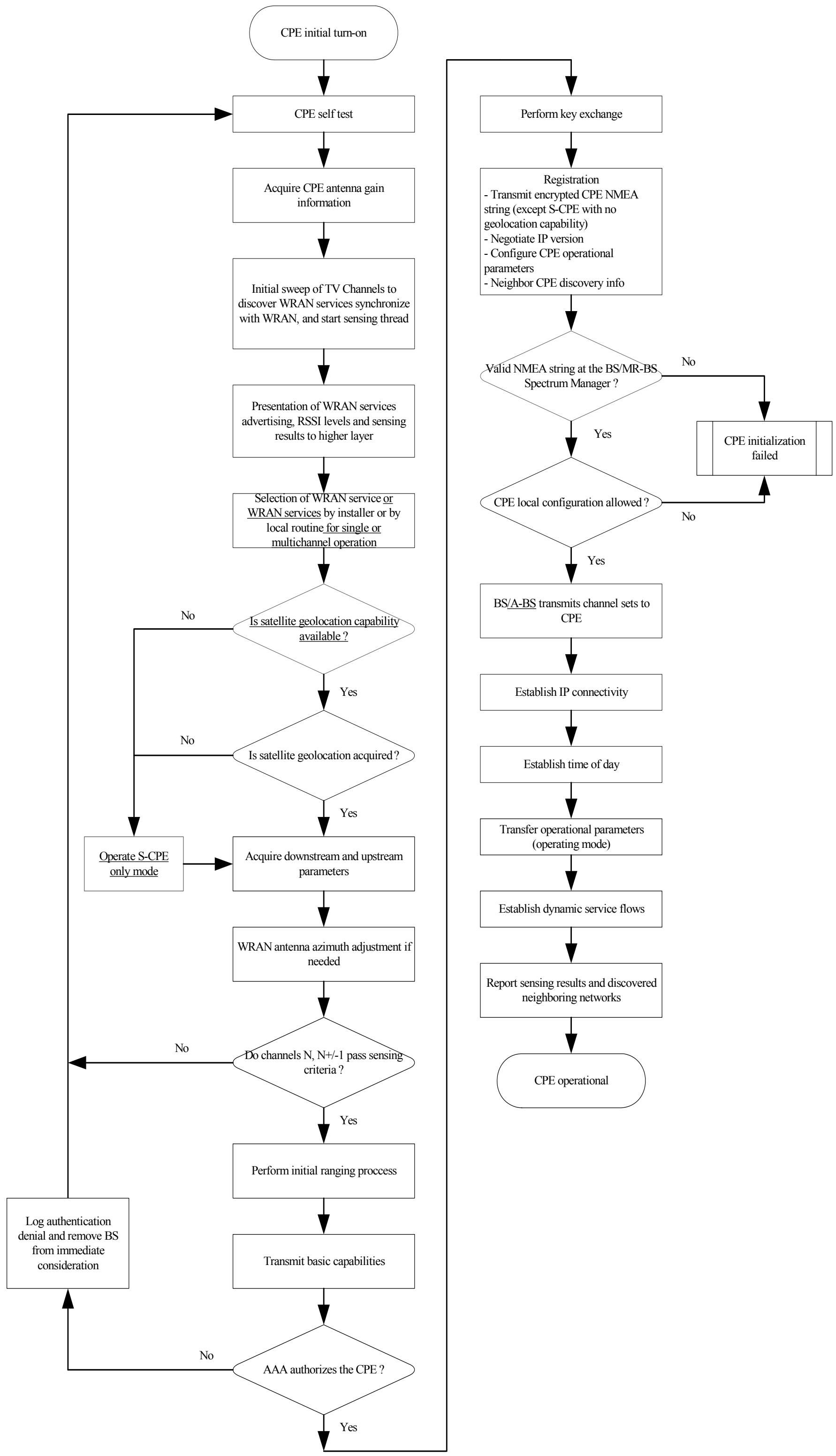


Figure 49c—CPE initialization procedure for A-WRAN

7.14.4.2 CPE performs self test

On initialization or after signal loss, the CPE shall perform a self test.

7.14.4.3 CPE antenna gain information acquisition

The CPE shall determine if its antenna is integrated or not by querying it using the M-ANTENNA-INTEGRATED primitive structure described in 10.7.6.1 and 10.7.6.2. The CPE shall acquire the antenna information including the maximum antenna gain information for the channels that can be used in the regulatory domain of interest. This information is stored in a MIB, *wranIfBsCpeAntennaGainTable*. If the antenna is integrated to the CPE TRU, this MIB object shall be pre-populated by the manufacturer of the CPE. If the antenna is not integrated into the CPE TRU, the MIB object shall be populated by querying the AU through the interface defined in 9.12.2. The information at the antenna shall be pre-populated by the antenna manufacturer.

7.14.4.4 CPE senses for and identifies A-WRAN services and incumbents

The CPE identifies A-WRAN services from detecting the A-BS or the distributed scheduling A-CPE. The CPE shall perform spectrum sensing to detect the A-BS or the distributed scheduling A-CPE and may perform spectrum sensing to detect and identify legitimate incumbent services that are to be protected on each active A-WRAN channel in the area and its adjacent channels as described in 10.3.2.

7.14.4.5 Present sensing results to the higher layers

As a result of spectrum sensing, the available A-BSs or distributed scheduling A-CPEs in the area are presented to the application layer program via connection C2 and MIBs through M-SAP as shown in IEEE 802.22 reference architecture (Figure 7). The application may be running on the CPE or on an attached computer. The data presented includes the operating channel of the A-BS and RSSL in addition to the A-WRAN service being advertised.

7.14.4.6 CPE chooses an A-WRAN service for single channel operation or for multi-channel operation

An A-WRAN service or multiple WRAN services are selected at the higher layers of the CPE after preliminary sensing and identification of available A-BSs or distributed scheduling A-CPEs and the presence of incumbents in the area as the previous subclauses describe. The CPE SSA shall issue an M-WRAN-SERVICE-REPORT primitive to request the higher layers through the NCMS to select a channel from the available A-WRAN service list that is included in the primitive, as described in 10.7.4.1. The SSA shall receive an M-WRAN-SERVICE-RESPONSE primitive with the selected channel from the NCMS, as described in 10.7.4.3. Once the channel is selected, it and its adjacent channels are more rigorously sensed in order to detect the presence of a weak incumbent service that might be masked by the selected A-WRAN service. This procedure is described in more detail in 10.3.2.

7.14.4.7 CPE performs satellite-based geolocation

The CPE shall acquire geolocation data from a satellite-based geolocation receiver when it will operate as a fixed mode or as a distributed scheduling A-CPE. A CPE shall not progress to the next step of initialization for the fixed-mode operation or the distributed scheduling A-CPE operation until the satellite-based geolocation technology successfully establishes lock and acquires valid geolocation data from the satellites. The CPE sends the NMEA string to the A-BS during registration (see 7.14.2.11).

7.14.4.8 Acquire DS and US parameters

7.14.4.8.1 Overview

DS and US parameters can be acquired from two sources: an A-BS and a distributed scheduling A-CPE.

7.14.4.8.2 Obtaining DS parameters from an A-BS

The MAC shall search for the SCH for PHY-OM1 (Clause 9) or FCH for PHY-OM2 (Clause 9a) from the A-BS, which indicates the beginning of the frame in normal mode and the allocated frame in self-coexistence mode. To improve the joining latency, the CPE shall use energy detection to help ascertain about the presence/absence of an A-BS in a particular channel. If the energy detected is below the detection threshold, the CPE can safely move to the next channel.

After having received an SCH or FCH in a channel, the CPE shall perform sensing not only in the detected operating channel, but also in all other affected channels. During this sensing, the CPE shall attempt to identify incumbent operation. If incumbents are detected on the operating channel or either first adjacent channel, the MAC shall cause the CPE to cease transmitting application traffic on the channel and, at the first transmit opportunity, send a short control message to the A-BS indicating that it is using a channel occupied by an incumbent. When the A-BS receives such notification, it may take numerous actions as described in Figure 96. The aggregate duration of the short control messages shall not exceed the Channel Closing Transmission Time (see Table 276) of transmissions by the A-WRAN system before remedying the interference condition (e.g., changing channels, backing off transmit EIRP, terminating transmissions).

Provided no incumbents are found, the CPE may proceed to the next step. Here, the MAC shall search for the DS-MAP MAC management messages. The CPE achieves MAC synchronization once it has received at least one DS-MAP message. A CPE MAC remains in synchronization as long as it continues to successfully receive the FCH, DS-MAP, and DCD messages for its channel(s). If the Lost DS-MAP Interval (Table 273) has elapsed without a valid DS-MAP message or the T1 interval (Table 273) has elapsed without a valid DCD message or Lost FCH counts of FCH are missed, a CPE shall try to reestablish synchronization. The process of acquiring synchronization is illustrated in Figure 49d. The process of maintaining synchronization is illustrated in Figure 49e.

7.14.4.8.3 Obtaining DS parameters from a distributed scheduling A-CPE

As another method to obtain DS parameters, the MAC may search for a DRZ-FCH (7.5.2b) transmitted from a distributed scheduling A-CPE, which indicates the beginning of the DS DRZ (7.4b.3.3).

After having received a DRZ-FCH in a channel, the CPE shall perform sensing not only in the detected operating channel but also in all other affected channels. During this sensing, the CPE shall attempt to identify incumbent operation. If incumbents are detected on the operating channel or either first adjacent channel, the MAC shall cause the CPE to cease transmitting application traffic on the channel and, at the first transmit opportunity in a US DRZ, send a short control message to the distributed scheduling A-CPE indicating that it is using a channel occupied by an incumbent. When the distributed scheduling A-CPE receives such notification, it shall forward the received short control message to the A-BS. When the A-BS receives such notification, it may take numerous actions as described in Figure 96. The aggregate duration of the short control messages shall not exceed the Channel Closing Transmission Time (see Table 276) of transmissions by the A-WRAN system before remedying the interference condition (e.g., changing channels, backing off transmit EIRP, terminating transmissions).

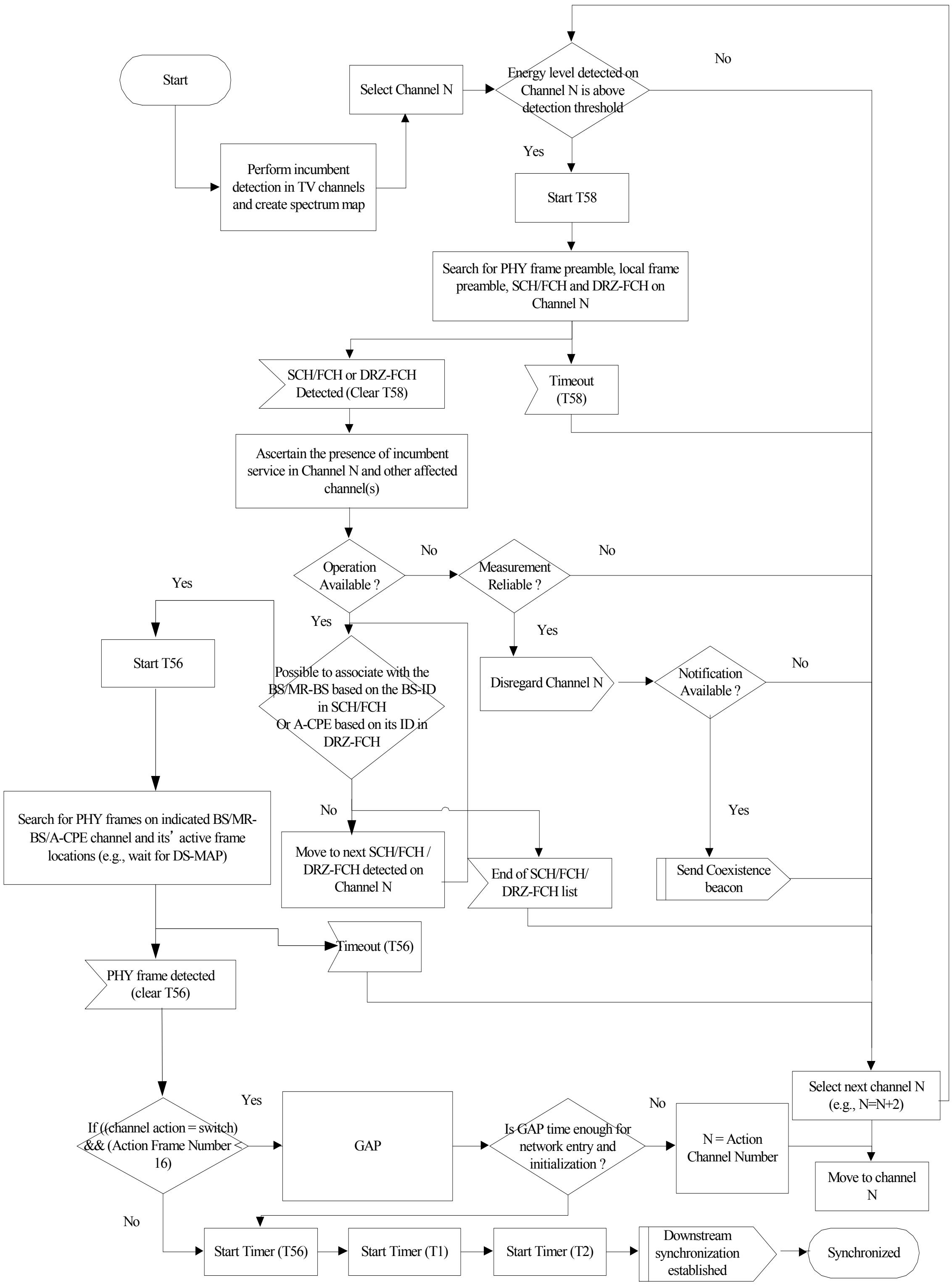


Figure 49d—Obtaining DS parameters

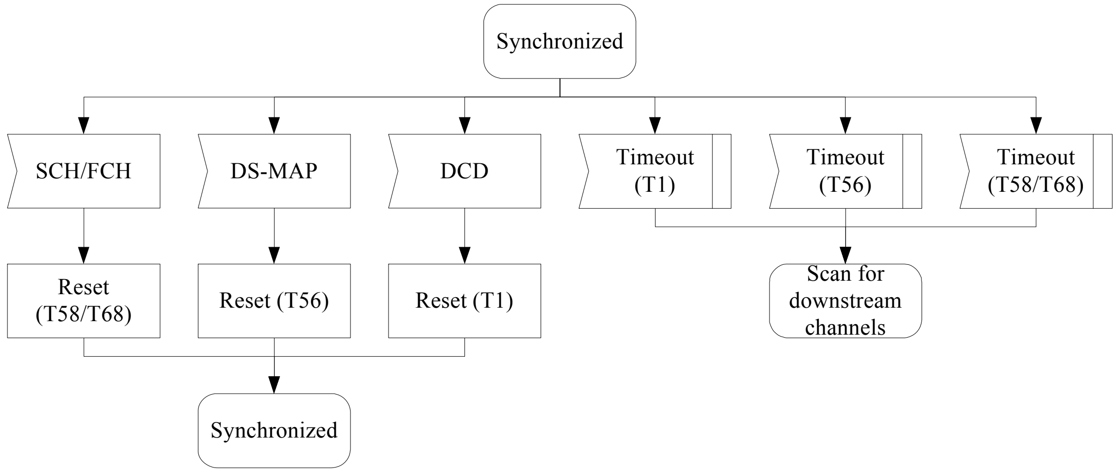


Figure 49e—Maintaining DS parameters

Provided no incumbents are found, the CPE may proceed to the next step. Here, the MAC shall search for the DS-MAP MAC management messages, which are transmitted from the distributed scheduling A-CPE, in a DS DRZ. The CPE achieves MAC synchronization to the distributed scheduling A-CPE once it has received at least one DS-MAP message. A CPE MAC remains in synchronization as long as it continues to successfully receive the DRZ-FCH, DS-MAP, and DCD messages for its channel(s) within a DRZ. If the lost DS-MAP Interval (Table 273) has elapsed without a valid DS-MAP message or the T1 interval (Table 273) has elapsed without a valid DCD message or lost DRZ-FCH counts of DRZ-FCH are missed, a CPE shall try to reestablish synchronization. The process of acquiring synchronization is illustrated in Figure 49d. The process of maintaining synchronization is illustrated in Figure 49f.

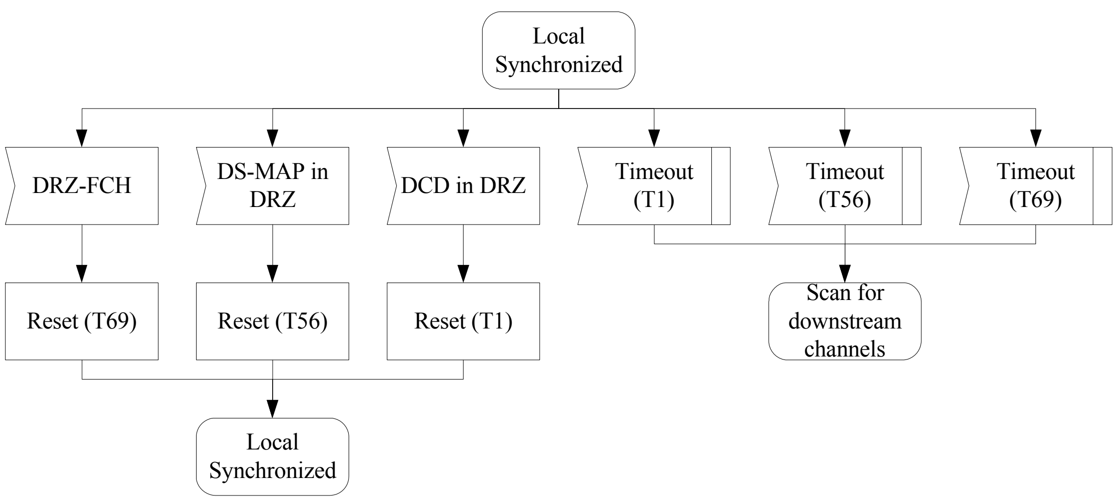


Figure 49f—Maintaining DS parameters in DRZ

7.14.4.8.4 Obtaining US parameters from an A-BS

After synchronization to the A-BS, the CPE shall wait for a UCD message from the A-BS in order to retrieve a set of transmission parameters for a possible US channel. These messages are transmitted periodically from the A-BS for all available US channels and are addressed to the MAC broadcast address.

If no US channel can be found after a suitable timeout period, then the CPE shall continue scanning to find another DS channel. The process of obtaining US parameters is illustrated in Figure 37.

The CPE shall determine from the channel description parameters whether it may use the US channel. If the channel is not suitable, then the CPE shall continue scanning to find another DS channel. If the channel is suitable, the CPE shall extract the parameters for this US from the UCD. It then shall wait for the next DS-MAP message and extract the time synchronization from this message. Then, the CPE shall wait for a bandwidth allocation map for the selected channel. It may begin transmitting US in accordance with the MAC operation and the bandwidth allocation mechanism.

The CPE shall perform initial ranging at least once. If initial ranging is not successful, the procedure is restarted from scanning to find another DS channel.

The CPE MAC is considered to have valid US parameters as long as it continues to successfully receive the SCH/FCH, US-MAP, and UCD messages. If at least one of these messages is not received within the time intervals specified in Table 273, the CPE shall not use the US. This is illustrated in Figure 49g.

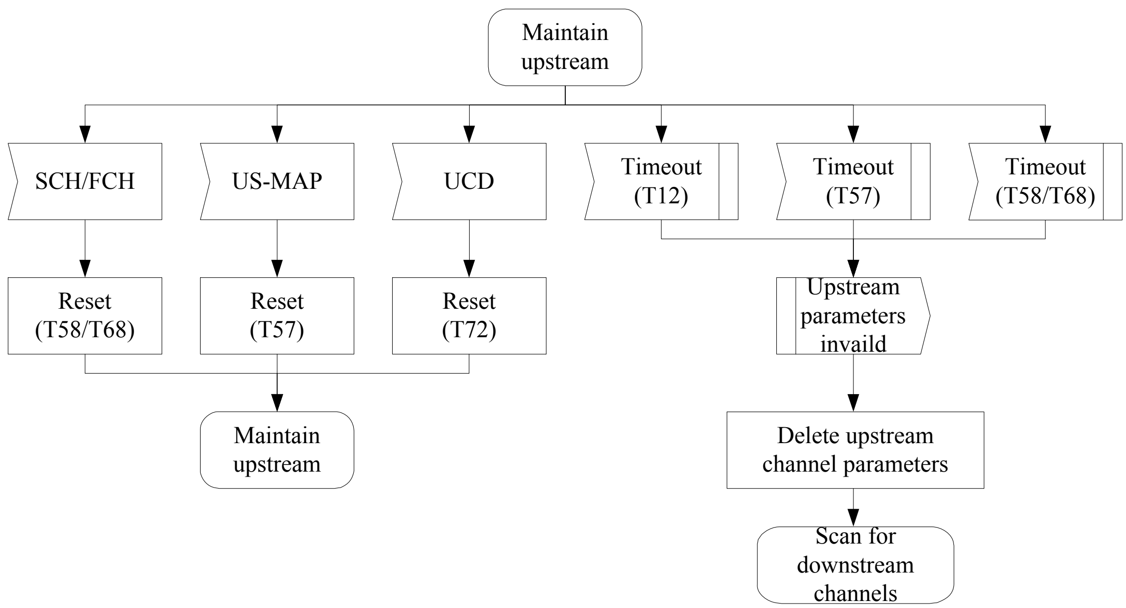


Figure 49g—Maintaining US parameters

7.14.4.8.5 Obtaining US parameters from a distributed scheduling A-CPE

After synchronization to the distributed scheduling A-CPE, the CPE shall wait for a UCD message from the distributed scheduling A-CPE in order to retrieve a set of transmission parameters for a possible US channel. These messages are transmitted periodically in a DS DRZ from the distributed scheduling A-CPE for the available US channels and are addressed to the MAC broadcast address.

If no US channel can be found after a suitable timeout period, then the CPE shall continue scanning to find another DS channel. The process of obtaining US parameters is illustrated in Figure 37.

The CPE shall determine from the channel description parameters whether it may use the US channel. If the channel is not suitable, then the CPE shall continue scanning to find another DS channel. If the channel is suitable, the CPE shall extract the parameters for this US from the UCD. It then shall wait for the next DS-MAP message and extract the time synchronization from this message. Then, the CPE shall wait for a bandwidth allocation map for the selected channel. It may begin transmitting US in accordance with the MAC operation and the bandwidth allocation mechanism.

The CPE shall perform initial ranging to the distributed scheduling A-CPE at least once. If initial ranging is not successful, the procedure is restarted from scanning to find another DS channel.

The CPE MAC is considered to have valid US parameters as long as it continues to successfully receive the DRZ-FCH, US-MAP, and UCD messages. If at least one of these messages is not received within the time intervals specified in Table 273, the CPE shall not use the US. This is illustrated in Figure 49h.

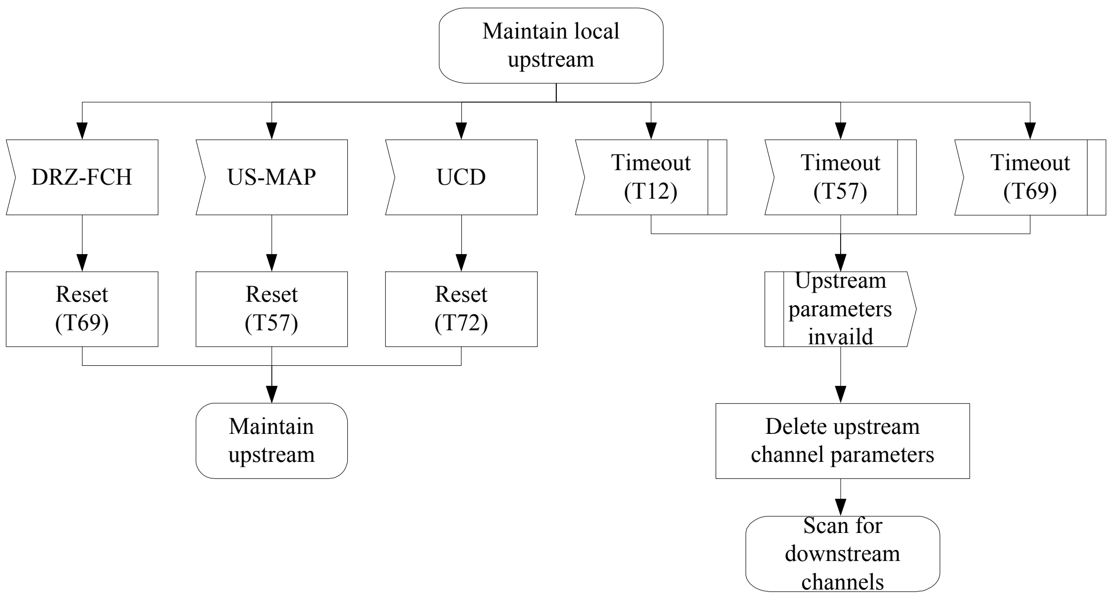


Figure 49h—Maintaining US parameters in DRZ

7.14.4.9 CPE transmits ranging/CDMA burst

7.14.4.9.1 General

From the result of synchronization as described in 7.14.4.8, initial ranging will be performed. There are three methods of CPE transmit initial ranging: initial ranging to an A-BS, initial ranging to a distributed scheduling A-CPE, and initial ranging to a centralized scheduling A-CPE on relaying.

The selected channel is analyzed to determine if it passes the restrictions specified in 10.3.2. If the selected channel does not pass these restrictions, the association with the selected A-BS or distributed scheduling A-CPE is unsuccessful, and the selected channel shall be removed from further consideration. Available A-BSs or distributed scheduling A-CPEs are again presented to the higher layers for selection if there exist any other A-BSs or distributed scheduling A-CPEs with which to associate.

Next the selected channel and the channels that could incur harmful interference by operation on this selected channel shall be more finely sensed to determine if there exists a weak protected incumbent signal that was not detected at an earlier stage in the CPE initialization procedure. This process is described in 10.3.2.

Time in this subclause shall be referenced to two positions in space. One position will be that of the A-BS or distributed scheduling A-CPE, and the other position will be that of the CPE. Many such CPE positions will exist. Ranging is the process of acquiring the correct timing offset and EIRP adjustments such that the

CPE's transmissions are aligned at the A-BS or distributed scheduling A-CPE position. Ranging also adjusts transmit EIRP of the various CPEs such that the OFDMA signal received at the A-BS or distributed scheduling A-CPE arrives with compatible amplitudes from all the CPEs.

Although a CPE successfully obtains DS parameters from an A-BS, in particular, ranging to the A-BS as described in 7.14.4.9.2 may fail due to the CPE transmitting power constraint. However, the CPE is still able to have an uplink transmission to the A-BS by relaying on a centralized scheduling A-CPE. In this case, the CPE may perform ranging to a centralized scheduling A-CPE for the relaying operations to acquire the correct timing offset and EIRP adjustments aligned at the centralized scheduling A-CPE.

The timing delays through the PHY shall be constant to within 25% of the shortest symbol cyclic prefix as indicated in 9.9.1.

7.14.4.9.2 CDMA initial ranging and automatic adjustments to an A-BS

First, a CPE shall synchronize to the frame preamble in order to perform initial ranging to an A-BS. At this point, the CPE shall scan the US-MAP message to find an Initial Ranging Interval. The A-BS may allocate an Initial Ranging Interval consisting of one or more transmission opportunities. The CPE shall extract the number of initial ranging codes (see Table 31, element ID 150) from the UCD MAC management message.

The CPE randomly selects the CDMA code as described in 7.15.2.3.1 and sends the initial ranging CDMA code on the US allocation dedicated for that purpose. The A-BS receives the CDMA code. As many CPEs may contend for ranging, the CDMA code received may be the sum of many CPE transmissions. The A-BS isolates each of these transmissions and computes the ranging adjustments based on the relative time of arrival of each CPE US burst, i.e., the timing offset, so that all these bursts arrive at the A-BS at the beginning of the symbol period within sufficient tolerance.

Ranging adjusts each CPE's timing offset such that each CPE appears to be co-located with the A-BS. The CPE shall set its initial timing offset to "zero advance" as if it was physically co-located with the A-BS. When the Initial Ranging transmission opportunity occurs, the CPE shall send a CDMA code. After reception and decoding of this CDMA code, the A-BS will react by sending a RNG-CMD MAC message in a following frame with the same CDMA code and indicate the timing advance that the CPE should use for its US transmissions (see Table 44) so that the beginning of its bursts is aligned with the center of the cyclic prefix within the tolerance indicated in 9.9.1.

When the Initial Ranging transmission opportunity occurs, the CPE shall send a CDMA code. Thus, the CPE sends the message as if it were co-located with the A-BS.

The CPE shall calculate the transmit EIRP per subcarrier for initial ranging, $EIRP_{IR\_CPE}$, from the following equation:

$$EIRP_{IR\_CPE} = EIRP_{A\text{-}BS} + RSS_{IR\_A\text{-}BS\_nom} - (RSS_{IR\_CPE} - G_{RX\_CPE}) + 10 \times \log(N_{IR\_sub}/N_{sub})$$

where

$RSS_{IR\_A\text{-}BS\_nom}$ and $EIRP_{A\text{-}BS}$	are defined in a DCD IE (see Table 23)
G_{RX_CPE}	is the antenna gain at the CPE
RSS_{IR_CPE}	is the RSSL measured by the CPE, which is then corrected by the CPE antenna gain to represent the RSSL for an isotropic antenna
N_{IR_sub}	is the number of subcarriers used by the CPE for initial ranging
N_{sub}	is 1680 for PHY-OM1 or 840 for PHY-OM2

The CPE shall send a CDMA code with a power level resulting in the $EIRP_{IR\_CPE}$ per subcarrier. If the CPE does not receive a response after waiting at least one frame to allow processing at the A-BS, the CPE shall send a new CDMA code at the next appropriate Initial Ranging transmission opportunity with 1 dB higher power level. The CPE shall, however, stop increasing the power level at the following condition:

$$EIRP_{IR\_MAX} + 10\times\log(N_{IR\_sub}) > EIRP_{CPE\_MAX}$$

where

$EIRP_{CPE\_MAX}$	is the upper bound in maximum transmitted EIRP for the CPE on the current operating channel as described in Table 108 of 7.7.11.3.2.1 or 4 W for the fixed CPE, whichever is the smallest
$EIRP_{IR\_CPE\_MAX}$	is the upper bound for the increased $EIRP_{IR\_CPE}$

If the CPE receives a RNG-CMD message containing the parameters of the code it has transmitted and the status "continue," it shall consider the transmission attempt unsuccessful but implement the corrections specified in the RNG-CMD and issue another CDMA code after the appropriate backoff delay. If the CPE receives an US-MAP containing a CDMA allocation IE with the parameters of the code it has transmitted, it shall consider the RNG-CMD reception successful and proceed to send a unicast RNG-REQ (on Initial Ranging FID, allocated to Cell SID) on the allocated BW.

Once the A-BS has successfully received the RNG-REQ message, it shall return a RNG-CMD message using the initial ranging connection (see 12.2). Within the RNG-CMD message shall be the Station ID (SID) assigned to this CPE. The message shall also contain information on the required CPE EIRP level, the offset frequency adjustment, and the proper timing advance when needed. At this point the A-BS shall start using invited Initial Ranging Intervals addressed to the CPE's Basic FID to complete the ranging process, unless the status of the RNG-CMD message is "success," in which case the initial ranging procedure shall end.

If the status of the RNG-CMD message is "continue," the CPE shall wait for an individual Initial Ranging Interval assigned to its Basic FID. Using this interval, the CPE shall transmit another RNG-REQ message using the Basic FID along with any power level and timing offset corrections.

The A-BS shall return another RNG-CMD message to the CPE with any additional fine-tuning required. The ranging request/response steps shall be repeated until the response contains a "Ranging Successful" notification or the A-BS aborts ranging. Once successfully ranged (timing, frequency and EIRP are within tolerance at the A-BS), the CPE shall join normal data traffic in the US. In particular, the retry counts and timer values for the ranging process are defined in Table 273.

On receiving a RNG-CMD instruction to move to a new channel during initial ranging, the CPE shall obtain a new SID via initial ranging and registration.

It is possible that the RNG-CMD may be lost after transmission by the A-BS. The CPE shall recover by timing out and reissuing its Initial RNG-REQ. Since the CPE is uniquely identified by the source MAC address in the Ranging Request, the A-BS may immediately reuse the SID previously assigned. If the A-BS assigns a new SID, it shall immediately age out the old SID and associated CPE.

7.14.4.9.3 CDMA initial ranging and automatic adjustments to a distributed scheduling A-CPE (Local initial ranging)

A CPE shall synchronize to the local frame preamble within a DRZ in order to perform initial ranging to the distributed scheduling A-CPE. At this point, the CPE shall scan the US-MAP message to find an Initial Ranging Interval within a local cell managed by a distributed scheduling A-CPE. The distributed scheduling A-CPE may allocate an Initial Ranging Interval consisting of one or more transmission opportunities in a

US DRZ. The CPE shall extract the number of initial ranging codes (see Table 31, element ID 150) from the UCD MAC management message.

The CPE randomly selects the CDMA code as described in 7.15.2.3.1 and sends the initial ranging CDMA code on the US DRZ allocation dedicated for that purpose. The distributed scheduling A-CPE receives the CDMA code. As many CPEs may contend for ranging, the CDMA code received may be the sum of many CPE transmissions. The distributed scheduling A-CPE isolates each of these transmissions and computes the ranging adjustments based on the relative time of arrival of each CPE US burst, i.e., the timing offset, so that all these bursts arrive at the distributed scheduling A-CPE at the beginning of the symbol period within sufficient tolerance.

Ranging adjusts each CPE's timing offset such that each CPE appears to be co-located with the distributed scheduling A-CPE. The CPE shall set its initial timing offset to "zero advance" as if it was physically co-located with the distributed scheduling A-CPE. When the Initial Ranging transmission opportunity occurs in the DRZ, the CPE shall send a CDMA code. After reception and decoding of this CDMA code, the distributed scheduling A-CPE will react by sending a RNG-CMD MAC message in a following frame with the same CDMA code and indicate the timing advance that the CPE should use for its US transmissions (see Table 44) so that the beginning of its bursts is aligned with the center of the cyclic prefix within the tolerance indicated in 9.9.1.

When the Initial Ranging transmission opportunity occurs in the DRZ, the CPE shall send an initial ranging CDMA code. Thus, the CPE sends the message as if it were co-located with the distributed scheduling A-CPE.

The CPE shall calculate the transmit EIRP per subcarrier for initial ranging, $EIRP_{IR\_CPE}$, from the following equation:

$$EIRP_{IR\_CPE} = EIRP_{A\text{-}CPE} + RSS_{IR\_A\text{-}CPE\_nom} - (RSS_{IR\_CPE} - G_{RX\_CPE}) + 10\times\log(N_{IR\_sub}/N_{sub})$$

where

$RSS_{IR\_A\text{-}CPE\_nom}$ and $EIRP_{A\text{-}CPE}$	are defined in a DCD IE (see Table 23)
G_{RX_CPE}	is the antenna gain at the CPE
RSS_{IR_CPE}	is the RSSL measured by the CPE, which is then corrected by the CPE antenna gain to represent the RSSL for an isotropic antenna
N_{IR_sub}	is the number of subcarriers used by the CPE for initial ranging
N_{sub}	is 1680 for PHY-OM1 or 840 for PHY-OM2

The CPE shall send a CDMA code with a power level resulting in the $EIRP_{IR\_CPE}$ per subcarrier. If the CPE does not receive a response after waiting at least one frame to allow processing at the distributed scheduling A-CPE, the CPE shall send a new CDMA code at the next appropriate Initial Ranging transmission opportunity with 1 dB higher power level. The CPE shall, however, stop increasing the power level at the following condition:

$$EIRP_{IR\_MAX} + 10\times\log(N_{IR\_sub}) > EIRP_{CPE\_MAX}$$

where

$EIRP_{CPE\_MAX}$	is the upper bound in maximum transmitted EIRP for the CPE on the current operating channel as described in Table 108 of 7.7.11.3.2.1 or 4 W for the fixed CPE, whichever is the smallest
$EIRP_{IR\_CPE\_MAX}$	is the upper bound for the increased $EIRP_{IR\_CPE}$

If the CPE receives a RNG-CMD message containing the parameters of the code it has transmitted and the status “continue,” it shall consider the transmission attempt unsuccessful but implement the corrections specified in the RNG-CMD and issue another CDMA code after the appropriate backoff delay. If the CPE receives an US-MAP containing a CDMA allocation IE with the parameters of the code it has transmitted, it shall consider the RNG-CMD reception successful and proceed to send a unicast RNG-REQ (on Initial Ranging FID, allocated to Cell SID) on the allocated BW.

Once the distributed scheduling A-CPE has successfully received the RNG-REQ message, it shall return a RNG-CMD message using the initial ranging connection (see 12.2). Within the RNG-CMD message shall be the one SID, which is selected from the Local SID Group (7.7.7.3.6), assigned to this CPE. Note that a distributed scheduling A-CPE shall obtain the Local SID Group (7.7.7.3.6) used in a local cell from the A-BS at registration. The RNG-CMD message shall also contain information on the required CPE EIRP level, the offset frequency adjustment, and the proper timing advance when needed. At this point the distributed scheduling A-CPE shall start using the invited Initial Ranging Intervals addressed to the CPE’s Basic FID to complete the ranging process, unless the status of the RNG-CMD message is “success,” in which case the initial ranging procedure shall end.

If the status of the RNG-CMD message is “continue,” the CPE shall wait for an individual Initial Ranging Interval assigned to its Basic FID. Using this interval, the CPE shall transmit another RNG-REQ message using the Basic FID along with any power level and timing offset corrections.

The distributed scheduling A-CPE shall return another RNG-CMD message to the CPE with any additional fine-tuning required. The ranging request/response steps shall be repeated until the response contains a “Ranging Successful” notification or the A-CPE aborts ranging. Once successfully ranged (timing, frequency and EIRP are within tolerance at the A-CPE), the CPE shall join normal data traffic in the US. In particular, the retry counts and timer values for the ranging process are defined in Table 273.

On receiving a RNG-CMD instruction to move to a new channel during initial ranging, the CPE shall obtain a new SID via initial ranging and registration.

It is possible that the RNG-CMD may be lost after transmission by the distributed scheduling A-CPE. The CPE shall recover by timing out and reissuing its Initial RNG-REQ. Since the CPE is uniquely identified by the source MAC address in the Ranging Request, the distributed scheduling A-CPE may immediately reuse the SID previously assigned. If the distributed scheduling A-CPE assigns a new SID, it shall immediately age out the old SID and associated CPE.

7.14.4.9.4 CDMA initial ranging and automatic adjustments by relaying on a centralized scheduling A-CPE (Relay initial ranging)

Although a CPE successfully obtains DS parameters from an A-BS, CDMA initial ranging to the A-BS as described in 7.14.4.9.2 may fail due to the CPE transmitting power constraint. However, a CPE is still able to have an uplink to the A-BS by relaying on a centralized scheduling A-CPE. A CPE shall synchronize to the frame preamble in order to perform initial ranging to an A-BS. At this point, the CPE shall scan the US-MAP message to find an Initial Ranging Interval in AZ and Initial Ranging Interval in CRZ if present. The A-BS may allocate an Initial Ranging Interval consisting of one or more transmission opportunities within a US subframe CRZ. The CPE shall extract the number of initial ranging codes and may extract the number of CRZ initial ranging codes (see Table 31, element ID 155) from the UCD MAC management message.

The CPE randomly selects the CDMA code as described in 7.15.2.3.1, sends the initial ranging CDMA code to the A-BS on the Initial Ranging Interval, and sends the CRZ initial ranging CDMA code to the centralized scheduling A-CPE on the CRZ Initial Ranging Interval as well in the US allocation dedicated for that purpose. The initial ranging between the CPE and the A-BS shall be as described in 7.14.4.9.2. The following describes when the CRZ initial ranging is performed between the CPE and the centralized scheduling A-CPE.

The centralized scheduling A-CPE may receive the CRZ Initial Ranging CDMA code within the Initial Ranging Interval in a US subframe CRZ. As many CPEs may contend for ranging, the CDMA code received may be the sum of many CPE transmissions. The centralized scheduling A-CPE isolates each of these transmissions and computes the ranging adjustments based on the relative time of arrival of each CPE US burst, i.e., the timing offset, so that all these bursts arrive at the centralized scheduling A-CPE at the beginning of the symbol period within sufficient tolerance.

Ranging adjusts each CPE's timing offset such that each CPE appears to be co-located with the centralized scheduling A-CPE. The CPE shall set its initial timing offset to "zero advance" as if it was physically co-located with the centralized scheduling A-CPE. When the Initial Ranging transmission opportunity occurs in the CRZ, the CPE may send a CRZ initial ranging CDMA code. After reception and decoding of this CDMA code, the centralized scheduling A-CPE will send a RNG-RPT message (7.7.31) to the A-BS, where instead of the centralized scheduling A-CPE the A-BS will react by sending a RNG-CMD MAC message in a following frame with the received CDMA code and indicate the timing advance that the CPE should use for its US transmissions (see Table 44) so that the beginning of its bursts is aligned with the center of the cyclic prefix within the tolerance indicated in 9.9.1. The CPE randomly selects the CRZ initial ranging CDMA code as described in 7.15.2.3.3 and sends the CDMA code to the centralized scheduling A-CPE on the Initial Ranging Interval in the CRZ. Thus, the CPE sends the message as if it were co-located with the centralized scheduling A-CPE.

The CPE shall calculate the transmit EIRP per subcarrier for initial ranging, $EIRP_{IR\_CPE}$, from the following equation:

$$EIRP_{IR\_CPE} = EIRP_{A\text{-}CPE} + RSS_{IR\_A\text{-}CPE\_nom} - (RSS_{IR\_CPE} - G_{RX\_CPE}) + 10\times\log(N_{IR\_sub}/N_{sub})$$

where

$RSS_{IR\_A\text{-}CPE\_nom}$ and $EIRP_{A\text{-}CPE}$	are defined in a DCD IE (see Table 23)
G_{RX_CPE}	is the antenna gain at the CPE
RSS_{IR_CPE}	is the RSSL measured by the CPE, which is then corrected by the CPE antenna gain to represent the RSSL for an isotropic antenna
N_{IR_sub}	is the number of subcarriers used by the CPE for initial ranging
N_{sub}	is 1680 for PHY-OM1 or 840 for PHY-OM2

The CPE shall send a CDMA code with a power level resulting in the $EIRP_{IR\_CPE}$ per subcarrier. If the CPE does not receive a response after waiting at least one frame to allow processing at the centralized scheduling A-CPE, the CPE shall send a new CDMA code at the next appropriate Initial Ranging transmission opportunity with 1 dB higher power level. The CPE shall, however, stop increasing the power level at the following condition:

$$EIRP_{IR\_MAX} +10\times\log(N_{IR\_sub}) > EIRP_{CPE\_MAX}$$

where

$EIRP_{CPE\_MAX}$	is the upper bound in maximum transmitted EIRP for the CPE on the current operating channel as described in Table 108 of 7.7.11.3.2.1 or 4 W for the fixed CPE, whichever is the smallest
$EIRP_{IR\_CPE\_MAX}$	is the upper bound for the increased EIRPIR_CPE

If the CPE receives a RNG-CMD message containing the parameters of the code from the A-BS it has transmitted and the status "continue," it shall consider the transmission attempt unsuccessful but implement the corrections specified in the RNG-CMD and issue another CDMA code after the appropriate backoff delay. If the CPE receives an CRZUS-MAP containing a CDMA allocation IE with the parameters of the code it has transmitted, it shall consider the RNG-CMD reception successful and proceed to send a unicast RNG-REQ (on Initial Ranging FID, allocated to Cell SID) on the allocated BW. The centralized scheduling A-CPE shall transmit the RNG-REQ received from the CPE to the A-BS.

Once the A-BS has successfully received the RNG-REQ message, the A-BS shall return a RNG-CMD message to the CPE. Within the RNG-CMD message shall be the SID assigned to this CPE. In addition, the centralized scheduling A-CPE shall maintain the SID of the CPE broadcasted by the RNG-CMD.

Moreover, a CPE can successfully perform CDMA initial ranging to the several devices including an A-BS and centralized scheduling A-CPEs. In this case, the CPE shall select one of those.

7.14.4.9.5 Ranging parameter adjustment

Adjustment of local parameters (e.g., transmit EIRP) in a CPE as a result of the receipt or non-receipt of a RNG-CMD message is considered to be implementation-dependent with the following restrictions:

a) All parameters shall be within the approved range at all times.
b) EIRP adjustment shall start from the initial value selected with the algorithm described in 7.14.4.9.2, 7.14.4.8.3, or 7.14.4.8.4 unless a valid EIRP setting is available from non-volatile storage, in which case this value may be used as the starting point.
c) EIRP adjustment shall be capable of being reduced or increased by the specified amount in response to the RNG-CMD messages.
d) If, during initialization, EIRP is increased to the maximum value as determined in 7.14.4.9.2, 7.14.4.8.3, or 7.14.4.8.4 without a response from the A-BS, it shall go back to the minimum EIRP and ramp up to its maximum EIRP four (4) times before aborting the ranging process with this base station.

On receiving a RNG-CMD message, the CPE shall not transmit until the radio frequency (RF) signal has been adjusted in accordance with the RNG-CMD and has stabilized.

7.14.4.10 CPE transmit basic capabilities for a relay network

7.14.4.10.1 CPE transmit basic capabilities to a distributed scheduling A-CPE

Immediately following the completion of initial ranging in a DRZ, the CPE informs the distributed scheduling A-CPE of its basic capabilities by transmitting a CBC-REQ message (see Table 105) with its capabilities set to “on” (see Figure 39). Note that T18 is a timer used to wait for CBC-RSP timeout, and the default value is indicated in Table 272.

The distributed scheduling A-CPE responds with a CBC-RSP message (see Table 106) with the intersection of the CPE’s and distributed scheduling A-CPE’s capabilities set to “on” (see Figure 40 and Figure 49i, respectively). The timer T9 refers to the time allowed between when the distributed scheduling A-CPE sends a RNG-CMD to a CPE and receives a CBC-REQ from that same CPE, and the minimum value is specified in Table 272. Note that the CPE capability information is presented in 7.7.7.3.4. When T9 expires, the SID assigned during ranging shall be aged out, and the CPE shall have to attempt the ranging process over again while not exceeding the maximum number of CDMA ranging retries indicated in Table 273.

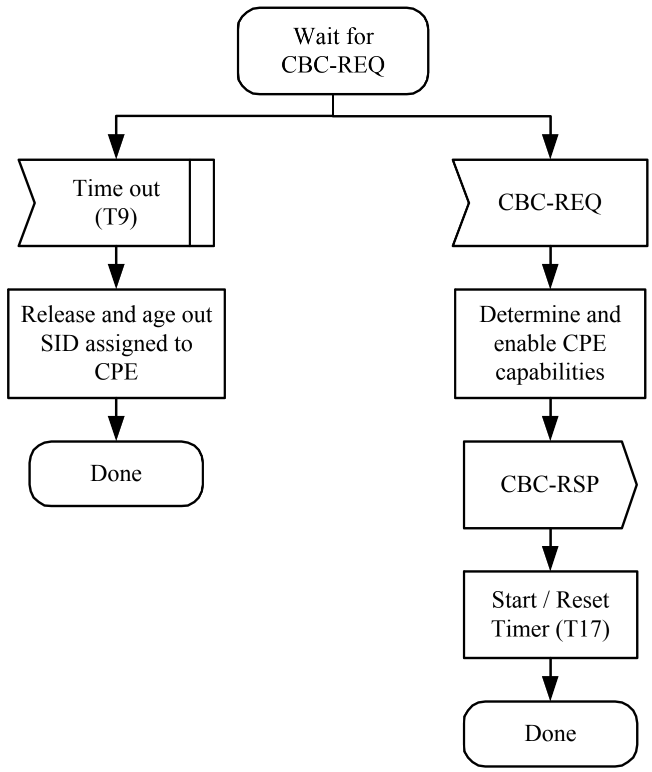


Figure 49i—Negotiate basic capabilities at distributed scheduling A-CPE

7.14.4.10.2 CPE transmit basic capabilities relaying on a centralized scheduling A-CPE

Immediately following the completion of initial ranging in a CRZ, the CPE informs the centralized scheduling A-CPE of its basic capabilities by transmitting a CBC-REQ message (see Table 105) with its capabilities set to “on” (see Figure 39). Note that T18 is a timer used to wait for CBC-RSP timeout, and the default value is indicated in Table 272. When the centralized scheduling A-CPE receives the CBC-REQ messages from the CPEs, the centralized scheduling A-CPE may transmit CBC-REQ message alone or a Container message (7.7.26) containing the received CBC-REQ messages to the A-BS (see Figure 49j). Note that the Container messages may contain not only CBC-REQ messages but also other management messages. Note that T61 is a timer used to wait for Container ACK timeout, which is indicated in Table 272.

When the A-BS has successfully received the CBC-REQ message by encoding the received Container message, it shall return a Container ACK message (7.7.26.2) with a confirmation code for the CBC-REQ to the centralized scheduling A-CPE. If the confirmation code for a certain management message is not “success,” the centralized scheduling A-CPE shall retransmit the indicated management message to the A-BS (see Figure 49k). After correctly receiving the CBC-REQ, the A-BS responds with a CBC-RSP message (see Table 106) to the CPE, with the intersection of the CPE’s and A-BS’s capabilities set to “on.” The timer T9 refers to the time allowed between when the A-BS sends a RNG-CMD to a CPE and receives a CBC-REQ from that same CPE, and the minimum value is specified in Table 272. Note that the CPE capability information is presented in 7.7.7.3.4. When T9 expires, the SID assigned during ranging shall be aged out, and the CPE shall have to attempt the ranging process over again while not exceeding the maximum number of CDMA ranging retries indicated in Table 273.

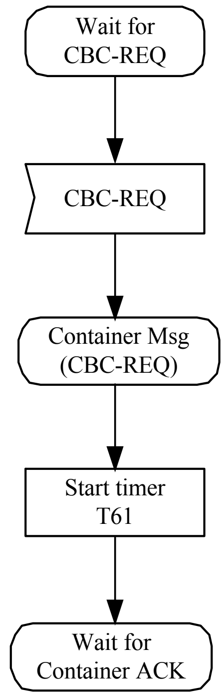


Figure 49j—Wait for CBC-REQ and sending container message including CBC-REQ at a centralized scheduling A-CPE

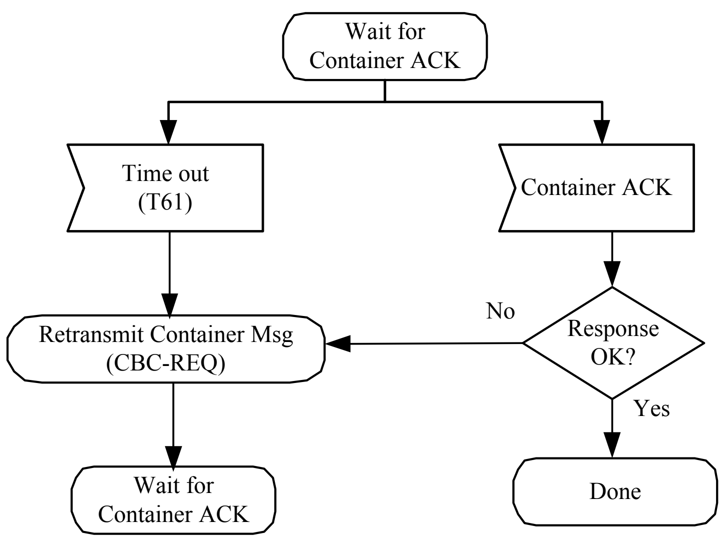


Figure 49k—Wait for Container ACK at a centralized scheduling A-CPE

7.14.4.11 CPE authentication and key exchange

Once configuration of the required basic capabilities is completed, the CPE and AAA continue with performing authentication and exchanging keys, as described in Clause 8. If the AAA and CPE cannot authenticate each other, authentication of the CPE fails for the selected A-WRAN service. This A-WRAN service on the selected channel is removed from further consideration. If there are any other A-BSs available with which to associate, the updated list of available A-WRAN services is presented to the higher user layers.

7.14.4.12 Registration for a relay network

7.14.4.12.1 Overview

Registration is the process by which the CPE verifies its configuration with the A-BS. If the CPE supports a configuration that is set by the A-BS, it is allowed entry into the network and thus becomes manageable. To register with an A-BS, the CPE shall send a REG-REQ message to the A-BS directly or send it through a centralized scheduling A-CPE or a distributed scheduling A-CPE by relaying. The REG-REQ message shall include a CPE NMEA Location string IE except for Mode I CPE (see Table A.2).

See 7.14.2.11 for registration procedures, using “A-BS instead of “BS” in the text.

7.14.4.12.2 Local cell management on relay

A local cell is the grouping of S-CPEs attached to the A-BS through a particular distributed A-CPE. When an S-CPE completes registration or de-registration at the distributed scheduling A-CPE, the A-CPE must update the A-BS with any changes to the current membership of the local cell. This is necessary for the A-BS to be able to have a complete picture of the topology of the network.

In order to determine if a local cell update (LCU) is required, the distributed scheduling A-CPE watches for Container Messages or stand-alone management messages coming from the A-BS. For each MAC PDU encapsulated in a Container Message (CON-MSG), the PDU Type subfield (see 7.7.26.1) indicates the purpose of the message encapsulated by the MAC PDU being sent to an S-CPE. The PDU Type field in the CON-MSG shall be handled as follows:

— PDU Type = 0x00, REG-RSP:
  — The A-BS sends REG-RSP to the S-CPE, and then the S-CPE completes the registration upon receiving MAC PDU containing this message (as forwarded by A-CPE).
  — In this case the A-CPE shall send the LCU-IND message to the A-BS to update local cell membership (Figure 49l) and wait for an LCU-ACK sent from the A-BS. Figure 49m presents the procedure where the A-CPE waits for an LCU-ACK, and Figure 49n presents the procedure where the A-BS sends an LCU-ACK after it has received an LCU-INC from the A-CPE.
— PDU Type = 0x01, DREG-CMD with Action Code = 0x04 or 0x05:
  — The A-BS asks the S-CPE to either terminate operation and shutdown (Action Code = 0x04) or reinitialize on another operating channel (Action Code = 0x05). In either case the S-CPE ceases operation because it is fully de-registered.
  — In this case the A-CPE shall send the LCU-IND message to the A-BS to update local cell membership (Figure 49l) and wait for an LCU-ACK sent from the A-BS. Figure 49m presents the procedure where the A-CPE waits for an LCU-ACK, and Figure 49n presents the procedure where the A-BS sends an LCU-ACK after it has received an LCU-INC from the A-CPE.
— PDU Type = 0x02, DREG-CMD with Action Code = 0x01, 0x02, 0x03:
  — The A-BS asks the S-CPE to only listen for transmission on Basic/Primary Management/ Secondary Management FID (Action Code = 0x02), temporarily suspend operation (Action Code = 0x01), or resume operation (Action Code = 0x03).
  — In this case the A-CPE shall not send the LCU-IND message to the A-BS.
— PDU Type = 0x03, Any Other PDU:
  — The A-BS sends any other non-registration or de-registration message or general MAC PDU to the S-CPE.
  — In this case the A-CPE shall not send the LCU-IND message to the A-BS.

The PDU Type field shall be set to 0x03 when the A-CPE sends a CON-MSG in the US to the A-BS.

Given the rules for processing the PDU Type field in the CON-MSG, it is clear that the A-CPE shall not be capable of originating REG-RSP and DREG-CMD messages to be sent to an S-CPE itself.

Regarding other local cell operations, the A-CPE shall be capable of originating messages related to ranging (i.e., RNG-CMD) and basic capability negotiation (i.e., CBC-RSP) with the S-CPE locally in the access zone.

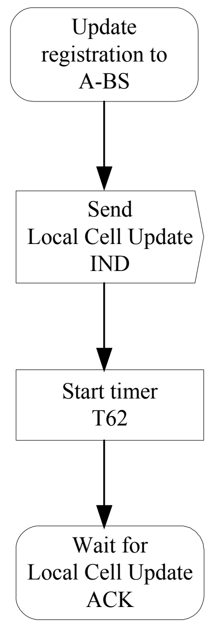


Figure 49l—Sending LCU-IND from a distributed scheduling A-CPE

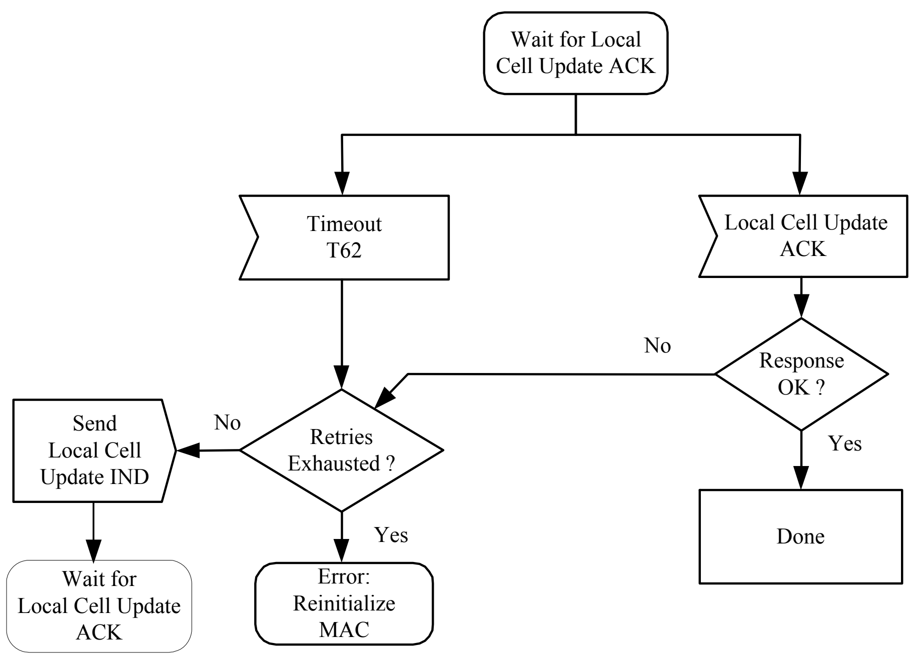


Figure 49m—Wait for LCU-ACK at a distributed scheduling A-CPE

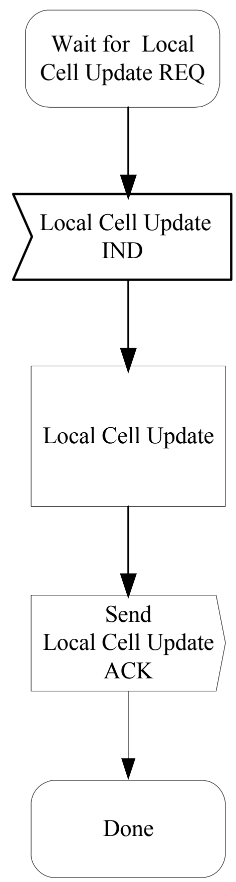


Figure 49n—Local cell update at A-BS

7.14.4.13 A-BS transmits channel sets to CPE

The A-BS shall send the channel sets to the new CPE. The channel sets are described in 10.2.3. The channel sets that are sent to the initializing CPE are the backup channels and the candidate channels. The channel sets are sent in a DCD message, as described in 7.7.1 and in Table 24 to Table 26. The A-BS shall send DCD channel information elements 11 and 12. Table 26 describes information element 12 as the backup and candidate channel list. It is a prioritized list of the channels with the backup channel set higher in priority than the candidate channel set. The two sets are identified by sending information element 11, which provides the number of the higher prioritized backup channel set. Each channel in DCD information element 12 is characterized by both the channel number.

The distributed scheduling A-CPE shall send the channel sets received from A-BS to the new CPE, which is registered with the distributed scheduling A-CPE. The channel sets are described in 10.2.3. The channel sets that are sent to the initializing CPE are the backup channels and the candidate channels. The channel sets are sent in a DCD message in a DRZ, as described in 7.7.1 and in Table 24 to Table 26. The distributed scheduling A-CPE shall send DCD channel information elements 11 and 12. Table 26 describes information element 12 as the backup and candidate channel list. It is a prioritized list of the channels with the backup channel set higher in priority than the candidate channel set. The two sets are identified by sending information element 11, which provides the number of the higher prioritized backup channel set. Each channel in DCD information element 12 is characterized by both the channel number.

7.14.4.14 Establish IP connectivity

The CPE shall invoke DHCP mechanism (IETF RFC 2131 [B20]) in order to obtain an IP address and any other parameters needed to establish IP connectivity. If the CPE has a configuration file, the DHCP response shall contain the name of a file that contains further configuration parameters.

Establishment of IP connectivity shall be performed on the CPE's secondary management connection as shown in Figure 45.

In case where dynamic IP configuration is not preferred, the CPE shall obtain an IP address from its base station.

7.14.4.15 Establish time of day

The CPE and A-BS need to have the current date and time. This is required for time-stamping logged events for retrieval by the management system. This needs not be authenticated and needs to be accurate only to the nearest second. The current date and time may be obtained from a local time source or a remote service such as an NTP server. See Figure 46.

Successfully acquiring the Time of Day is not mandatory for a successful registration, but is necessary for ongoing operation. The specific timeout for Time of Day Requests is implementation dependent.

7.14.4.16 Transfer operational parameters

The CPE shall download the CPE's configuration file using TFTP on its own secondary management connection as shown in Figure 47. The CPE shall use an adaptive timeout for TFTP based on binary exponential backoff.

When the configuration file download has completed successfully, the CPE shall notify the A-BS directly or through the A-CPE by transmitting the TFTP-CPLT message on the CPE's primary management connection. Transmissions shall continue successfully until a TFTP-RSP message is received with response "OK" from the A-BS (see Figure 48 and Figure 49) or the CPE terminates retransmission due to retry exhaustion.

Upon sending a REG-RSP, the A-BS shall wait for a TFTP-CPLT. If the timer T13 (defined in Table 272) expires, the A-BS shall restart the registration process (REG-REQ/RSP) with the CPE (see Figure 48). Note that the Timer T26 refers to the time waited for TFTP-RSP. If T26 expires, then TFTP-CPLT is attempted until the maximum number of retries is exhausted. Upon the exhaustion, the CPE shall be deregistered (i.e., forced to reinitialize MAC) by sending a DREG-REQ with Action Code set to 0x05 to force itself to reattempt system access or 0x04 to shut itself down (see Figure 49).

7.14.4.17 Establish dynamic service flows

After the transfer of operational parameters for the CPE, the A-BS shall send DSA-REQ messages (Table 64) to the CPE to set up pre-provisioned service flows belonging to the CPE. The CPE responds with DSARSP messages. This is described further in 7.18.7.1.

7.14.4.18 Neighboring network discovery

After a CPE has registered with an A-WRAN A-BS, it shall perform neighboring network discovery in order to identify other nearby A-WRANs and enable efficient self-coexistence, if the CPE has not already done so. The neighboring network discovery involves listening to the medium for CBP packets or A-BS transmitted by other A-WRAN A-BSs. This network discovery mechanism is described in 7.20.1.3.

7.15 Ranging

Insert the following paragraphs after the first paragraph in the preliminary text of 7.15:

An A-WRAN system provides a further ranging, which will be performed between CPEs and the distributed scheduling A-CPE as well as between CPEs and the centralized scheduling A-CPE for relaying.

The A-WRAN ranging can be categorized as the following ranging operations:

a) Between CPEs and A-BS (ranging)
b) Between CPEs and A-BS from relaying on the centralized scheduling A-CPE (relay ranging)
c) Between CPEs and the distributed scheduling A-CPE (local ranging)

7.15.1 DS management

Insert the following subclause heading (7.15.1.1) immediately after the 7.15.1 heading (the text formerly in 7.15.1 is now in 7.15.1.1):

7.15.1.1 DS management (A-BS and CPE)

Insert the following subclauses (7.15.1.2 and 7.15.1.3 and their figures) after 7.15.1.1:

7.15.1.2 Local DS management (distributed scheduling A-CPE and S-CPE)

To maintain efficient local cell operations between the distributed scheduling A-CPE and S-CPEs, the DS burst profile in a DRZ is determined by the distributed scheduling A-CPE according to the quality of the signal that is received by each S-CPE. To reduce the volume of US traffic in a DRZ, the S-CPE monitors the CINR and compares the average value against the allowed range of operation. As shown in Figure 50, threshold levels bound this region. These thresholds parameters are specified in the DCD message transmitted by the distributed scheduling A-CPE and shall be used by S-CPEs to determine their optimal burst profile. If the received CINR falls outside of the allowed operating region as determined by the threshold parameters, the S-CPE requests a change to a new burst profile using one of the following two methods:

a) If the S-CPE has been granted US bandwidth in a DRZ (a data grant allocation to the S-CPE's Basic FID), the S-CPE shall send a RNG-REQ message in that allocation. The distributed scheduling A-CPE responds with a RNG-CMD message.
b) If a grant is not available and the S-CPE requires a more robust burst profile on the DS, the S-CPE shall send a RNG-REQ message in an Initial Ranging interval of the DRZ.

In either of these methods, the message is sent using the S-CPE's Basic FID. The coordination of message transmission and reception relative to actual change of modulation is different depending upon whether an S-CPE is transitioning to a more or less robust burst profile. Figure 52a shows the case where an S-CPE is transitioning to a more robust profile, and Figure 52b illustrates the transition to a less robust profile.

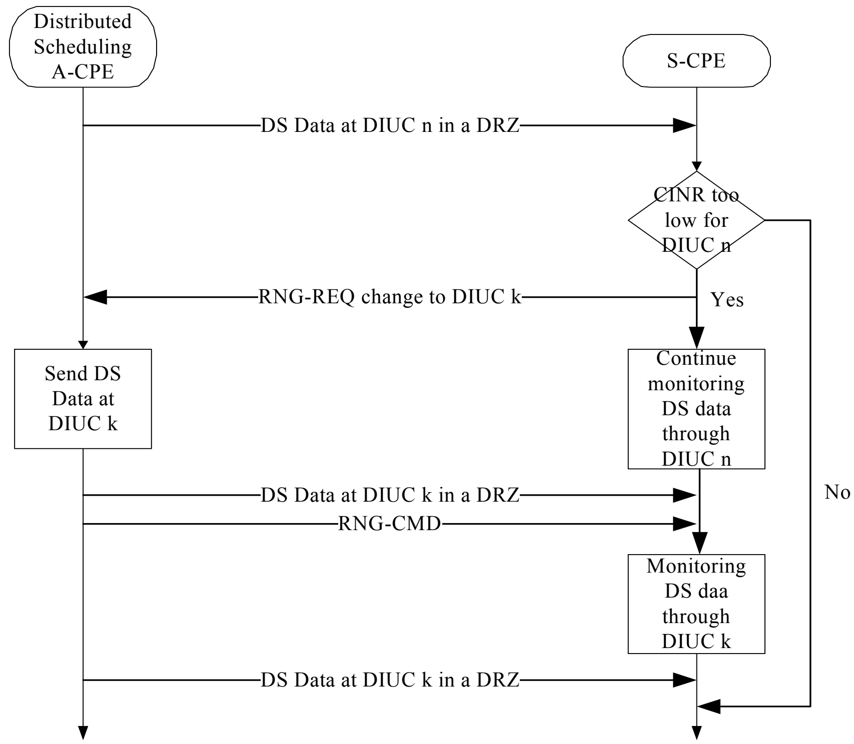


Figure 52a—Change to a more robust profile in a local cell

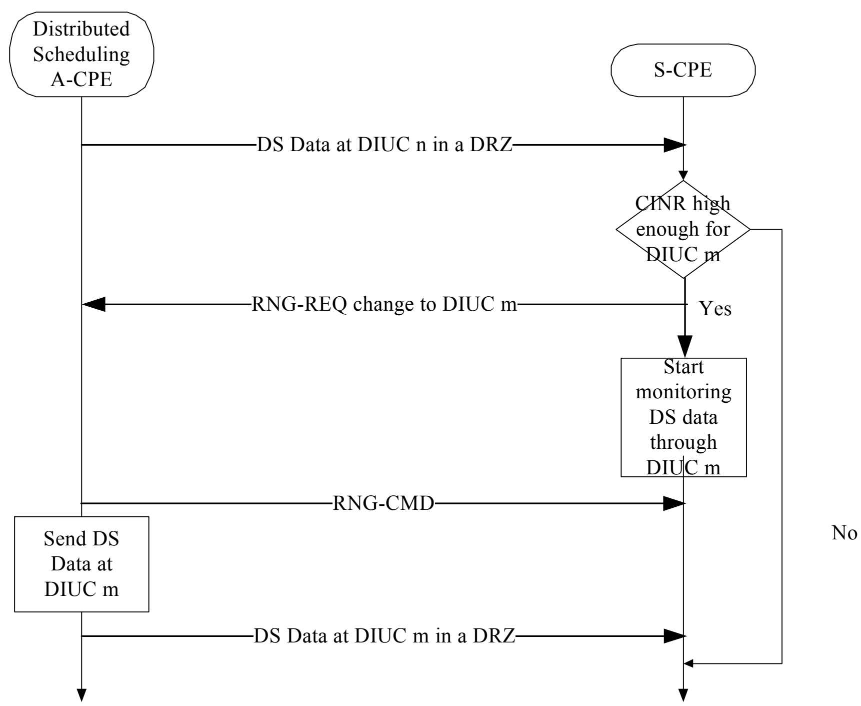


Figure 52b—Change to a less robust profile in a local cell

7.15.1.3 Relay DS management (A-BS and S-CPE via centralized scheduling A-CPE)

Direct DS from the A-BS to the S-CPE may transit to relay DS from the A-BS to the S-CPE through the centralized scheduling A-CPE as shown in Figure 52c when the relay DS has a higher gain than the DS, and vice versa.

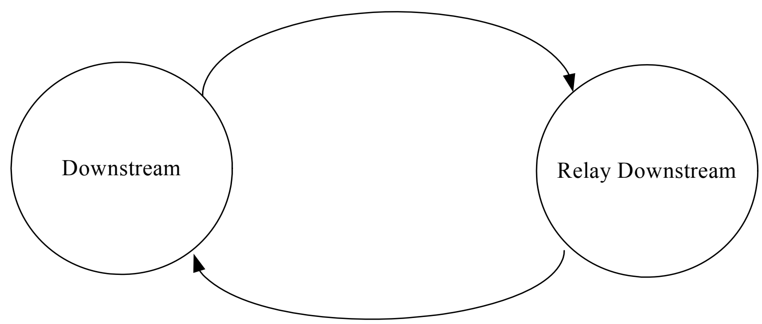


Figure 52c—Transit between DS and relay DS

The transit from DS to relay DS may be performed from the request of each S-CPE. Before an S-CPE transits DS to relay DS, the S-CPE shall confirm the relay DS burst profile by the following relay DS test procedure (see Figure 52d).

- The S-CPE shall detect a centralized scheduling A-CPE for relay by a CRZ initial ranging procedure.
- If CRZ initial ranging is successfully finished, the S-CPE requests the A-BS to start a relay DS test by sending a DS Transit Test Request (DTT-REQ, 7.7.27.1), which includes a selected centralized scheduling A-CPE's SID (Figure 52e).
- The A-BS sends a DS Transit Test Response (DTT-RSP, 7.7.27.2), which indicates the start frame of a bandwidth allocation for a relay DS test, to the S-CPE.
- During the allocated bandwidth, the A-BS transmits test frames to the S-CPE by relaying on the centralized scheduling A-CPE (Figure 52f).
- The S-CPE calculates relay DS burst profile and reports the calculation result (DST-RPT, 7.7.27.3), which includes a relay DS bust profile, to the A-BS.
- Based on the relay DS burst profile, the A-BS decides to transit from DS to relay DS, and a DS Transmit Confirmation (DST-CFM, 7.7.27.4) is sent to the S-CPE (Figure 52g).

Before an S-CPE transits from relay DS to DS, on the other hand, the S-CPE shall confirm the DS burst profile.

- The S-CPE shall confirm DS burst profile from monitoring signals such as a frame preamble, FCH, or DS-MAP transmitted by the A-BS.
- The S-CPE reports the DS burst profile to the A-BS by using a DST-RPT (7.7.27.3).
- Based on the relay DS burst profile, the A-BS decides to transit from relay DS to DS, and a DST-CFM (7.7.27.4) is sent to the S-CPE.

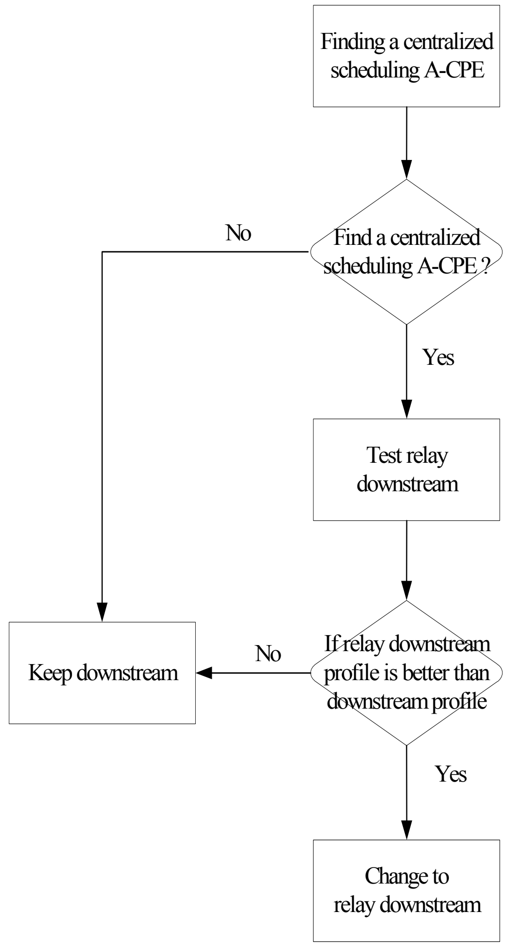


Figure 52d—Relay DS test procedure

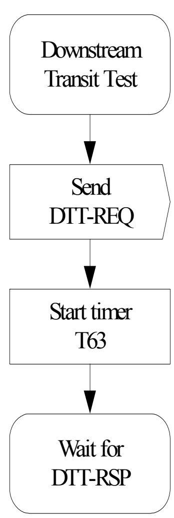


Figure 52e—DS transit request—CPE

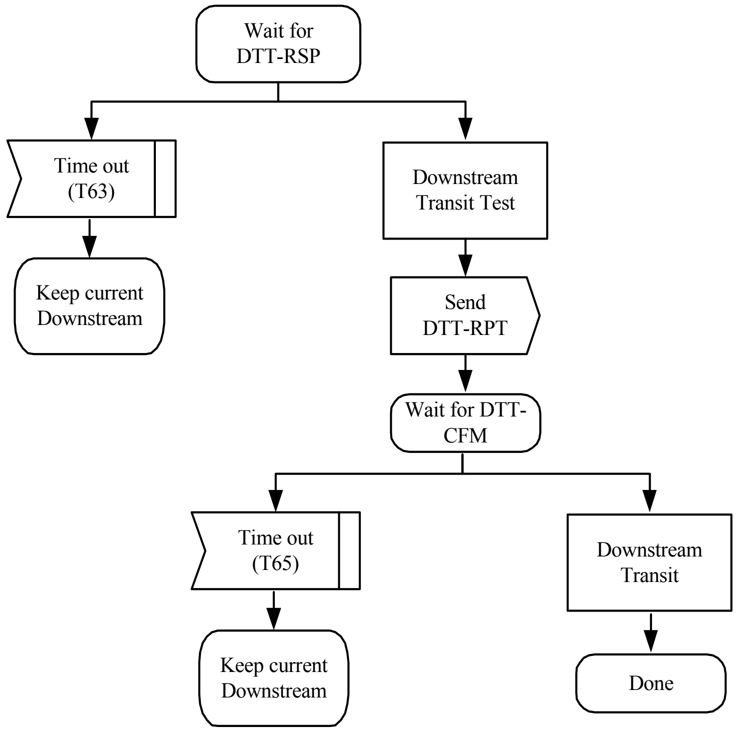


Figure 52f—Wait for DTT-RSP and DS Transit Test—CPE

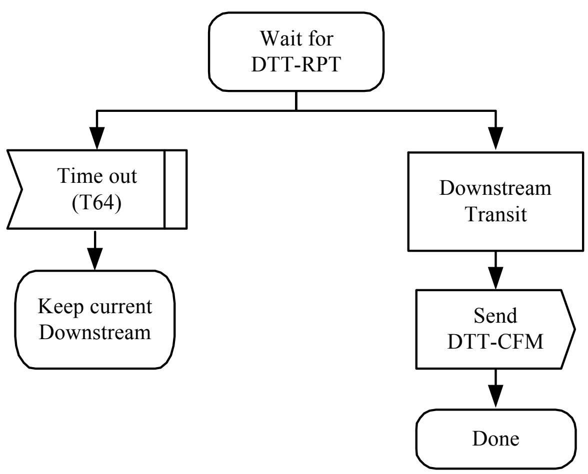


Figure 52g—Wait for DTT-RPT—A-BS

During relay DS, the S-CPE requests a change to a relay DS burst profile using one of the following methods:

— If the S-CPE has been granted US bandwidth in a CRZ (a data grant allocation to the S-CPE's Basic FID), the S-CPE shall send a RNG-REQ message to the centralized scheduling A-CPE in the bandwidth. If a grant is not available, the S-CPE shall send a RNG-REQ message in a CRZ Initial

Ranging interval to the centralized scheduling A-CPE. The centralized scheduling A-CPE continues with the following procedure:

- If the centralized scheduling A-CPE has been granted US bandwidth in an AZ and
  - If the centralized scheduling A-CPE has no change of DS burst profile, then the centralized scheduling A-CPE shall send the RNG-REQ message received from the S-CPE to the A-BS.
  - If the centralized scheduling A-CPE needs to change the DS burst profile, then the centralized scheduling A-CPE shall send a Container message including the RNG-REQ message received from the S-CPE and the RNG-REG message itself to the A-BS.
- If a grant is not available for the centralized scheduling A-CPE and
  - If the centralized scheduling A-CPE has no change of DS burst profile, then the centralized scheduling A-CPE shall send the RNG-REQ message received from the S-CPE in a CRZ Initial Ranging interval to the A-BS.
  - if the centralized scheduling A-CPE needs to change the DS burst profile, then the centralized scheduling A-CPE shall send a Container message including the RNG-REQ message received from the S-CPE and the RNG-REG message itself in an Initial Ranging interval to the A-BS.

- The A-BS responds with a RNG-CMD message and broadcasts the DCD with the relay DS burst profile.

7.15.2 US management

Change the preliminary text of 7.15.2 as follows:

Upstream ranging management consists of two procedures: initial ranging and periodic ranging. Initial ranging (see 7.14) allows a CPE joining the network to acquire correct transmission parameters, such as time offset and Tx EIRP level, so that the CPE can communicate with the BS/A-BS or the distributed scheduling A-CPE. Initial Ranging is categorized as initial ranging between CPEs and A-BS, relay initial ranging between CPEs and A-BS from relaying on the centralized scheduling A-CPE, and local initial ranging between CPEs and the distributed scheduling A-CPE. The WRAN/A-WRAN PHY specifies a ranging subchannel and a set of special pseudo-noise ranging codes. Initial ranging is performed by using initial ranging codes at initial ranging subchannel in an AZ, relay initial ranging is performed by using CRZ initial ranging codes at relay initial ranging subchannel in a CRZ, and local initial ranging is performed by DRZ initial ranging codes at local initial ranging subchannel in a DRZ. Subsets of codes shall be allocated in the UCD channel encoding for initial ranging, periodic ranging requests, and BRs so that the BS/A-BS can determine the purpose of the received code by the subset to which the code belongs. CPEs that wish to perform one of the aforementioned operations shall select, with equal probability, one of the codes of the appropriate subset, modulate it onto the ranging subchannel, and subsequently transmit in the ranging slot selected with equal probability from the available ranging slots on the upstream subframe. A CPE shall select one Ranging Slot from all available ranging slots in the upstream frame using a uniform random process. Details on the modulation and ranging codes are specified in 9.9.2. Following initial ranging, periodic ranging allows the CPE to adjust transmission parameters so that it can maintain upstream communications with the BS/A-BS.

The following subclauses summarize the general algorithm for initial ranging and periodic ranging.

Insert the following subclauses (7.15.2.3 and 7.15.2.4 and their subclauses) after 7.15.2.2:

7.15.2.3 CDMA initial ranging and automatic adjustments for a relay network

7.15.2.3.1 CDMA initial ranging and automatic adjustments (A-BS and CPE)

A CPE that wishes to perform initial ranging with CDMA code in an AZ shall take the following steps:

a) The CPE, after acquiring downlink synchronization and uplink transmission parameters from the A-BS in an AZ, shall select one Ranging Slot using the random backoff. The random backoff shall use a binary truncated exponent algorithm. After selecting the Ranging Slot, the CPE shall choose a Ranging Code (from the Initial Ranging domain) using a uniform random process. The selected Ranging Code is sent to the A-BS (as a CDMA code) in the selected Ranging Slot.

b) The A-BS cannot tell which CPE sent the CDMA ranging request; therefore, upon successfully receiving a CDMA ranging code, the A-BS broadcasts a ranging response message (RNG-CMD) that advertises the received ranging code as well as the ranging slot (OFDMA symbol number, etc.) where the CDMA ranging code has been identified. This information is used by the CPE that sent the CDMA ranging code to identify the ranging response message that corresponds to its ranging request. The ranging response message contains all the needed adjustments (e.g., time, EIRP, and possibly frequency corrections) and a status notification.

c) Upon receiving a RNG-CMD message with the "Continue" status, the CPE shall continue the ranging process as done on the first entry (using random selection rather than random backoff) with ranging codes randomly chosen from the initial ranging domain sent on the ranging slots.

d) When the A-BS receives an initial-ranging CDMA code that requires no corrections, the A-BS shall provide BW allocation for the CPE using the CDMA_Allocation_IE to send an RNG-REQ message. Sending the RNG-CMD message with status "Success" is optional.

e) The initial ranging process is over after receiving RNG-CMD message, which includes a valid SID (following a RNG-REQ transmission on a CDMA Allocation IE). If this RNG-CMD message includes a "continue" indication, the ranging process should be continued using the ranging mechanism.

f) The timeout required for the CPE to wait for RNG-CMD, following or not following a CDMA Allocation IE, is defined by the timer T3.

7.15.2.3.2 CDMA local initial ranging and automatic adjustments (distributed scheduling A-CPE and S-CPE)

A CPE acquires local downlink synchronization and local uplink transmission parameters from distributed scheduling A-CPE only.

A CPE that wishes to perform local initial ranging with CDMA code in a DRZ shall take the following steps:

a) The CPE, after acquiring downlink synchronization and uplink transmission parameters from the distributed scheduling A-CPE, shall select one Ranging Slot in a DRZ (DRZ Ranging Slot) using the random backoff. The random backoff shall use a binary truncated exponent algorithm. After selecting the DRZ Ranging Slot, the CPE shall choose a Ranging Code (from the Initial Ranging domain) using a uniform random process. The selected Ranging Code is sent to the distributed scheduling A-CPE (as a CDMA code) in the selected DRZ Ranging Slot.

b) The distributed scheduling A-CPE cannot tell which CPE sent the CDMA ranging request; therefore, upon successfully receiving a ranging code, the distributed scheduling A-CPE broadcasts a RNG-CMD message that advertises the received DRZ ranging code as well as the DRZ ranging slot (OFDMA symbol number, etc.) where the ranging code has been identified. This information is used by the CPE that sent the ranging code to identify the RNG-CMD message that corresponds to its ranging request. The RNG-CMD message contains all the needed adjustments (e.g., time, EIRP, and possibly frequency corrections) and a status notification.

c) Upon receiving a RNG-CMD message with the "Continue" status, the CPE shall continue the ranging process as done on the first entry (using random selection rather than random backoff) with ranging codes randomly chosen from the DRZ initial ranging domain sent on the DRZ Ranging Slots.
d) When the distributed scheduling A-CPE receives an initial-ranging CDMA code that requires no corrections, the distributed scheduling A-CPE shall provide BW allocation in a DRZ for the CPE using the CDMA_Allocation_IE to send an RNG-REQ message. Sending the RNG-CMD message with status "Success" is optional.
e) The DRZ initial ranging process is over after receiving RNG-CMD message, which includes a valid SID (following a RNG-REQ transmission on a CDMA Allocation IE). The distributed scheduling A-CPE shall choose one SID from the Local SID Group for the CPE's SID. If this RNG-CMD message includes a "continue" indication, the ranging process should be continued using the ranging mechanism.
f) The timeout required for the CPE to wait for RNG-CMD, following or not following a CDMA Allocation IE, is defined by the timer T3.

7.15.2.3.3 CDMA relay initial ranging and automatic adjustments (centralized scheduling A-CPE and S-CPE)

A CPE attempting to acquire downlink synchronization and uplink transmission parameters from the A-BS in an AZ shall perform initial ranging with CDMA code. However, the initial ranging request from the CPE may not arrive to the A-BS due to the transmission power constraint of the CPE. In this case, a certain centralized scheduling A-CPE may perform relay initial ranging for the CPE.

a) The CPE, after acquiring downlink synchronization and uplink transmission parameters from the A-BS, may select one Ranging Slot in an US CRZ (CRZ Ranging Slot) using the random backoff. The random backoff shall use a binary truncated exponent algorithm. After selecting the CRZ Ranging Slot, the CPE shall choose a CRZ Initial Ranging Code (from the CRZ initial Ranging domain) for the CRZ Ranging Slot using a uniform random process. The selected CRZ Ranging Code is sent to the centralized scheduling A-CPE in the selected CRZ Ranging Slot. In this stage, the CPE is not aware whether the centralized scheduling A-CPE exists within the transmission range of the CPE.
b) The centralized scheduling A-CPE may receive many CRZ Ranging Codes in the CRZ Ranging Slot. The centralized scheduling A-CPE cannot tell which CPE sent the ranging request; therefore, upon successfully receiving a CRZ ranging code during the CRZ Ranging Slot, the centralized scheduling A-CPE sends a RNG-RPT message (7.7.31) that contains initial ranging adjustment information such as the initial ranging status, the received CRZ ranging code, and the received CRZ ranging slot (OFDMA symbol number, etc.) where the CRZ ranging code has been identified.
c) When an A-BS receives the RNG-RPT with the status set to 0 (require initial ranging adjustment), the A-BS transmits RNG-CMD to the CPE, where the RNG-CMD message contains all the needed adjustments (e.g., time, EIRP, and possibly frequency corrections) and a status notification.
d) When the CPE receives several RNG-CMD messages sent from the A-BS, the CPE chooses one RNG-CMD from the received RNG-CMDs for the further ranging.
e) Upon receiving a RNG-CMD message with the "Continue" status, the CPE shall continue the ranging process as done on the first entry with CRZ ranging codes on the CRZ ranging slot to the centralized scheduling A-CPE.
f) When an A-BS receives the RNG-RPT with the status set to 1 (initial ranging done), the A-BS allocates a CRZ US bandwidth by using CDMA_Allocation_IE in the CRZ US-MAP IE in which the CPE transmitted RNG-REQ to the centralized scheduling A-CPE. In this stage, a valid SID is

not assigned for the CPE. The centralized scheduling A-CPE shall transmit the RNG-REQ received from the CPE to the A-BS.

g) On successfully receiving the RNG-REQ, the A-BS shall provide a valid SID for the CPE by sending a RNG-CMD message. If this RNG-CMD message includes a "continue" indication, the ranging process should be continued using the ranging mechanism.
h) The timeout required for the CPE to wait for RNG-CMD is defined by the timer T3.

7.15.2.4 CDMA Periodic ranging and automatic adjustments for a relay network

7.15.2.4.1 CDMA periodic ranging and automatic adjustments (A-BS and CPE)

The following summarizes the general algorithm for CDMA periodic ranging between the A-BS and the CPE:

a) The CPE shall choose randomly a Ranging Slot (with random selection with equal probability from available Ranging Slots in a single frame) at the time in an AZ to perform the ranging, and then it chooses randomly a Periodic Ranging Code and sends it to the A-BS (as a CDMA code).
b) If the CPE does not receive a response, the CPE may send a new CDMA code at the next appropriate ranging transmission opportunity at one step higher EIRP level.
c) The A-BS cannot tell which CPE sent the CDMA ranging request; therefore, upon successfully receiving a CDMA periodic ranging code, the A-BS broadcasts a ranging response (RNG-CMD) message that advertises the received periodic ranging code as well as the ranging slot (OFDMA symbol number, etc.) where the CDMA periodic ranging code has been identified. This information is used by the CPE that sent the CDMA periodic ranging code to identify the ranging response message that corresponds to its ranging request. The ranging response message contains all the needed adjustments (e.g., time, EIRP, and possibly frequency corrections) and a status notification.
d) Upon receiving a RNG-CMD message with the "Continue" status, the CPE shall continue the ranging process with further periodic ranging codes randomly chosen. Upon receiving an RNG-CMD message with success status, the CPE shall restart timer T4 with the appropriate value depending on whether the CPE is fixed or portable (see Table 273).
e) The A-BS may send an unsolicited RNG-CMD as a response to a CDMA-based bandwidth-request or any other data transmission from the CPE.
f) Upon timeout of the CPE internal T4 timer, the CPE shall perform Periodic Ranging according to the procedure above.
g) When the CPE receives an unsolicited RNG-CMD message, it shall reset the periodic ranging timer and adjust the parameters (timing, EIRP, etc.) as notified in the RNG-CMD message.

7.15.2.4.2 CDMA local periodic ranging and automatic adjustments (distributed scheduling A-CPE and CPE)

The following summarizes the general algorithm for CDMA periodic ranging between the distributed scheduling A-CPE and the CPE in a local cell:

a) The CPE shall choose randomly a Ranging Slot (with random selection with equal probability from available Ranging Slots in a single frame) at the time in a DRZ to perform the ranging, and then it chooses randomly a Periodic Ranging Code and sends it to the distributed scheduling A-CPE (as a CDMA code).
b) If the CPE does not receive a response, the CPE may send a new CDMA code at the next appropriate ranging transmission opportunity at one step higher EIRP level.
c) The distributed scheduling A-CPE cannot tell which CPE sent the CDMA ranging request; therefore, upon successfully receiving a CDMA periodic ranging code, the distributed scheduling

A-CPE broadcasts a ranging response (RNG-CMD) message that advertises the received periodic ranging code as well as the DRZ ranging slot (OFDMA symbol number, etc.) where the CDMA periodic ranging code has been identified. This information is used by the CPE that sent the CDMA periodic ranging code to identify the ranging response message that corresponds to its ranging request. The ranging response message contains all the needed adjustments (e.g., time, EIRP, and possibly frequency corrections) and a status notification.

d) Upon receiving a RNG-CMD message with the “Continue” status, the CPE shall continue the ranging process with further periodic ranging codes randomly chosen. Upon receiving an RNG-CMD message with success status, the CPE shall restart timer T4 with the appropriate value depending on whether the CPE is fixed or portable (see Table 273).
e) The distributed scheduling A-CPE may send an unsolicited RNG-CMD as a response to a CDMA-based bandwidth-request or any other data transmission from the CPE.
f) Upon timeout of the CPE internal T4 timer, the CPE shall perform Periodic Ranging according to the procedure above.
g) When the CPE receives an unsolicited RNG-CMD message, it shall reset the periodic ranging timer and adjust the parameters (timing, EIRP, etc.) as notified in the RNG-CMD message.

7.15.2.4.3 CDMA relay periodic ranging and automatic adjustments (centralized scheduling A-CPE and CPE)

The following summarizes the general algorithm for CDMA periodic ranging between the centralized scheduling A-CPE and the CPE:

a) The CPE shall choose randomly a Ranging Slot (with random selection with equal probability from available Ranging Slots in a single frame) at the time in a CRZ to perform the ranging, and then it chooses randomly a CRZ Periodic Ranging Code and sends it to the centralized scheduling A-CPE (as a CDMA code).
b) If the CPE does not receive a response, the CPE may send a new CDMA code at the next appropriate ranging transmission opportunity at one step higher EIRP level.
c) The centralized scheduling A-CPE cannot tell which CPE sent the CDMA ranging request; therefore, upon successfully receiving a CDMA periodic ranging code, the centralized scheduling A-CPE sends a RNG-RPT message that contains ranging adjustment information such as the ranging status, the received CRZ periodic ranging code, and the CRZ ranging slot (OFDMA symbol number, etc.) where the CDMA periodic ranging code has been identified. This information is used by the CPE that sent the CDMA periodic ranging code to identify the ranging response message that corresponds to its ranging request. The ranging response message contains all the needed adjustments (e.g., time, EIRP, and possibly frequency corrections) and a status notification.
d) Upon receiving a RNG-CMD message with the “Continue” status, the CPE shall continue the ranging process with further periodic ranging codes randomly chosen. Upon receiving an RNG-CMD message with success status, the CPE shall restart timer T4 with the appropriate value depending on whether the CPE is fixed or portable (see Table 273).
e) The A-BS may send an unsolicited RNG-CMD as a response to a CDMA-based bandwidth-request or any other data transmission from the CPE.
f) Upon timeout of the CPE internal T4 timer, the CPE shall perform Periodic Ranging according to the procedure above.
g) When the CPE receives an unsolicited RNG-CMD message, it shall reset the periodic ranging timer and adjust the parameters (timing, EIRP, etc.) as notified in the RNG-CMD message.

7.16 Channel descriptor management

Change the first, second, and last paragraphs of 7.16 as follows:

As previously presented, channel descriptor messages (i.e., DCD and UCD) are broadcast by the BS/A-BS to all associated CPEs at periodic intervals as well as broadcast by the distributed scheduling A-CPE to the associated CPEs in its local cell at periodic intervals. Among other things, these channel descriptors define burst profiles, which are used by US-MAP and DS-MAP messages for allocating upstream and downstream transmissions, respectively. Once broadcast by the BS/A-BS or the distributed scheduling A-CPE and received by its associated CPEs, a given channel descriptor shall remain valid until a new channel descriptor message with a different value for the Configuration Change Count field is again broadcast by the BS/A-BS or the distributed scheduling A-CPE. When this happens, this new channel descriptor shall overwrite all the information of the previous descriptor. When the distributed scheduling A-CPE receives a new DS channel descriptor for channel switching from the BS/A-BS, the distributed scheduling A-CPE shall immediately broadcast the new DS channel descriptor with the same information of channel switching (i.e., channel action, action mode, and action frame number) to the associated CPEs in the local cell so the operating channel in the local cell can be changed to the same channel of the BS/A-BS's cell at the same time.

Once channel descriptors are known to all CPEs in ~~an IEEE 802.22~~ a WRAN BS's cell or A-WRAN A-BS's cell, the BS/A-BS shall set the UCD/DCD Count value in an AZ, contained in US-MAP and DS-MAP messages, equal to the Configuration Change Count of the desired channel descriptor. Once channel descriptors are known to all CPEs in the distributed scheduling A-CPE's local cell, the distributed scheduling A-CPE shall set the UCD/DCD Count value in a DRZ, contained in US-MAP and DS-MAP messages, equal to the Configuration Change Count of the desired channel descriptor. This way, a BS/A-BS or a distributed scheduling A-CPE can easily indicate to the CPEs which burst profile is to be used for a given allocation and hence provide high flexibility to the BS/A-BS or the distributed scheduling A-CPE in controlling which burst profile to use at any given time by simply changing the UCD/DCD Count value.

. . .

Finally, note that the Configuration Change Count shall be incremented by 1 modulo 256 for every new migration of channel descriptor. After issuing a DS-MAP or US-MAP message with the Configuration Change Count equal to that of the new generation, the old channel descriptor ceases to exist and the BS/A-BS or the distributed scheduling A-CPE shall not refer to it anymore. When migrating from one generation to the next, the BS/A-BS or the distributed scheduling A-CPE shall schedule the transmissions of the UCD and DCD messages in such a way that each CPE has the possibility to successfully hear it at least once.

7.18 QoS

7.18.9 Service Flow Management

7.18.9.3 Dynamic Service Addition

7.18.9.3.1 CPE-initiated DSA

Insert the following subclause (7.18.9.3.1.1) after 7.18.9.3.1:

7.18.9.3.1.1 A-BS and A-CPE behavior during CPE-initiated DSA

When a DSA-REQ message is sent from a CPE, the centralized scheduling A-CPE and the A-BS may deal with the message in the following way:

— The centralized scheduling A-CPE may add the acceptable QoS parameter set to the DSA-REQ if it cannot support the requested QoS parameter set. It then sends the DSA-REQ to the A-BS using the primary management CID of the CPE.
— The centralized scheduling A-CPE may include a Per-RS QoS TLV in the DSA-REQ to the A-BS. The Per-RS QoS TLV in this case represents the maximum latency at the centralized scheduling A-CPE to relay the requested QoS parameter set. If the A-BS receives the Per-RS QoS TLV, the A-BS shall consider the value in the Per-RS QoS TLV and the values in the requested QoS parameter set.
— The centralized scheduling A-CPE may get the updated SF parameters and confirmation code from the DSA-RSP and DSA-ACK sent from the A-BS and the CPE, respectively.
— Upon receiving the DSA-REQ from the CPE via the centralized scheduling A-CPE, the A-BS sends back a response to the CPE in the same way defined for non-relay systems. The admission control algorithm is out of the scope of this standard.
— If the service flow parameters are changed, the A-BS shall send a DSC-REQ to the centralized scheduling A-CPE before sending a DSA-RSP to the SS.

7.18.9.3.2 BS-initiated DSA

Insert the following subclause (7.18.9.3.2.1) after 7.18.9.3.2:

7.18.9.3.2.1 A-BS and A-CPE behavior during A-BS-initiated DSA

When an A-BS initiates a DSA-REQ message to a CPE via a centralized scheduling A-CPE, the centralized scheduling A-CPE and the A-BS may deal with the message in the following way:

— If the service flow parameters are changed, the A-BS shall send a DSC-REQ to the centralized scheduling A-CPE before sending the DSA-REQ to the CPE in the same manner as defined above.
— The A-BS may include a Per-RS QoS TLV in the DSA-REQ to the centralized scheduling A-CPE. If the centralized scheduling A-CPE receives the Per-RS QoS TLV, the centralized scheduling A-CPE shall use the values in the Per-RS QoS TLV instead of the ones in the service flow parameters.
— When the centralized scheduling A-CPE can support the requested QoS parameter set, it sends the DSA-REQ to the CPE using the primary management CID of the CPE.
— When the centralized scheduling A-CPE cannot support the requested QoS parameter set in the DSA-REQ, it sends the DSA-RSP with the CC set to reject-RS-not-supported-parameter-value to the A-BS indicating that it can support the requested QoS parameter set. The DSA-RSP may contain the acceptable QoS parameter set that the centralized scheduling A-CPE can support.
— The centralized scheduling A-CPE may get the updated SF parameters and confirmation code from the DSA-RSP and DSA-ACK sent from the CPE and the A-BS, respectively.

7.18.9.4 Dynamic Service Change

7.18.9.4.1 CPE-initiated DSC

Insert the following subclause (7.18.9.4.1.1) after 7.18.9.4.1:

7.18.9.4.1.1 A-BS and centralized scheduling A-CPE behavior during CPE-initiated DSC

When a DSC-REQ message is sent from a CPE, a centralized scheduling A-CPE and the A-BS may deal with the message in the following way:

— The centralized scheduling A-CPE may add the acceptable QoS parameter set to the DSC-REQ if it cannot support the requested QoS parameter set. It then sends the DSC-REQ to the A-BS using the primary management CID of the CPE.

— The centralized scheduling A-CPE may include the Per-RS QoS TLV in the DSC-REQ to the A-BS. The Per-RS QoS TLV in this case represents the maximum latency at the centralized scheduling A-CPE to relay the requested QoS parameter set. If the A-BS receives the Per-RS QoS TLV, the A-BS shall consider the value in the Per-RS QoS TLV and the values in the requested QoS parameter set.
— The centralized scheduling A-CPE may get the updated SF parameters and confirmation code from the DSC-RSP and DSC-ACK sent from the A-BS and the CPE, respectively.
— Upon receiving the DSC-REQ from the CPE via the centralized scheduling A-CPE, the A-BS sends back a response to the CPE in the same way defined for non-relay systems. The admission control algorithm is out of the scope of this standard.
— If the service flow parameters are changed, the A-BS shall send a DSC-REQ to the centralized scheduling A-CPE before sending a DSC-RSP to the CPE.

7.18.9.4.2 BS-initiated DSC

Insert the following subclause (7.18.9.4.2.1) after 7.18.9.4.2:

7.18.9.4.2.1 A-BS and centralized scheduling A-CPE behavior during A-BS-initiated DSC

When an A-BS initiates a DSC-REQ message to a CPE via a centralized scheduling A-CPE, the centralized scheduling and the A-BS may deal with the message in the following way:

— If the service flow parameters are changed, the A-BS shall send a DSC-REQ to the centralized scheduling A-CPE before sending the DSC-REQ to the CPE.
— The A-BS may include a Per-RS QoS TLV in the DSC-REQ to the centralized scheduling A-CPE. If the centralized scheduling A-CPE receives the Per-RS QoS TLV, the centralized scheduling A-CPE shall use the values in the Per-RS QoS TLV instead of the ones in the service flow parameters.
— When the centralized scheduling A-CPE can support the requested QoS parameter set, it sends the DSC-REQ to the CPE using the primary management CID of the CPE.
— When the centralized scheduling A-CPE cannot support the requested QoS parameter set in the DSC-REQ, it sends a DSC-RSP with the CC set to reject-RS-not-supported-parameter-value to the A-BS indicating that it cannot support the requested QoS parameter set. The DSC-RSP may contain the acceptable QoS parameter set that the centralized scheduling A-CPE can support.
— The centralized scheduling A-CPE may get the updated SF parameters and confirmation code from the DSC-RSP and DSC-ACK sent from the CPE and the A-BS, respectively.

7.18.9.5 Dynamic Service Deletion

7.18.9.5.1 CPE-initiated DSD

Insert the following subclause (7.18.9.5.1.1) after 7.18.9.5.1:

7.18.9.5.1.1 A-BS and centralized scheduling A-CPE behavior during CPE-initiated DSD

When a DSD-REQ message is sent from a CPE, the centralized scheduling A-CPE relays it to the A-BS using the primary management CID of the CPE. After processing the DSD-REQ, the A-BS replies with a DSD-RSP using the CPE primary management CID. When the centralized scheduling A-CPE receives the DSD-RSP, it deletes the service flow information and relays it to the CPE.

7.18.9.5.2 BS-initiated DSD

Insert the following subclause (7.18.9.5.2.1) after 7.18.9.5.2:

7.18.9.5.2.1 A-BS and centralized scheduling A-CPE behavior during A-BS-initiated DSD

When an A-BS initiates a DSD-REQ message to a CPE via a centralized scheduling A-CPE using the primary management CID of the CPE, the centralized scheduling A-CPE relays it to the CPE using the primary management CID of the CPE. When the centralized scheduling A-CPE receives a DSD-RSP sent from the CPE, it deletes the service flow information and relays it to the A-BS.

7.19 Incumbent protection

Insert the following paragraph after the second paragraph in the preliminary text of 7.19:

An A-WRAN shall support incumbent protection on relay connection between an A-BS and CPEs. The incumbent protection procedures when the direct connection exists between the A-BS and CPEs shall follow the operations described from 7.19.1 to 7.19.6. The measurement management and notification procedures of incumbent protection for a relay network are shown in 7.19.2.1 and 7.19.4.2, respectively.

7.19.2 Measurements management

Insert the following subclause (7.19.2.1 and its figure) after 7.19.2:

7.19.2.1 Measurements management for a relay network

Measurement management performs a wide range of measurement activities, either related to incumbent detection or to self-coexistence.

In an A-WRAN network, measurement requests can be performed from the A-BS.

When a centralized scheduling A-CPE receives a BLM-REQ from the A-BS, it shall send it to the destination CPE. The CPE shall report back to the A-BS through the centralized scheduling A-CPE with a BLM-REP message that contains measurement results. Then, the A-BS sends the corresponding acknowledgment (BLM-ACK) on the next DS opportunity following the reception of the measurement report (see Figure 93a).

When a distributed scheduling A-CPE receives a BLM-REQ from the A-BS, it shall perform measurement management within the local cell by sending a BLM-REQ to the CPE. The CPE shall report back to the A-BS through the distributed scheduling A-CPE with the BLM-REP message that contains measurement results. Then, the A-BS sends the corresponding acknowledgment (BLM-ACK) on the next DS opportunity following the reception of the measurement report (see Figure 93a).

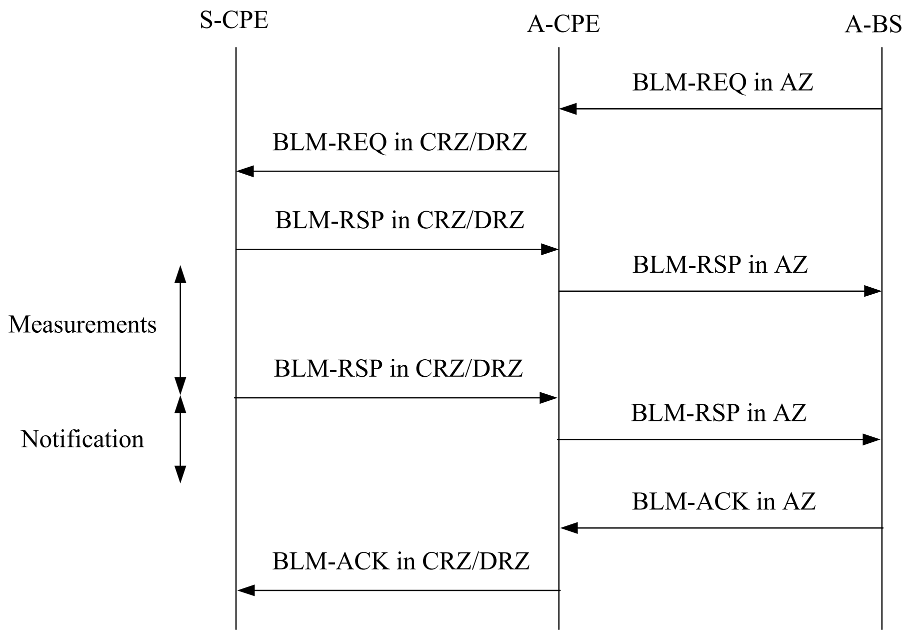


Figure 93a—Measurement message flow between A-BS and CPE through A-CPE

7.19.4 Measurement report and notification

Insert the following subclause (7.19.4.2) after 7.19.4.1.2.2:

7.19.4.2 Measurement report and notification for a relay network

The CPE may have an US bandwidth allocation in a CRZ to send the UCS notification to the centralized scheduling A-CPE or may have an US bandwidth allocation in a DRZ to send UCS notification to the distributed scheduling A-CPE. Those A-CPEs shall relay the UCS notification transmitted by the CPE to the A-BS in an AZ by using one of UCS notifications, i.e., US bandwidth allocation, opportunistic UCS notification, and CDMA-based UCS notification.

The CPE may use an opportunistic UCS notification interval in a CRZ to send the UCS notification to the centralized scheduling A-CPE, or may use an opportunistic UCS notification interval in a DRZ to send UCS notification to the distributed scheduling A-CPE. Those A-CPEs shall relay UCS notification transmitted by the CPE to the A-BS in an AZ by using one of UCS notifications that are US bandwidth allocation, opportunistic UCS notification, and CDMA-based UCS notification.

Upon reception of UCS notification codes from CPEs, a centralized scheduling A-CPE shall relay the UCS notification codes to the A-BS. The A-BS does not respond with an allocation on the CPE’s SID and Basic FID since the allocation is not yet known at this time. Instead, it broadcasts a CDMA_Allocation_IE, which specifies the code and allocation in a CRZ that was used by the CPE. This allows the CPE to determine whether it has been given an allocation by matching the CDMA code that was used for the CDMA UCS notification message and the code broadcast by the A-BS. The CPE shall use the allocation to transmit a MAC PDU to the centralized scheduling A-CPE with the UCS field in the MAC header properly set. The centralized scheduling A-CPE shall send the UCS notification to the A-BS by using any possible way of UCS notification (7.19.4.1.2.1 and 7.19.4.1.2.2).

Upon reception of UCS notification codes, a distributed scheduling A-CPE does not respond with an allocation on the CPE’s SID and Basic FID since the allocation is not yet known at that time. Instead, it broadcasts a CDMA_Allocation_IE, which specifies the code that was used by the CPE. This allows the

CPE to determine whether it has been given an allocation by matching the CDMA code that was used for the CDMA UCS notification message and the code broadcast by the distributed scheduling A-CPE. The CPE shall use the allocation to transmit a MAC PDU with the UCS field in the MAC header properly set. The distributed scheduling A-CPE shall send the UCS notification to the A-BS by using any possible way of UCS notification (7.19.4.1.2.1 and 7.19.4.1.2.2).

7.20 Self-coexistence

Change the last paragraph of the preliminary text of 7.20 as follows:

The Coexistence Beacon protocol (CBP) is the transport mechanism for the coexistence elements supported in this standard, and CBP packets can be transmitted over the air or through the backhaul. The BSs and CPEs shall be capable of transmitting and receiving CBP packets over the air as specified in 9.5. In order to implement eventual coexistence mechanism over the backhaul, the CBP information from IEEE 802.22 base stations shall be encapsulated in IP packets for transport over the backhaul. A WRAN runs in normal mode by default and transits to self-coexistence mode when the WRAN can detect and decode an SCH or a CBP burst from an adjacent WRAN cell on PHY-OM1. An A-WRAN runs in normal mode by default and transits to self-coexistence mode when the A-WRAN can detect and decode an Extended Frame Control Header (Ex-FCH) or a CBP burst from an adjacent A-WRAN cell on PHY-OM2. During the SCH or Ex-FCH reception procedure in the A-WRAN, the total preamble length of PHY-OM1 is greater than that of PHY-OM2. However, using CBP scheduling, PHY-OM2 can guarantee a required level.

7.20.1 Coexistence Beacon Protocol (CBP)

7.20.1.1 CBP packet structure

Change the text of 7.20.1.1 as follows (Figure 100 remains unchanged):

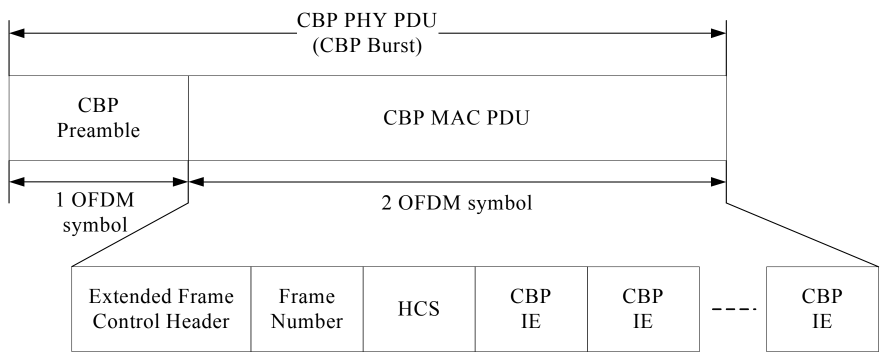
The structure of a CBP packet (i.e., CBP PHY PDU) for PHY-OM1 is shown in Figure 100. The burst starts with a CBP preamble that shall be common across all IEEE 802.22 networks on PHY-OM1 (see 9.4.1.1) and that shall be different from the superframe preamble. After the CBP preamble, the CBP MAC PDU as described in Table 8 shall be transmitted. The CBP MAC PDU shall be two OFDM symbols long.

By including the SCH data (which contains information about the IEEE 802.22 cell) as part of the beacon MAC header, the transmitting CPE or BS/A-CPE conveys necessary information to allow neighboring network discovery and coordination of quiet periods and SCWs. Including the SCH is a way to advertise the schedule of QPs and SCWs to CPEs in other neighboring cells.

The SCH information is needed in situations where WRANs or A-WRANs are operating in different channels as well as when they are operating co-channel or on adjacent channels. In the first case, the SCH information obtained through detecting and demodulating the SCH or through reception of the CBPs allows other WRANs/A-WRANs to discover the schedule of QPs, which can be used for out-of-band sensing. In case WRANs/A-WRANs are operating co-channel or on adjacent channels, the SCH, received through the CBPs, will signal the schedule of QPs and SCWs in addition to containing other IEs that can be used to signal frame allocations, when needed.

For communication using CBP over the backhaul, the CBP MAC PDU (see Figure 100) shall be encapsulated into an IP packet.

The structure of a CBP packet (i.e., CBP PHY PDU) for PHY-OM2 is shown in Figure 100a. The burst starts with a CBP preamble that shall be common across all IEEE 802.22 networks on PHY-OM2 (see 9a.4.1.2) and that shall be different from the frame preamble. After the CBP preamble, the CBP MAC PDU as described in Table 8a shall be transmitted. The CBP MAC PDU shall be two OFDM symbols long.



<u>**Figure 100a—Structure of a CBP packet**</u>

<u>By including the Extended Frame Control Header (which contains information about the A-WRAN cell) as part of the beacon MAC header, the transmitting CPE or A-BS conveys necessary information to allow neighboring network discovery and coordination of quiet periods and SCWs. Including the Extended Frame Control Header is a way to advertise the schedule of QPs and SCWs to CPEs in other neighboring cells.</u>

<u>The Extended Frame Control Header information is needed in situations where A-WRANs are operating in different channels as well as when they are operating co-channel or on adjacent channels. In the first case, the Extended Frame Control Header information obtained through detecting and demodulating the Extended Frame Control Header or through reception of the CBPs allows other A-WRANs to discover the schedule of QPs, which can be used for out-of-band sensing. In case WRANs are operating co-channel or on adjacent channels, the Extended Frame Control Header, received through the CBPs, will signal the schedule of QPs and SCWs in addition to containing other IEs that can be used to signal frame allocations, when needed.</u>

<u>For communication using CBP over the backhaul, the CBP MAC PDU (see Figure 100a) shall be encapsulated into an IP packet.</u>

<u>The A-BS controls access to the medium within the SCW. The A-BS shall decide which CPEs transmit CBP packets in each scheduled active UIUC=0.</u>

Insert the following subclause (7.20.4 and its subclauses) after 7.20.3.2.2.6:

7.20.4 Self-coexistence for a relay network

7.20.4.1 General

Self-coexistence in A-WRAN networks shall follow the mechanisms described in 7.20.1, 7.20.2, and 7.20.3, which will be performed by the negotiation of the A-BS and the neighboring A-BSs.

For self-coexistence in A-WRAN networks, the SCW shall be synchronized at all CPEs within an A-WRAN network. For synchronizing SCW, in PHY-OM1 or PHY-OM2, one of the following can be transmitted.

1) BS/A-BS transmits SCH in PHY-OM1.
2) A-BS transmits Frame Control Header in PHY-OM2.
3) A-BS transmits Frame Control Header + Extended Frame Control Header in PHY-OM2.

When a CPE receives one of these transmissions, the CPE forwards it to the A-BS and then synchronizes the SCW within an A-WRAN network. When a distributed scheduling A-CPE receives the SCW schedule information from the A-BS, it shall arrange the SCW schedule within a local cell by sending the same information from the respective transmission listed above, which it has received from the A-BS to the CPEs in a local cell.

7.20.4.2 Mechanism for inter-A-BS self-coexistence on a relay network

The self-coexistence operations among A-WRAN cells shall follow the top-level procedure illustrated in Figure 101 and described as follows:

1) The A-BS of an A-WRAN cell is powered on.
2) The A-BS performs network discovery, which includes discovering
   - TV channel occupancies of the neighboring A-WRAN cells
   - SCW reservations of the neighboring A-WRAN cells
   - Frame reservation patterns of the neighboring A-WRAN cells on specific channels (this information can be obtained from the received CBP packets)
3) The A-BS performs channel acquisition based on the Spectrum Etiquette algorithm (as described in 7.20.3.1).
4) If the A-BS successfully acquires a channel, it goes to the normal mode of data service operations on the acquired channel [as described in step 5) below]. If the A-BS fails to acquire any empty channel, it selects a channel occupied by one or more other A-WRAN cells and identifies whether the potential interference comes directly from the other A-BSs or from the CPEs belonging to the other A-WRAN cells, or both. If it comes only from the other A-BSs, the new A-BS initiates the DS/US Split adjustment mechanism [i.e., skips step 5) and goes to step 6)]. If the potential interference comes from the CPEs, it performs the Inter-WRAN On-demand Frame Contention operations on the selected channel by accessing a contention-based SCW (see 7.20.1.2) [i.e., skips step 5) and step 6) and goes to step 7)]. Note that since the new A-BS arriving on the channel does not have a frame for itself yet, it cannot involve its CPEs in this initial contention process. Only CBP bursts transmitted directly from the new A-BS will be able to support the frame contention process in this initial phase. As a result, the process may go initially to step 6) but then move to step 7) when the CPEs belonging to the new A-WRAN cell start to operate and report potential interference through their CBP bursts.
5) The A-BS enters the normal mode of data service operations (see 7.3). During the normal service operations, the A-BS may receive external demands (received from other A-WRAN cells) for sharing its occupied data frames on the operating channel. When this occurs and when the A-BS cannot find another empty channel for its operation through the Spectrum Etiquette algorithm, the A-BS performs the Inter-WRAN On-demand Frame Contention operations on its operating channel [as described in step 6)]. If an empty channel is found, then the A-BS moves its cell to this new channel and enters the normal mode of data service operations (see 7.3).
6) The A-BS performs the DS/US Split adjustment mechanism. This can be done only if the CBP burst received directly from the other A-BSs or received by a CPE and forwarded to the A-BS contains information related to transmission 1), 2), and/or 3) listed in 7.20.4.1. Once it has acquired information on the Current DS/US Split, Claimed DS/US Split, and the DS/US Change Offset, it applies the same basic algorithm as used for Quiet Period Scheduling described in Table 184 and transmits its updated parameters to the other A-BSs so that they do the same and converge toward a common DS/US Split, which will vary depending on the compound traffic requirements for the A-BSs involved. The adjustment of the DS/US Split through this distributed negotiation process, based on the fact that all A-BSs have their frames aligned (see 9.10), will allow the concurrent use of the same frames by these A-BSs and avoid interference caused by an A-BS that would be still transmitting while the other A-BSs have started their US subframe and are trying to receive signals from their CPEs. Note that this will cover the cases where A-BSs would interfere with each other even though there is no CPE

being interfered with (i.e., no CPE in the overlap area). There may also be cases where CPEs will receive interference from various A-BSs while these A-BSs do not interfere with each other as a result of clever A-BS antenna installation that will block the signal path between the A-BSs. The normal case will however be when both A-BSs and CPEs are interfered with. For these two latter cases, step 7) will be needed to distribute the frames to the various A-BSs and, since there would not be concurrent use of these frames, there is then no longer a need to synchronize the DS/US split in these cases.

7) The A-BS performs the On-demand Frame Contention operations with a neighboring A-WRAN cell on the selected channel and then goes to the self-coexistence mode of data services operations [as described in step 8)]. A neighboring A-WRAN cell can contend for some of the frames used by the current A-BS as long as it occupies a number of frames that is larger that the minimum stated in variable Frame_Contention_Min (see Table 274). The required message flow and the On-Demand Frame Contention Protocol are described in 7.20.3.2.

8) The A-BS enters the self-coexistence mode of data services operations (see 7.3). During the self-coexistence mode of data service operations, the A-BS may receive either internal demands (received from the inside of the A-BS's own cell) for additional spectrum resources or external demands (received from other A-WRAN cells) for sharing its occupied frames on the operating channel. When either of these events occurs, the A-BS reinitiates the spectrum acquisition process starting from step 3) (Spectrum Etiquette for channel acquisition).

7.20.4.3 CBP-based neighboring network discovery

7.20.4.3.1 Overview

During network entry and initialization and before any data transmission takes place, the A-BS and CPE shall perform a network discovery procedure by scanning the wireless medium for CBP packets that contain one of the transmissions listed in 7.20.4.1. This discovery procedure is part of the A-BS and CPE initialization procedures described in 7.14.

During normal operation, the A-BS and CPEs can discover other nearby A-WRAN cells by listening to the medium on the lookout for CBP packets that contain one of the transmissions listed in 7.20.4.1. These transmissions can be received from other cells on the same channel or from cells on different channels. This can be accomplished through the scheduling of the Coexistence UIUC = 1 for passive mode SCW. If a CBP packet containing one of the transmissions listed in 7.20.4.1 is received by the CPE that is managed by the A-BS, it shall package that information and transport it to its A-BS (see Table 172).

7.20.4.3.2 Discovery with SCW

The A-BS can discover other A-WRAN cells by scheduling SCWs in passive mode, during which it may request one or more of its CPEs to listen to the current operating channel to look for CBP packets from other A-WRANs or to listen to other channels for CBP packets. These CBP packets can contain one of the transmissions listed in 7.20.4.1 that originate from other A-BSs or CPEs associated with other A-BSs.

7.21 Quiet periods and sensing

7.21.2 Synchronization of overlapping quiet periods

Change the second paragraph of the preliminary text of 7.21.2 as follows (the dashed list after this paragraph remains unchanged):

Hence, BSs shall synchronize their quiet periods with other nearby BSs/A-BSs. This is done using the fields available in the SCH (see Table 1) or Extended Frame Control Header (see Table 2b) that are used to schedule quiet periods for intra-frame (see 7.21.1.1) and inter-frame sensing (see 7.21.1.2), and which are also carried in CBP packets (see 7.6.1.3.1). The BS/A-BS shall be responsible for setting these fields whenever transmitting an SCH or an Extended Frame Control Header. These QP scheduling fields are sent in the following three sets of parameters in a self-coexistence situation:

7.21.2.1 Intra-frame quiet period synchronization

Change the first and third paragraphs of 7.21.2.1 as follows:

The “current” set of intra-frame quiet period parameters is used by the BS/A-BS to indicate to its CPEs the quiet periods that are currently scheduled. Before becoming “current,” this set of QP scheduling parameters has to be confirmed by all coexisting WRAN cells through the CBP mechanism following a negotiation among these WRAN cells. The “claimed” set of intra-frame quiet period parameters is used by each BS/A-BS to announce its new scheduling requirement for quiet periods considering the performance of the sensing techniques used by its CPEs, i.e., the sensing time needed to meet the required sensing threshold. This “claimed” set is broadcast by the SCH or the Extended Frame Control Header and retransmitted to the other coexisting WRAN cells by the CBP mechanism so that negotiation can take place to arrive at a common quiet period schedule that meets the maximum QP requirement while minimizing the overhead by reducing the non-concurrent quiet periods as much as possible. This “claimed” quiet period schedule, once it has become common to all coexisting WRAN cells can then be scheduled to become the “current” quiet period parameter set after sufficient time is given for the negotiation to cover for inter-cell propagation.

. . .

Each BS/A-BS sends its claim to other coexisting BSs/A-BSs through the SCH or the Extended Frame Control Header, which is then carried by the CBP mechanism. Each BS/A-BS that receives a new “claim” shall compare it to its own claim and either replace the incoming claim by its larger claim for the QP repetition rate (i.e., number of 1’s in the bitmap/cycle length) and/or QP duration or keep it as is if its own claim is smaller. If its own claim is larger and the updating results in a new claim that is larger than the “current” QP repetition rate and/or duration, the BS shall reset the Claimed Intra-frame Quiet Period Offset to the minimum number of frames required to make sure that all coexisting BSs have received the claim (e.g., 2 hops, that is 2 superframes or frames) before sending it in the SCH and relaying it through the CBP mechanism. If the new claim is smaller than the “current” scheduling, the Claimed QP Offset parameter is repeated unchanged, and the incoming scheduling parameters are also repeated unchanged.

7.21.2.2 Inter-frame Quiet Period Synchronization

Change the first and second sentences of the first paragraph in 7.21.2.2 as follows:

The BS/A-BS that receives information about other collocated IEEE 802.22 cells (either directly or reported through CPEs) shall synchronize with all quiet periods scheduled by the other cells for the inter-frame QP schedule. To synchronize inter-frame sensing quiet periods, the BS uses the information contained in the SCH or the Extended Frame Control Header, but in addition to that, the BS shall apply a random mechanism to decide whether to change its quiet period schedule.

Change the first sentence of the second paragraph in 7.21.2.2 as follows:

For example, consider that BS 1 received information on the SCH or the Extended Frame Control Header transmitted by a collocated BS 2.

Insert the following subclause (7.21.4 and its subclauses and figures) after 7.21.3:

7.21.4 Quiet periods and sensing for a relay network

7.21.4.1 Quiet period synchronization for an A-BS's cell

For Quiet period synchronization for an A-BS's cell containing S-CPEs and A-CPEs as shown in Figure 111a, the A-BS can schedule the quiet periods either in the explicit mode, which is done through the use of CHQ-REQ MAC message as described in 7.7.17.3, or in the implicit mode using the sensing related fields in the SCH on PHY-OM1 or the Extended Frame Control Header on PHY-OM2.

Quiet period allocation shall follow the same mechanisms described in 7.21.1.

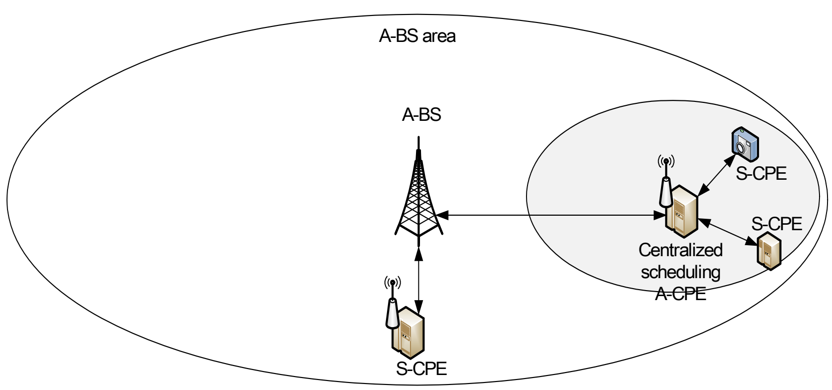


Table 111a—Quiet period synchronization within an A-BS's cell

7.21.4.2 Quiet period synchronization for a local network

The Quiet periods shall be synchronized at all CPEs within an A-WRAN network. Some S-CPEs located in a local cell, which are managed by a distributed scheduling A-CPE, may not be synchronized by the Quiet period scheduling information transmitted from an A-BS because the S-CPEs are outside of the A-BS's cell as shown in Figure 111b. Instead of the A-BS, the distributed scheduling A-CPE shall transmit the Quiet period scheduling information transmitted from an A-BS to the S-CPE within a local cell.

In the implicit quiet period scheduling, when a distributed scheduling A-CPE receives an SCH or an Extended Frame Control Header from the A-BS, the distributed scheduling A-CPE shall send the SCH or the Extended Frame Control Header followed by DRZ-FCH to synchronize the quiet period in a local cell.

In the explicit quiet period scheduling, the A-BS uses the CHQ-REQ MAC message described in 7.7.17.3 to advertise the intra-frame sensing schedule and all the relevant parameters for sensing. When the distributed scheduling A-CPE receives a CHQ-REQ MAC message from the A-BS, it shall send the CHQ-REQ MAC message to the CPEs within a local cell. This explicit mode should not be used in a self-coexistence operation since the quiet period scheduling information may not be made available to the other A-WRAN systems operating in the area. Only the implicit mode should be used in a self-coexistence situation.

Quiet period allocation shall follow the same mechanisms described in 7.21.1.

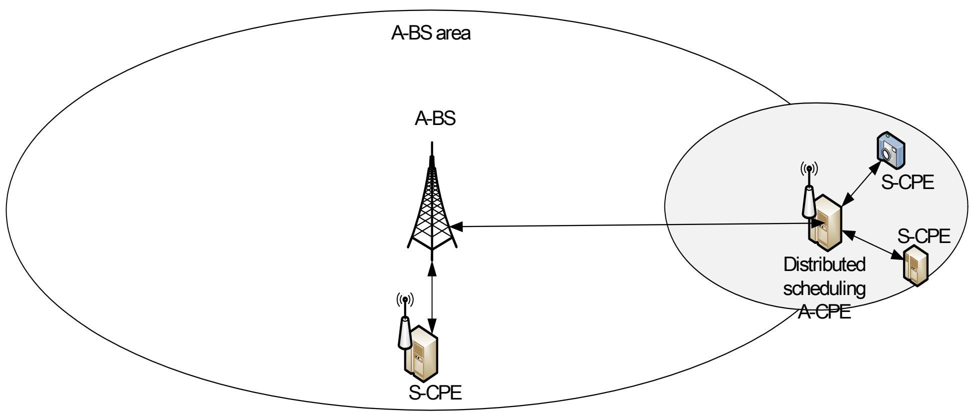


Figure 111b—Quiet period synchronization for a local network

7.22 Channel management

Insert the following subclause (7.22.3 and its subclauses, figure, and tables) after 7.22.2:

7.22.3 Channel management on a relay network

7.22.3.1 Overview

Two modes of channel management supported by WRAN, which are an embedded mode and an explicit mode, are also supported in A-WRAN.

In the embedded mode in A-WRAN, the A-BS shall transmit all IEs related to channel management to all CPEs in the cell. A distributed scheduling A-CPE shall transmit all channel management IEs received from the A-BS to the CPEs managed by the distributed scheduling A-CPE.

In the explicit mode in A-WRAN, the channel management messages could be sent by the A-BS to the specific CPEs directly or relayed through a centralized scheduling A-CPE or a distributed scheduling A-CPE. When a A-CPE receives a channel management message not targeted to the A-CPE, the A-CPE shall relay the channel management message to the target CPE. In A-WRAN, Figure 112a depicts the message flow between A-BS and CPE relayed on A-CPE when the Confirmation Need field is set.

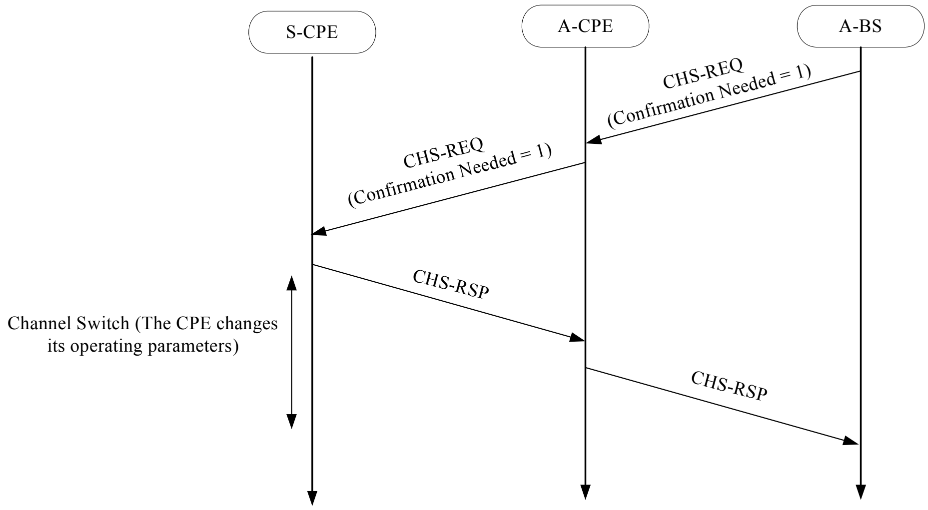


Figure 112a—Message flow between A-BS and CPE relayed on A-CPE when confirmation is required

7.22.3.2 Initialization and channel sets updating

In this subclause, procedures of channel list initialization and updating on relay are addressed.

In order to maintain the channel sets, an A-BS maintains the following available channel sets: Operating, Backup, Candidate, Protected, Occupied, and Unclassified. Each S-CPE and centralized scheduling A-CPE within the A-BS's cell maintains only the first three channel sets: Operating, Backup, and Candidate. Each distributed scheduling A-CPE maintains the same channel sets as the A-BS's channel set. These individual sets have different update steps. For example, on the CPE side managed by the A-BS, the Operating set is confirmed by every received SCH or FCH, and the Backup and Candidate sets are updated after receiving the DCD. On the CPE side managed by the distributed scheduling A-CPE, the Operating set is confirmed by every received DRZ-FCH, and the Backup and Candidate sets are updated after receiving the DCD in DRZ. After synchronization, the A-BS should send an IPC-UPD message to the CPE to update the set of channels prohibited from incumbent operation for the newly connected CPE to allow skipping these channels to speed up the sensing process. These relations are summarized in Table 185a and Table 185b. For the A-BS, channel sets are updated after each quiet period either at a periodic interval or at aperiodic intervals. The A-BS shall send all channel sets to the distributed scheduling A-CPE.

Table 185a—Update channel set information in CPE

Message	Field	Information
SCH	BS_ID	Operating channel on which the SCH is received on PHY-OM1
FCH	BS_ID	Operating channel on which the SCH is received on PHY-OM2
DCD	Number for Backup channels	Number of backup channels
	Backup and candidate channel list	List of backup and candidate channels
IPC-UPD	Incumbent Prohibited Channels Update	Channels that cannot carry incumbent signals since their operation is prohibited (e.g., channel 37 in the USA) and thus they can be skipped during the sensing process

Table 185b—Update channel set information in CPE for DRZ

Message	Field	Information
DRZ-FCH	BS_ID	Operating channel on which the DRZ-FCH is received
DCD	Number for Backup channels	Number of backup channels
	Backup and candidate channel list	List of backup and candidate channels
IPC-UPD	Incumbent Prohibited Channels Update	Channels that cannot carry incumbent signals since their operation is prohibited (e.g., channel 37 in the USA) and thus they can be skipped during the sensing process

When a CPE turns on, it scans the channels to identify the available A-WRAN operations and proceeds with the selection of one of these services (see 10.3.2). Such selection identifies the operating channel. As part of the CPE initialization, the list of backup and candidate channels is sent in the DCD message by the A-BS or the distributed scheduling A-CPE. This procedure is closely related with obtaining the downlink parameters procedure (see 7.14.2). After association of a new CPE, the A-BS or the distributed scheduling A-CPE shall send the IPC-UPD message to indicate the list of channels prohibited from incumbent operation to the CPE so that it can skip incumbent sensing on these channels. Channel sets in the CPE are updated after periodically receiving the DCD message. For the A-BS, if channel sets are changed as a result of BLM-REP messages, the A-BS sends the backup and candidate channel list in its DCD message. When the distributed scheduling A-CPE receives the updated channel list from the A-BS, the distributed scheduling A-CPE sends the updated backup and candidate channel list in its DCD message in DRZ to the CPE.

7.22.3.3 Scheduling of channel switching time

When the A-BS decides to switch channels during normal operation, it shall execute the following procedure to determine when to schedule the channel switching operation:

- The A-BS selects the first backup channel from its backup/candidate channel list, it shall select a waiting time T46 to make sure that all its CPEs are prepared for the channel switch. The value of T46 is a configuration parameter that could be set by the management interface. The first requirement is that the value of T46 shall be smaller or equal to the maximum allowed channel moving time, and the second requirement is that the value is long enough for the CPEs to recover from an incumbent detection.
- Then, the A-BS schedules the channel switch using the channel management procedure described in 7.19.5.
- When the distributed scheduling A-CPE receives the channel switch requirement from the A-BS, the distributed scheduling A-CPE shall make sure that all its CPEs in a local cell are prepared for the channel switch within the available switching time (see Switch Count in 7.7.17.1), which will be transmitted by the A-BS.

Change the title and first paragraph of 7.23 as follows:

7.23 Synchronization of the IEEE 802.22 base stations and IEEE 802.22b base stations

The BSs and A-BSs on PHY-OM1 shall synchronize the absolute local start time of their superframe period, to the start of every minute referenced to UTC to a tolerance of less than or equal to ± 2 µs. The A-BS on PHY-OM2 shall synchronize the absolute local start time of their frame period, to the start of every minute referenced to UTC to a tolerance of less than or equal to ± 2 µs.

Insert the following subclauses (7.24 and 7.25 and their subclauses and figures) after 7.23:

7.24 Multi-channel operation

7.24.1 General

This subclause describes the multi-channel operation, which is required to support enhanced broadband services and monitoring applications that require high data throughput. A single channel operation is supported as shown in Figure 112b with maximum date rate of 22.69 Mbps. In Figure 112b, each CPE (CPE 1~CPE 5) is using the operating channel f1 to communicate within the service area of BS where the operating channel f1 is assigned by the spectrum manager using the available channel list. Even though several available channels may exist in the list, due to the constraint of the single channel operation of IEEE Std 802.22-2011, those available channels cannot be utilized effectively since multi-channel operation is not supported. Multi-channel operation and Multi-hop relay operation are mutually exclusive. Channel aggregation mode can be configured as Bulk Transmission mode for increasing the transmission throughput or configured as Diversity mode for robust transmission as shown in 7.7.7.3.4.13. Only one type of multi-channel transmission mode shall be in operation at a given time. This is accomplished by an exchange of the CPE Operational Capability IE (7.7.7.3.4.13) in REG-REQ during the A-CPE registration (7.14.4). When the A-BS responds, it selects the multi-channel transmission mode, and then it sets the mode of the A-CPE in the CPE Operational Capability IE in the REG-RSP that it sends back to the A-CPE. Once the A-CPE has been configured to use a multi-channel transmission mode, the procedures used to add, switch, or stop operation (7.24.2.2 through 7.24.2.5) can be engaged. When Transmit Diversity mode is selected, the same formatted MAC PDU is transmitted across all allocated channels. When Bulk Transmission mode is selected, a unique MAC PDU is transmitted across each allocated channel.

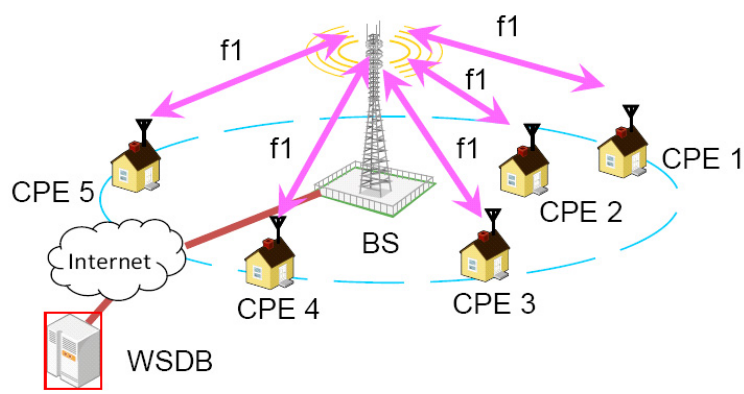


Figure 112b—Example of IEEE Std 802.22-2011 deployment configuration (Single channel operation)

The A-WRAN supports aggregate data rates greater than the maximum data rate supported by the IEEE Std 802.22-2011 in order to extend its regional area broadband services to a broader range of applications such as real-time and near real-time monitoring, emergency broadband services, remote medical services, etc. Therefore, multi-channel operation should be considered as a means to achieve throughput greater than the maximum throughput supported by the IEEE Std 802.22-2011.

The examples of multi-channel operation deployment configuration are shown in Figure 112c and Figure 112d, respectively. In Figure 112c, it is assumed that there are 2 available operating channels within the service area of the A-BS. In this example, multi-channel operation on A-BS is illustrated where only the A-BS is capable of receiving and transmitting over two or more operating channels and responsible for assigning the operating channel to the associated A-CPEs within its service area. By performing the multi-channel operation on A-BS, the A-BS can utilize the available operating channels by distributing the operating channels among the associated A-CPEs. The multi-channel operation on A-BS can improve the individual A-CPE's throughput by decreasing the total number of associated A-CPEs per operating channel. In Figure 112c, A-CPE 1 and A-CPE 2 are assigned to the operating channel f1 to communicate with the A-BS, and A-CPE 3, A-CPE 4, and A-CPE 5 are assigned to the operating channel f2 to communicate with the A-BS.

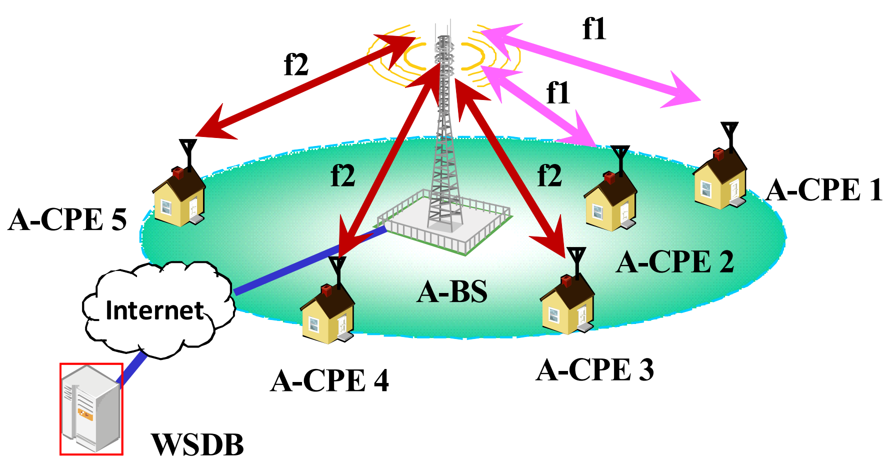


Figure 112c—Example of multi-channel operation deployment configuration (Multi-channel operation on A-BS)

In Figure 112d, it is assumed that there are five available operating channels within the service area of the A-BS. In this example, multi-channel operation on A-BS and A-CPEs is illustrated where both A-BS and associated A-CPEs are capable of receiving and transmitting over two or more operating channels. A-BS is responsible for assigning the operating channel to the associated A-CPEs within the service area for the utilization of available operating channels. In Figure 112d, A-CPE 1 is assigned to the operating channels f1, f2, and f3 to communicate with the A-BS, and A-CPE 2 is assigned to the operating channels f4 and f5 to communicate with the A-BS. In this example, the A-BS can improve the individual A-CPE's throughput by increasing the number of operating channels assigned to the associated A-CPEs.

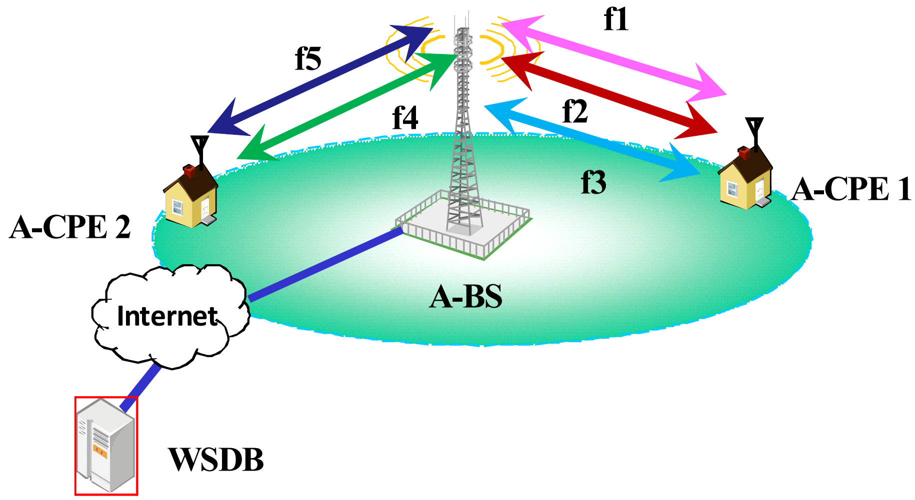


Figure 112d—Example of multi-channel operation deployment configuration (Multi-channel operation on A-BS and A-CPE)

7.24.2 Channel allocation manager

7.24.2.1 General

The channel allocation manager (CAM) shown in Figure 112e is responsible for the basic multi-channel operations such as add new operating channel operation (7.24.2.2), stop operating channel (7.24.2.4), and switch operating channel (7.24.2.5). All of the basic functions described in the CAM are necessary to support the multi-channel operation, which is different from the single channel operation.

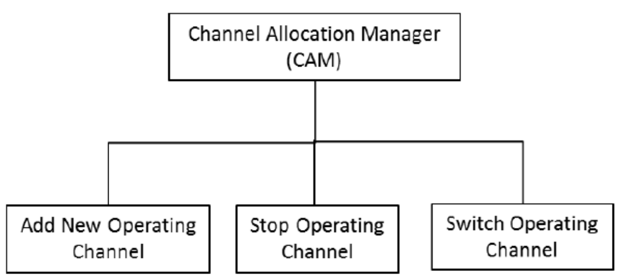


Figure 112e—Channel allocation manager

A channel allocation manager is needed to perform multi-channel operations, which are described in 7.24.2.2, 7.24.2.4, and 7.24.2.5.

In 7.24.2.2, detailed operation flow of add new operating channel is discussed. The add new operating channel function is responsible for allocating new operating channel to each available channel transceiver unit (CHU).

In 7.24.2.4, detailed operation flow of stop operating channel is discussed. The stop operating channel function is responsible for stopping the operating channel of the specific CHU.

In 7.24.2.5, detailed operation flow of switch operating channel is discussed. The switch operating channel function is responsible for switching the operating channel of the specific CHU.

A CHU is defined as a transceiver unit that operates in a specific channel operation within its operating frequency which consists of a MAC and a PHY.

7.24.2.2 Add new operating channel operation

7.24.2.2.1 General

When the A-BS is ready to operate under the multi-channel operation, the following procedure of adding new operating channel is performed on both the A-BS and A-CPE, which have the capability of receiving and transmitting over two or more operating channels.

The add new operating channel operation procedure shall consist of the following steps:

a) BS-CAM selects a specific BS-CHU.
b) BS-CAM commences operation request.
c) BS-CHU commences operation acknowledgment.
d) BS-CAM sends management information notification to BS-CHU.
e) BS-CHU memorizes management information.
f) BS-CHU performs frequency setting.
g) BS-CHU performs synchronization.
h) BS-CHU sends operation preparation completed notification to BS-CAM.
i) BS-CHU broadcasts SCH on PHY-OM1 or FCH on PHY-OM2.
j) BS-CAM checks unused BS-CHU.
k) CPE-CAM selects a specific CPE-CHU.
l) CPE-CAM sends BS search command (All or specific channel) to the specific CPE-CHU.
m) CPE-CHU performs BS search.
n) CPE-CHU sends BS detected notification to CPE-CAM.
o) CPE-CAM determines other operating CPE-CHU.
p) CPE-CAM performs BSID matching.
q) CPE-CAM sends BSID mismatch notification to CPE-CHU.
r) CPE-CAM sends proceed notification to CPE-CHU.
s) CPE-CHU performs synchronization.
t) CPE-CHU sends synchronization completed notification to CPE-CAM.
u) CPE-CAM checks unused CPE-CHU.
v) CPE-CAM sends registration request to CPE management unit.
w) CPE management unit sends registration completed notification to CPE-CAM.

The add new operating channel operation flow is shown in Figure 112f.

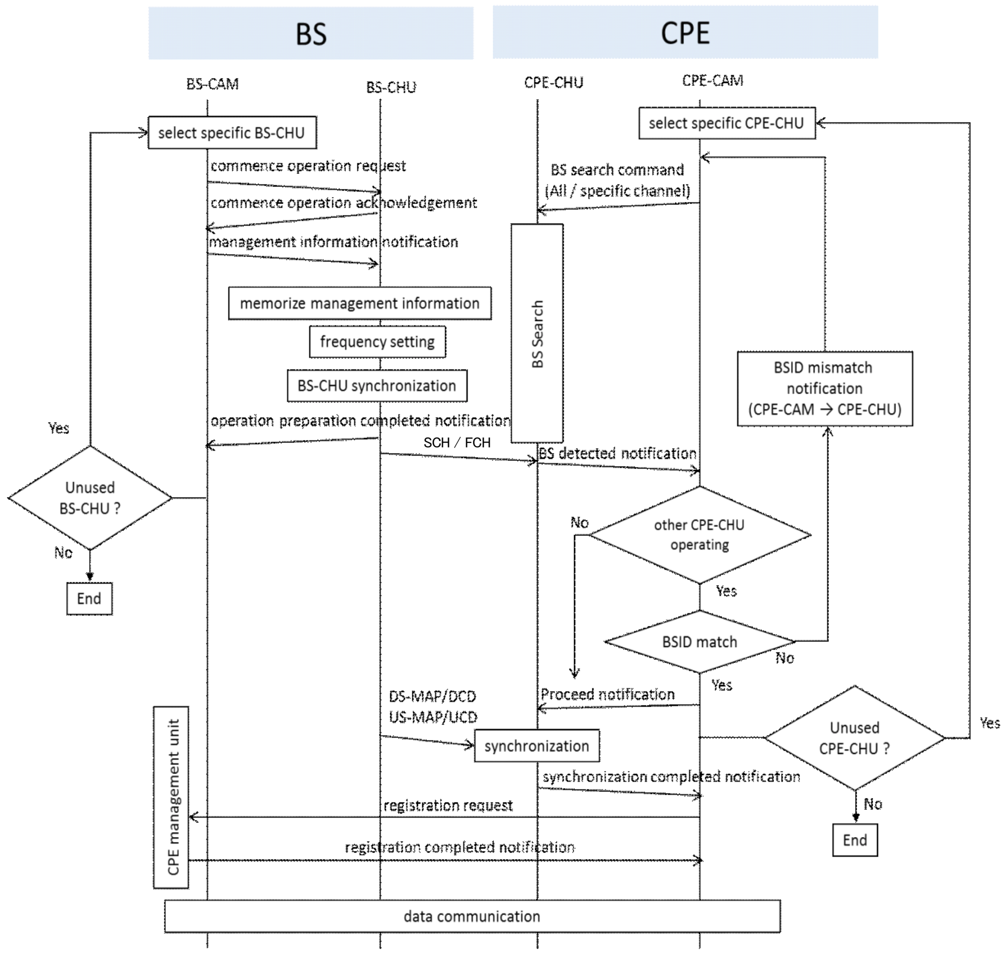


Figure 112f—Operation flow for adding new operating channel

7.24.2.2.2 BS-CAM selects a specific BS-CHU

The BS channel allocation manager (BS-CAM) shall select a specific BS channel transceiver unit (BS-CHU) that is the target of the add new operating channel operation. The BS-CAM shall select the BS-CHU that is in the state of unused or unassigned currently and whose hardware corresponds to the new operating channel's frequency. The operating channel selection procedure may be included in this step.

7.24.2.2.3 BS-CAM commences operation request

The BS-CAM shall send a commence operation request to the selected BS-CHU. The commence operation request may include the various parameters in connection with the PHY such as channel center frequency and its offset, etc., and some part of MIB information such as software version information, etc.

7.24.2.2.4 BS-CHU commences operation acknowledgment

The BS-CHU shall send a commence operation acknowledgment to the BS-CAM. The commence operation acknowledgment may include the specific BS-CHU MIB information that is needed by BS-CAM such as device ID or serial number of the BS-CHU, etc. The BS-CHU shall response with an error when the commence operation request is rejected due to reasons such as mismatch of the software version, etc.

7.24.2.2.5 BS-CAM sends management information notification to BS-CHU

The BS-CAM shall send a management information notification to the BS-CHU. The management information notification may mainly include the MIB information necessary for the BS-CHU and maintained by the BS-CAM such as the ID to identify the connection between BS and CPE (carrier index that is associated with the physical or logical channel), etc. If the BS-CHU has a part of the MAC layer function, then the information on MIB that is used by the MAC layer, such as Station ID, MAC Address of BS, etc., shall be included.

7.24.2.2.6 BS-CHU memorizes management information

The BS-CHU shall memorize the management information from the BS-CAM after the management information notification. Some part of the memorized information (MIB information) shall be immediately reflected on the BS-CHU or reflected as the initial value of the transition state.

7.24.2.2.7 BS-CHU performs frequency setting

The BS-CHU shall perform the frequency setting procedure. The channel center frequency and its offset that were received in the commence operation request or management information notification shall be reflected in the local oscillator of BS-CHU.

7.24.2.2.8 BS-CHU performs synchronization

The BS-CHU shall perform the BS-CHU synchronization procedure. On PHY-OM1, this procedure is intended for network synchronization to synchronize the superframe, frame, and TDD timing of a number of A-BSs. Basically, this procedure shall synchronize the superframe to the start of each minute of the UTC time obtained from a global navigation system such as GPS. On PHY-OM2, this procedure is intended for network synchronization to synchronize the frame and TDD timing of a number of A-BSs. Basically, this procedure shall synchronize the frame to the start of each minute of the UTC time. As a result, all the operating BS-CHUs shall be synchronized with each other.

7.24.2.2.9 BS-CHU sends operation preparation completed notification to BS-CAM

The BS-CHU shall send an operation preparation completed notification to the BS-CAM. The BS-CHU shall send a response indicating an error when it fails to complete the operation preparation procedure.

7.24.2.2.10 BS-CHU broadcasts SCH on PHY-OM1 or FCH on PHY-OM2

The BS-CHU shall periodically broadcast a radio frame that includes the SCH information on PHY-OM1 or FCH information on PHY-OM2.

7.24.2.2.11 BS-CAM checks unused BS-CHU

The BS-CAM shall check whether there is any unused BS-CHU. If an unused BS-CHU exists, then the BS-CAM shall proceed to the select specific BS-CHU procedure.

7.24.2.2.12 CPE-CAM selects a specific CPE-CHU

The CPE channel allocation manager (CPE-CAM) shall select a specific CPE channel transceiver unit (CPE-CHU) that is a target of the add new operating channel operation. The CPE-CAM shall select the CPE-CHU that is in the state of unused or unassigned. In many cases, this procedure is triggered when the A-BS lost condition occurs in the CPE where the CPE-CHU was selected.

7.24.2.2.13 CPE-CAM sends BS search command (All or specific channel) to the specific CPE-CHU

The CPE-CAM shall send an A-BS search command (All or specific channel) to the selected CPE-CHU. The A-BS search command (All or specific channel) shall be performed by searching all the frequency channels that correspond to the selected CPE-CHU or by searching one or more specific frequency channels. The specific channel information shall be indicated by using the extended DCD message or newly defined management message (7.7.29.2) to specify the A-BS operating channels that are not connected by any CPE or shall be estimated based on the backup channel information. To prevent overlapping with the other CPE-CHU channel, the channel that the other CPE-CHU has already used shall not be searched. Moreover, the channel that the other A-BS has already used and that is identified by a previous BS search command, etc., shall not be searched. The previous A-BS search command is referring to the unsuccessful A-BS search command that did not received a proceed notification from the CPE-CAM due to the BSID mismatch.

7.24.2.2.14 CPE-CHU performs BS search

The CPE-CHU shall perform the BS search command by attempting to detect the radio signal (preamble and SCH on PHY-OM1 or preamble and FCH on PHY-OM2) from the BS at the target frequency of the BS search command.

7.24.2.2.15 CPE-CHU sends BS detected notification to CPE-CAM

The CPE-CHU shall send an A-BS detected notification to the CPE-CAM when it is able to detect the signal strength greater than or equal to a predetermined value that is defined in the BS search procedure. The BS detected notification shall include the BSID, which is obtained by decoding the SCH information on PHY-OM1 or FCH on PHY-OM2.

7.24.2.2.16 CPE-CAM determines other operating CPE-CHU

The CPE-CAM shall determine whether there is any other operating CPE-CHU (connection status with BS). If there is no other operating CPE-CHU at that time, then it does not proceed to add new operating channel procedure (multi-channel operation). The CPE-CHU shall proceed to the synchronization process similarly to the conventional IEEE Std 802.22-2011.

7.24.2.2.17 CPE-CAM performs BSID matching

If another operating CPE-CHU is detected at that time, the CPE-CAM shall determine whether the BSID of the other operating CPE-CHU matches with the BSID obtained by the CPE-CHU during BS detected notification.

7.24.2.2.18 CPE-CAM sends BSID mismatch notification to CPE-CHU

If the BSID mismatch occurred, then the CPE-CAM shall send a BSID mismatch notification to the CPE-CHU, and the CPE-CHU shall resume its BS search process with the rest of the targeted frequency, or the BS-CAM shall send a specific target frequency of BS search command to the CPE-CHU.

7.24.2.2.19 CPE-CAM sends proceed notification to CPE-CHU

If the BSID match is confirmed, then the CPE-CAM shall send a proceed notification to the CPE-CHU to continue with the synchronization procedure.

7.24.2.2.20 CPE-CHU performs synchronization

The CPE-CHU shall continue with the synchronization procedure with the frequency that is detected in SCH on PHY-OM1 or FCH on PHY-OM2. In addition to the original synchronization procedure such as detecting and decoding the FCH, DS-MAP, etc. to obtain the parameters of the DS, this procedure shall include the reception of UCD message process to obtain the parameters of the US, the ranging process to adjust the TDD timing, etc.

7.24.2.2.21 CPE-CHU sends synchronization completed notification to CPE-CAM

As a response to the proceed notification procedure, the CPE-CHU shall send a synchronization completed notification to the CPE-CAM. By referring to these notifications, the CPE-CAM can recognize the multi-channel operation when two or more CPE-CHUs are connected with the BS.

7.24.2.2.22 CPE-CAM checks unused CPE-CHU

The CPE-CAM shall check whether there is any unused CPE-CHU. If the unused CPE-CHU exists, then the CPE-CAM shall proceed to the select specific CPE-CHU procedure.

7.24.2.2.23 CPE-CAM sends registration request to CPE management unit

The CPE-CAM shall send a registration request to the BS for CPE registration after completing the multi-channel operation capability. The registration request shall contain the information (carrier index, etc.) that can uniquely identify each channel used in the multi-channel operation. Some management messages may be exchanged only between the BS-CHU and CPE-CHU if necessary.

7.24.2.2.24 CPE management unit sends registration completed notification to CPE-CAM

The CPE management unit shall send a registration completed notification to the CPE-CAM.

7.24.2.3 Add new operating channel operation by using BS search command (specific channel)

7.24.2.3.1 General

As described in 7.24.2.2.13, the BS search command can be conducted in two modes (All or specific channel). In this subclause, the detailed operation flow for add new operating channel by using BS search command in specific channel mode is shown. In this operation flow, the BS-CHU and CPE-CHU shall have at least one operating channel to enable the exchange of management messages between the A-BS and A-CPE.

The operation flow for add new operating channel by using BS search command in specific channel mode shall consist of the following steps:

a) BS-CAM sends aggregation information to BS-CHU1.
b) BS-CHU1 forwards aggregation information to CPE-CHU1.
c) CPE-CHU1 forwards aggregation information to CPE-CAM.
d) BS-CAM selects a specific BS-CHU.
e) BS-CAM commences operation request.
f) BS-CHUn commences operation acknowledgment.
g) BS-CAM sends management information notification to BS-CHUn.
h) BS-CHUn memorizes management information.

i) BS-CHUn performs frequency setting.
j) BS-CHUn performs synchronization.
k) BS-CHUn sends operation preparation completed notification to BS-CAM.
l) BS-CHUn broadcasts SCH on PHY-OM1 or FCH on PHY-OM2.
m) BS-CAM checks unused BS-CHU.
n) CPE-CAM selects a specific CPE-CHU.
o) CPE-CAM sends BS search command (specific channel) to the specific CPE-CHUn.
p) CPE-CHUn performs BS search.
q) CPE-CHUn sends BS detected notification to CPE-CAM.
r) CPE-CAM determines other operating CPE-CHU.
s) CPE-CAM performs BSID matching.
t) CPE-CAM sends BSID mismatch notification to CPE-CHUn.
u) CPE-CAM sends proceed notification to CPE-CHUn.
v) CPE-CHUn performs synchronization.
w) CPE-CHUn sends synchronization completed notification to CPE-CAM.
x) CPE-CAM checks unused CPE-CHU.
y) CPE-CAM sends registration request to CPE management unit.
z) CPE management unit sends registration completed notification to CPE-CAM.

The operation flow for add new operating channel by using BS search command (specific channel) is shown in Figure 112g.

7.24.2.3.2 BS-CAM sends aggregation information to BS-CHU1

The BS-CAM shall send the aggregation information (7.7.29.2) to the operating BS-CHU1 periodically during multi-channel operation and the time at which to start a multi-channel operation.

7.24.2.3.3 BS-CHU1 forwards aggregation information to CPE-CHU1

The BS-CHU1 shall forward the aggregation information to the CPE-CHU1 after receiving the information from BS-CAM.

7.24.2.3.4 CPE-CHU1 forwards aggregation information to CPE-CAM

The CPE-CHU1 shall forward the aggregation information to the CPE-CAM after receiving the information from BS-CHU1. The aggregation information shall be designed as a newly defined management message from BS-CAM. The details of the management message CAM-ADD are described in 7.7.29.2. The BS-CHU1 and CPE-CHU1 do not need to understand the content of the message when performing the forwarding process.

7.24.2.3.5 BS-CAM selects a specific BS-CHU

The BS-CAM shall select a specific BS-CHU that is the target of the add new operating channel operation. The BS-CAM shall select the BS-CHU that is in the state of unused or unassigned currently and whose hardware corresponds to the new operating channel’s frequency. The operating channel selection procedure may be included in this step.

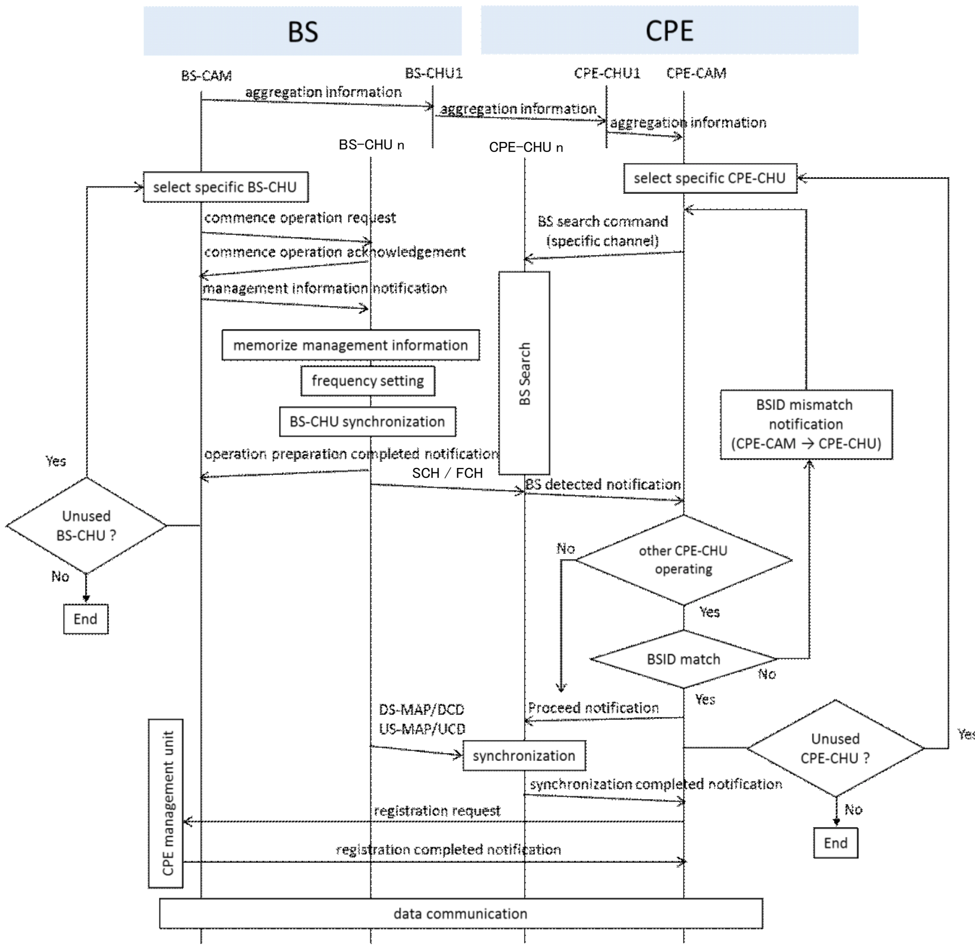


Figure 112g—Operation flow for adding new operating channel by using BS search command (specific channel)

7.24.2.3.6 BS-CAM commences operation request

The BS-CAM shall send a commence operation request to the selected BS-CHU. The commence operation request may include the various parameters in connection with the PHY such as channel center frequency and its offset, etc., and some part of MIB information such as software version information, etc.

7.24.2.3.7 BS-CHUn commences operation acknowledgment

The BS-CHU shall send a commence operation acknowledgment to the BS-CAM. The commence operation acknowledgment may include the specific BS-CHU MIB information that is needed by the BS-CAM such as device ID or serial number of the BS-CHU, etc. The BS-CHU shall response with an error when the commence operation request is rejected due to reasons such as mismatch of the software version, etc.

7.24.2.3.8 BS-CAM sends management information notification to BS-CHUn

The BS-CAM shall send a management information notification to the BS-CHU. The management information notification may mainly include the MIB information necessary for the BS-CHU and maintained by the BS-CAM such as the ID to identify the connection between BS and CPE (carrier index that is associated with the physical or logical channel), etc. If the BS-CHU has a part of the MAC layer function, then the information on MIB that is used by the MAC layer, such as Station ID, MAC Address of BS, etc., shall be included.

7.24.2.3.9 BS-CHUn memorizes management information

The BS-CHU shall memorize the management information from the BS-CAM after the management information notification. Some part of the memorized information (MIB information) shall be immediately reflected on the BS-CHU or reflected as the initial value of the transition state.

7.24.2.3.10 BS-CHUn performs frequency setting

The BS-CHU shall perform the frequency setting procedure. The channel center frequency and its offset that were received in the commence operation request or management information notification shall be reflected in the local oscillator of BS-CHU.

7.24.2.3.11 BS-CHUn performs synchronization

The BS-CHU shall perform the BS-CHU synchronization procedure. This procedure is intended for network synchronization to synchronize the superframe, frame, and TDD timing of a number of BS in a wireless communication system. Basically, this procedure shall synchronize the superframe to the start of each minute of the UTC time obtained from a global navigation system such as GPS. As a result, all the operating BS-CHUs shall be synchronized with each other.

7.24.2.3.12 BS-CHUn sends operation preparation completed notification to BS-CAM

The BS-CHU shall send an operation preparation completed notification to the BS-CAM. The BS-CHU shall send a response indicating an error when it fails to complete the operation preparation procedure.

7.24.2.3.13 BS-CHUn broadcasts SCH on PHY-OM1 or FCH on PHY-OM2

The BS-CHU shall periodically broadcast a radio frame that includes the SCH information on PHY-OM1 or FCH on PHY-OM2.

7.24.2.3.14 BS-CAM checks unused BS-CHU

The BS-CAM shall check whether there is any unused BS-CHU. If an unused BS-CHU exists, then the BS-CAM shall proceed to the select specific BS-CHU procedure.

7.24.2.3.15 CPE-CAM selects a specific CPE-CHU

The CPE-CAM shall select a specific CPE-CHU that is a target of the add new operating channel operation. The CPE-CAM shall select the CPE-CHU that is in the state of unused or unassigned. In many cases, this procedure is triggered when the BS lost condition occurs in the CPE where the CPE-CHU was selected.

7.24.2.3.16 CPE-CAM sends BS search command (specific channel) to the specific CPE-CHUn

The CPE-CAM shall send a BS search command (specific channel) to the selected CPE-CHU. The BS search command (specific channel) shall be performed by searching one or more specific frequency channels. The specific channel information shall be indicated by using the extended DCD message or newly defined management message (7.7.29.2) to specify the BS operating channels that are not connected by any CPE or shall be estimated based on the backup channel information. To prevent overlapping with the other CPE-CHU channel, the channel that the other CPE-CHU has already used shall not be searched. Moreover, the channel that the other BS has already used and that is identified by a previous BS search command, etc., shall not be searched.

7.24.2.3.17 CPE-CHUn performs BS search

The CPE-CHU shall perform the BS search command by attempting to detect the radio signal (preamble and SCH on PHY-OM1 or FCH on PHY-OM2) from the BS at the target frequency of the BS search command.

7.24.2.3.18 CPE-CHUn sends BS detected notification to CPE-CAM

The CPE-CHU shall send a BS detected notification to the CPE-CAM when it is able to detect the signal strength greater than or equal to a predetermined value that is defined in the BS search procedure. The BS detected notification shall include the BSID, which is obtained by decoding the SCH information on PHY-OM1 or FCH information on PHY-OM2.

7.24.2.3.19 CPE-CAM determines other operating CPE-CHU

The CPE-CAM shall determine whether there is any other operating CPE-CHU (connection status with BS). If there is no other operating CPE-CHU at that time, then it does not proceed to add new operating channel procedure (multi-channel operation). The CPE-CHU shall proceed to the synchronization process similarly to the conventional IEEE Std 802.22-2011.

7.24.2.3.20 CPE-CAM performs BSID matching

If another operating CPE-CHU is detected at that time, the CPE-CAM shall determine whether the BSID of the other operating CPE-CHU matches with the BSID obtained by the CPE-CHU during BS detected notification.

7.24.2.3.21 CPE-CAM sends BSID mismatch notification to CPE-CHUn

If the BSID mismatch occurred, then the BS-CAM shall send a BSID mismatch notification to the CPE-CHU. Then the CPE-CHU shall resume its BS search process with the rest of the targeted frequency, or the BS-CAM shall send a specific target frequency of BS search command to the CPE-CHU.

7.24.2.3.22 CPE-CAM sends proceed notification to CPE-CHUn

If the BSID match is confirmed, then the CPE-CAM shall send a proceed notification to the CPE-CHU to continue with the synchronization procedure.

7.24.2.3.23 CPE-CHUn performs synchronization

The CPE-CHU shall continue with the synchronization procedure with the frequency that is detected in SCH on PHY-OM1 or FCH on PHY-OM2. In addition to the original synchronization procedure such as detecting and decoding the FCH, DS-MAP, etc. to obtain the parameters of the DS, this procedure shall include the reception of UCD message process to obtain the parameters of the US, the ranging process to adjust the TDD timing, etc.

7.24.2.3.24 CPE-CHUn sends synchronization completed notification to CPE-CAM

As a response to the proceed notification procedure, the CPE-CHU shall send a synchronization completed notification to the CPE-CAM. By referring to these notifications, the CPE-CAM can recognize the multi-channel operation when two or more CPE-CHUs are connected with the BS.

7.24.2.3.25 CPE-CAM checks unused CPE-CHU

The CPE-CAM shall check whether there is any unused CPE-CHU. If the unused CPE-CHU exists, then the CPE-CAM shall proceed to the select specific CPE-CHU procedure.

7.24.2.3.26 CPE-CAM sends registration request to CPE management unit

The CPE-CAM shall send a registration request to the BS for CPE registration after completing the multi-channel operation capability. The registration request shall contain the information (carrier index, etc.) that can uniquely identify each channel used in the multi-channel operation. Some management messages may be exchanged only between the BS-CHU and CPE-CHU if necessary.

7.24.2.3.27 CPE management unit sends registration completed notification to CPE-CAM

The CPE management unit shall send a registration completed notification to the CPE-CAM.

7.24.2.4 Stop operating channel operation

7.24.2.4.1 General

When the BS is operating under the multi-channel operation, the following procedure of stop operating channel is performed on both the A-BS and A-CPE to stop the operating channel that is requested by the A-BS.

The stop operating channel operation procedure shall consist of the following steps:

a) BS-CAM sends stop operation request to BS-CHU.
b) BS-CHU starts stop operation timer.
c) BS-CHU sends stop operation request acknowledgment to BS-CAM
d) BS-CHU sends stop operation request to CPE-CHU.
e) CPE-CHU starts stop operation timer.
f) CPE-CHU sends stop operation notification to CPE-CAM.
g) CPE-CAM sends stop operation approval/command to CPE-CHU.
h) CPE-CHU sends stop operation request acknowledgment to BS-CHU.
i) CPE-CHU checks stop operation timer expired and stops operation.
j) CPE-CHU sends stop operation completed notification to CPE-CAM.
k) BS-CHU checks stop operation timer expired and stops operation.
l) BS-CHU sends stop operation completed notification to CPE management unit.

The stop operating channel operation flow is shown in Figure 112h.

7.24.2.4.2 BS-CAM sends stop operation request to BS-CHU

The BS-CAM shall send the stop operation request to the BS-CHU that is the target of the stop operating channel operation.

7.24.2.4.3 BS-CHU starts stop operation timer

The BS-CHU shall start the stop operation timer (T66) after receiving the stop operation request from the BS-CAM. The start of the stop operation timer shall determine the frame number where the operation is scheduled to stop.

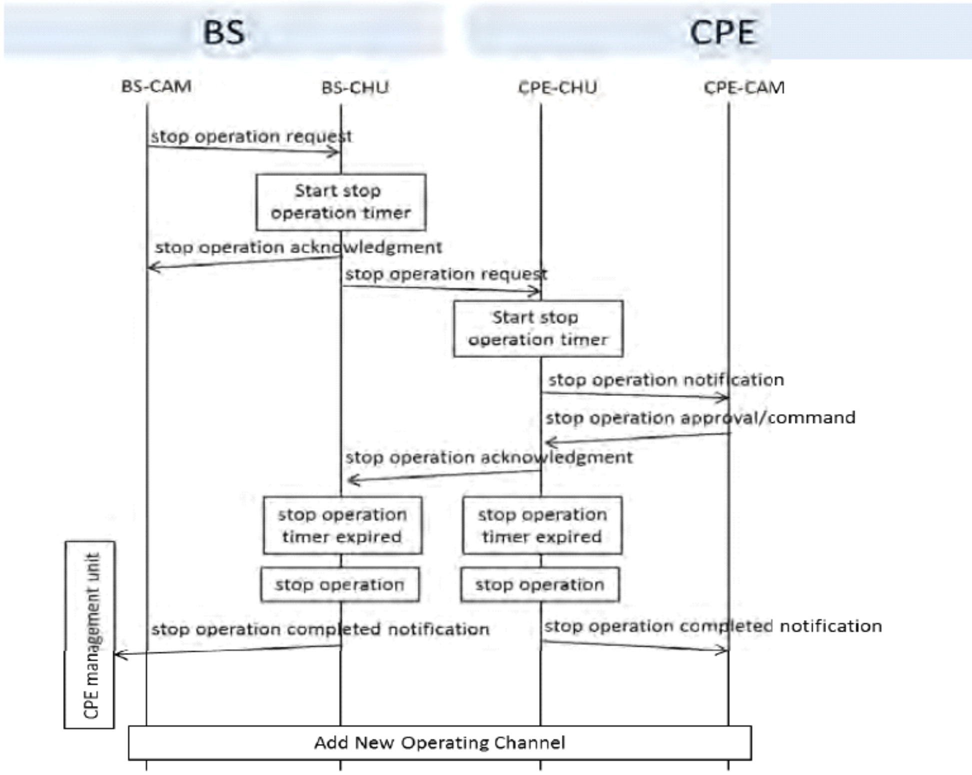


Figure 112h—Operation flow for stopping operating channel

7.24.2.4.4 BS-CHU sends stop operation request acknowledgment to BS-CAM

The BS-CHU shall send the stop operation request acknowledgment to the BS-CAM.

7.24.2.4.5 BS-CHU sends stop operation request to CPE-CHU

The BS-CHU shall send the stop operation request to the CPE-CHU by using the DS transmission. The stop operation request can be sent as a newly defined management message. The details of the management message CAM-STP are described in 7.7.29.3.

7.24.2.4.6 CPE-CHU starts stop operation timer

Based on the information that specifies the target of the stop operation channel, which can be obtained after receiving the stop operation request from the BS-CHU, the CPE-CHU shall confirm the target channel of the request. If the request is addressed to the CPE-CHU, then the CPE-CHU shall start the stop operation timer.

7.24.2.4.7 CPE-CHU sends stop operation notification to CPE-CAM

The CPE-CHU shall send the stop operation notification to the CPE-CAM.

7.24.2.4.8 CPE-CAM sends stop operation approval/command to CPE-CHU

The CPE-CAM shall send the stop operation approval/command to the CPE-CHU after the CPE-CAM is notified that the channel operation of the CPE-CHU will be stopped.

7.24.2.4.9 CPE-CHU sends stop operation request acknowledgment to BS-CHU

The CPE-CHU shall send the stop operation request acknowledgment to the BS-CHU after receiving the stop operation approval/command from the CPE-CAM. The stop operation acknowledgment can be sent as a newly defined management message through the US transmission. The details of the management message CAM-STP are described in 7.7.29.3.

7.24.2.4.10 CPE-CHU checks stop operation timer expired and stops operation

The CPE-CHU shall stop the operation when the stop operation timer expires, i.e., it has reached the frame number that was set during the set stop operation timer procedure. The CPE-CHU shall stop all transmission and reception after the stop operation procedure is performed.

7.24.2.4.11 CPE-CHU sends stop operation completed notification to CPE-CAM

The CPE-CHU shall send the stop operation completed notification to the CPE-CAM after completing the stop operation procedure.

7.24.2.4.12 BS-CHU checks stop operation timer expired and stops operation

The BS-CHU shall stop the operation when the stop operation timer expires and stop all the transmission and reception after the stop operation procedure is performed.

7.24.2.4.13 BS-CHU sends stop operation completed notification to CPE management unit

The BS-CHU shall send the stop operation completed notification to the BS-CAM and CPE management unit after completing the stop operation procedure. The BS-CHU and CPE-CHU that have stopped their operation will be the target CHUs for the add new operating channel procedure.

7.24.2.5 Switch operating channel operation

7.24.2.5.1 General

When the BS is operating under the multi-channel operation, the following procedure of switch operating channel is performed on both the A-BS and A-CPE to switch the operating channel that is requested by the A-BS.

The switch operating channel operation procedure shall consist of the following steps:

a) BS-CAM sends channel switch request to BS-CHU.
b) BS-CHU starts channel switch timer.
c) BS-CHU sends channel switch request acknowledgment to BS-CAM.
d) BS-CHU sends channel switch request to CPE-CHU.
e) CPE-CHU starts channel switch timer.
f) CPE-CHU sends channel switch notification to CPE-CAM.
g) CPE-CAM sends channel switch approval/command to CPE-CHU.
h) CPE-CHU sends channel switch request acknowledgment to BS-CHU.
i) BS-CHU checks channel switch timer expired and performs channel switch.
j) CPE-CHU checks channel switch timer expired and performs channel switch.
k) BS-CHU sends channel switch completed notification to BS-CAM.
l) BS-CHU broadcasts SCH on PHY-OM1 or FCH on PHY-OM2.

m) BS-CHU sends DS-MAP/DCD/US-MAP/UCD to CPE-CHU.

n) CPE-CHU sends channel switch completed notification to CPE-CAM.

o) CPE-CHU sends channel switch completed notification to CPE management unit.

The switch operating channel operation flow is shown in Figure 112i.

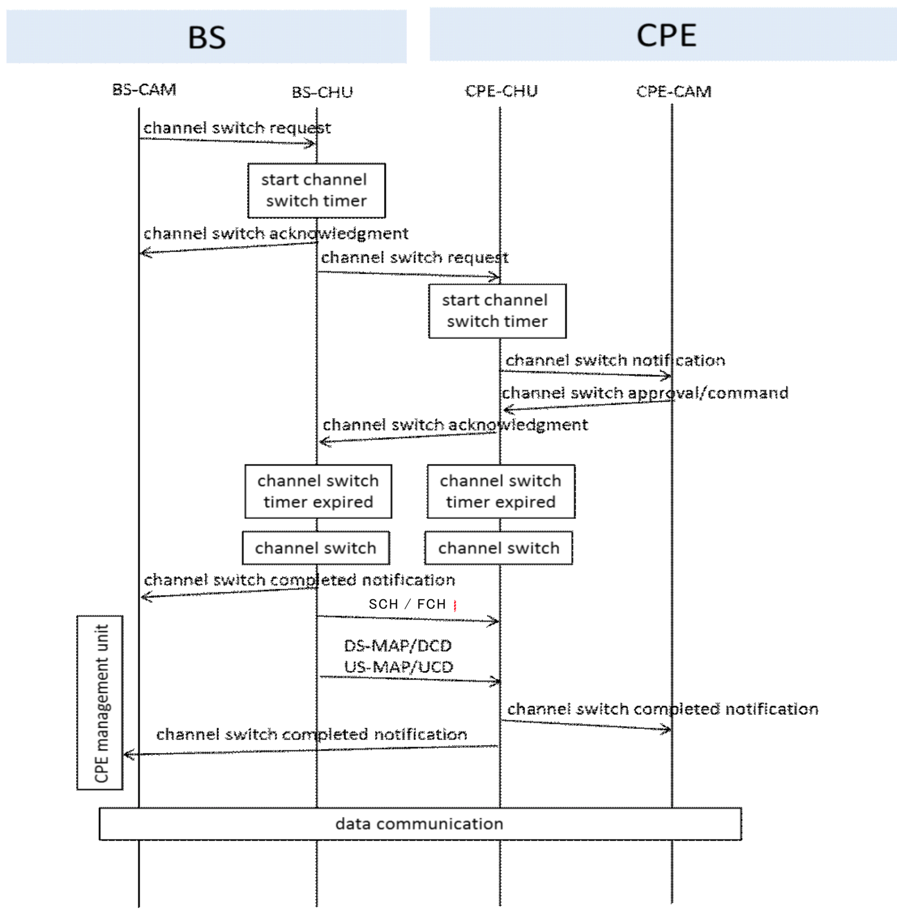


Figure 112i—Operation flow for switching operating channel

7.24.2.5.2 BS-CAM sends channel switch request to BS-CHU

The BS-CAM shall send the channel switch request to the BS-CHU that is the target of the switch operating channel operation. The BS-CHU shall correspond to the requested switch operating channel's frequency.

7.24.2.5.3 BS-CHU starts channel switch timer

The BS-CHU shall start the channel switch timer (T67) after receiving the channel switch request from the BS-CAM. The start of the channel switch timer shall determine the frame number where the new operating channel is scheduled to switch.

7.24.2.5.4 BS-CHU sends channel switch request acknowledgment to BS-CAM

The BS-CHU may send the channel switch request acknowledgment to the BS-CAM after the BS-CHU sent the channel switch request to the CPE-CHU as described in 7.24.2.5.5 for shortening the channel switch time.

7.24.2.5.5 BS-CHU sends channel switch request to CPE-CHU

The BS-CHU shall send the channel switch request to the CPE-CHU by using the DS transmission. The channel switch request can be sent as a newly defined management message. The details of the management message CAM-SWH are described in 7.7.29.5. The management message shall be broadcasted to all the CPEs, and the CPEs shall be able to receive and interpret the content of the management message.

7.24.2.5.6 CPE-CHU starts channel switch timer

The CPE-CHU shall start the channel switch timer after receiving the channel switch request from the BS-CHU.

7.24.2.5.7 CPE-CHU sends channel switch notification to CPE-CAM

The CPE-CHU shall send the channel switch notification to the CPE-CAM in order to acquire channel switch approval/command from the CPE-CAM.

7.24.2.5.8 CPE-CAM sends channel switch approval/command to CPE-CHU

The CPE-CAM shall send the channel switch approval/command to the CPE-CHU after the CPE-CAM is notified that the operating channel of the CPE-CHU will be switched.

7.24.2.5.9 CPE-CHU sends channel switch request acknowledgment to BS-CHU

The CPE-CHU shall send the channel switch request acknowledgment to the BS-CHU after receiving the channel switch approval/command from the CPE-CAM. The channel switch request acknowledgment can be sent as a newly defined management message through the US transmission. The details of the management message CAM-SWH are described in 7.7.29.5.

7.24.2.5.10 BS-CHU checks channel switch timer expired and performs channel switch

The BS-CHU shall switch to a new operating channel when the channel switch timer expires. The channel switch timer expires when it has reached the frame number that was set during the start channel switch timer procedure. The BS-CHU shall modify the operating parameters within the RTG period and shall change the frequency of the local oscillator in order to switch to a new operating channel. In most cases, a channel switch is performed because terminating the current operating channel is necessary; therefore, a channel switch is enforced even if the channel switch acknowledgment is not received from either one of the CPEs.

7.24.2.5.11 CPE-CHU checks channel switch timer expired and performs channel switch

The CPE-CHU shall switch to a new operating channel when the channel switch timer expires.

7.24.2.5.12 BS-CHU sends channel switch completed notification to BS-CAM

The BS-CHU shall send the channel switch completed notification to the BS-CAM after completing the channel switch procedure. This shall indicate that the channel switch procedure at the PHY of BS-CHU is completed (such as the frequency of the local oscillator of BS-CHU is locked to the new channel).

7.24.2.5.13 BS-CHU broadcasts SCH on PHY-OM1 or FCH on PHY-OM2

The BS-CHU shall broadcast a radio frame that includes the SCH information on PHY-OM1 or FCH on PHY-OM2.

7.24.2.5.14 BS-CHU sends DS-MAP/DCD/US-MAP/UCD to CPE-CHU

The BS-CHU shall send the DS-MAP/DCD/US-MAP/UCD information to CPE-CHU for the synchronization procedure.

7.24.2.5.15 CPE-CHU sends channel switch completed notification to CPE-CAM

The CPE-CHU shall send the channel switch completed notification to the CPE-CAM when the frame containing SCH on PHY-OM1 or FCH on PHY-OM2, etc., is received correctly. The channel switch completion notification shall indicate that the channel switch has been completed at the MAC layer.

7.24.2.5.16 CPE-CHU sends channel switch completed notification to CPE management unit

The CPE-CHU shall send the channel switch completed notification to the CPE management unit. The channel switch completed notification can be sent as a newly defined management message through the US transmission. The details of the management message CAM-SWH are described in 7.7.29.5. Upon receiving the management message, the CPE management unit in BS shall update the latest information of the CPEs.

7.24.3 Multi-channel operation at A-BS

This subclause explains the operation flow of the A-BS's channel allocation manager (BS-CAM) for commencing the multi-channel operation. The operation flow of commencing multi-channel operation at A-BS is shown in Figure 112j. In order to perform the multi-channel allocation necessary for multi-channel operation, three basic functions, which are add new operating channel, stop operating channel, and switch operating channel, are defined. The detailed explanation of each function and its operation flow are described in 7.24.2.2, 7.24.2.4, and 7.24.2.5.

In commencing multi-channel operation at the A-BS, the BS-CAM shall play the key role to decide the operating channel and determine the implementation of one of the three basic functions as shown in Figure 112j. The triggers for the BS-CAM to decide the operating channel are database access, BS sensing report, CPE sensing report, and BS channel scheduling. The database access trigger shall refer to the database access result that concluded there are changes in the available operating channels after accessing the whitespace database by the database access control in BS. The BS sensing report and CPE sensing report shall refer to the sensing report that concluded there are changes in the available operating channels after performing the sensing process. These are triggers caused by the changes in the available operating channels. The BS channel scheduling is when a particular operating channel is available under specific time scheduling by the BS.

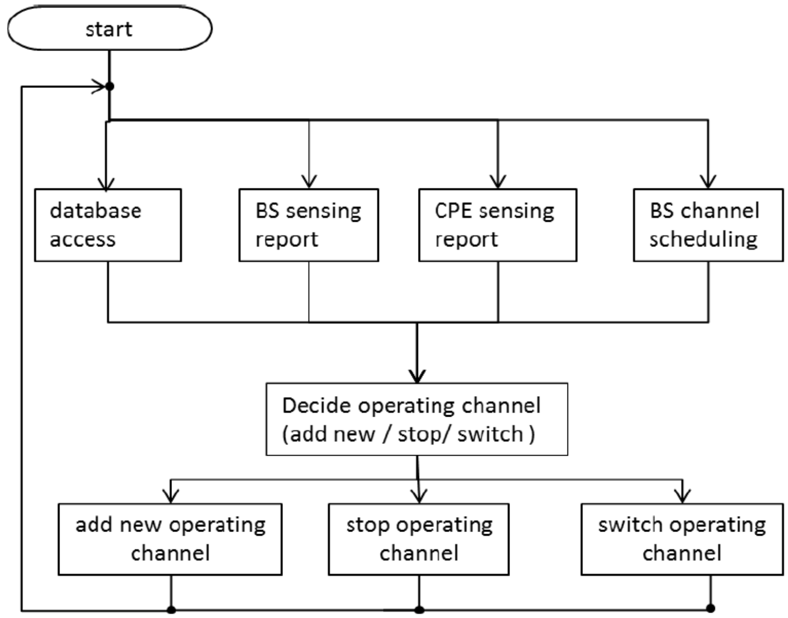


Figure 112j—Operation flow of commence multi-channel operation at A-BS

7.24.4 Multi-channel operation at A-CPE

This subclause explains the operation flow of the A-CPE's channel allocation manager (CPE-CAM) for commencing the multi-channel operation. The operation flow of commencing multi-channel operation at A-CPE is shown in Figure 112k. In order to perform the multi-channel allocation necessary for multi-channel operation, the CPE-CAM also possesses three basic functions, which are add new operating channel, stop operating channel, and switch operating channel. The detailed explanation of each function and its operation flow are described in 7.24.2.2, 7.24.2.4, and 7.24.2.5.

In commencing multi-channel operation at A-CPE, most of the triggers of the CPE-CAM operation result from the BS control messages. The triggers for the CPE-CAM to commence the multi-channel operation are BS control message, CPE incumbent sensing report, CPE channel scheduling, and BS lost message.The BS control message includes the switch operating channel and stop operating channel control messages. When the CPE-CAM receives the switch operating channel control message from the BS, it shall proceed to the switch operating channel procedure and switch to the operating channel as stated in the switch operating channel control message. When the CPE-CAM received the stop operating channel control message from the BS, it shall proceed to the stop operating channel procedure and stop the operating channel as stated in the stop operating channel control message. When the CPE incumbent sensing report shows the detection of incumbent or when the CPE channel scheduling is scheduled to stop the operating channel, the CPE-CAM shall proceed to the stop operating channel procedure as well. The BS lost message, which indicates the lost connection between a CPE-CHU and a BS, or the CPE channel scheduling for adding a new operating channel shall proceed to the add new operating channel procedure.

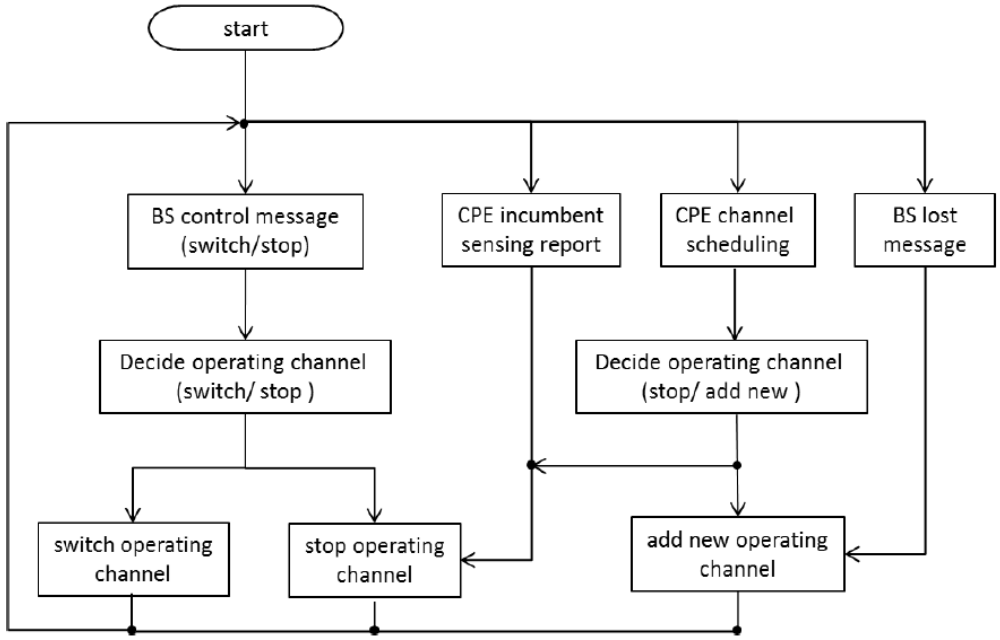


Figure 112k—Operation flow for commence multi-channel operation at A-CPE

7.25 Group Resource Allocation

A large number of CPEs may be connected to the A-BS. Among them, some CPEs have similar traffic patterns, such as payload size, traffic period, and data rate (PHY Mode), etc. It is a burden of MAP overhead to allocate the resources to all CPEs individually. The Group Resource Allocation (GRA) is very efficient for a group of CPEs communicating using a same PHY Mode and with a fixed payload size. The MAP overhead is significantly reduced by allocating the resources to the Group using bitmap format.

The group is composed of one A-CPE and many S-CPEs. Within the group, A-CPE is a controller of a group consisting of many S-CPEs. The A-CPE capabilities include access to the database services, identification of the group, network entry with A-BS, etc. All the S-CPEs within the group are synchronized to the A-CPE.

There are two types of group: fixed group and mobile (or portable) group. The type of group is determined according to the mobility of A-CPE. The A-CPE within fixed group is fixed on the building, house, tower, etc. The A-CPE within mobile (or portable) group is mobile (or portable) on the vehicles, etc.

The A-BS configures the group resource allocation by using the Group Resource Allocation Configuration (GRA-CFG) message, as shown in Table 173n. The A-BS creates a new group, identifies the devices that belong to the group, and allocates the resources on a group basis. The GRA-CFG message includes the characteristics of group, such as Device Bitmap Size, Bitmap of Station ID, Group ID, Group Type, and Group Location. The group resource allocation configuration can be updated using the Group Resource Allocation Update (GRA-UPD) message, as shown in Table 173o. The A-BS uses a GRA-UPD message to add a device to a group or delete a device from a group. The A-BS also uses a GRA-UPD message to update the location of group. The DS/US-MAP message defines the access to the DS/US resources, as shown in Table 25 and Table 34, respectively. The format of a DS/US-MAP IEs is defined for the Individual Resource Allocation (IRA), as shown in Table 26 and Table 35, respectively. And the format of a DS/US-MAP GRA IEs is defined for the Group Resource Allocation (GRA), as shown in Table 29d and Table 40d, respectively.

The backup and candidate channels can also be updated on a group basis using Backup and Candidate Channel List IE, as shown in Table 22. When Group Flag is set to 1, the backup and candidate channels are used locally within a group. Otherwise, when Group Flag is set to 0, the backup and candidate channels are used globally within a cell. The backup and candidate channels are selected using the mobility and the location of A-CPE. The same channel is selected as the backup (or candidate) channel between the fixed groups. But if the groups could overlap, the backup (or candidate) channel shall be different to avoid interference among groups. On the other hand, different channels are selected as the backup (or candidate) channel between the fixed and the mobile group or between the mobile groups. But if the groups could not overlap, the backup (or candidate) channel could be same for frequency reuse. The backup and candidate channel list of each group shall be updated according to the periodic monitoring, which checks whether the groups could overlap each other or a new group appears. Therefore, when a mobile group moves into other group, or when a new group or incumbent user appears within a cell, the A-BS and CPEs can reduce the signaling overhead and can prevent QoS degradation by avoiding frequent channel switching.

Figure 112l shows an example of how the backup channel is selected. There are three fixed groups and a single mobile group. The A-CPE of the fixed groups is installed at the fixed object, such as a farmhouse, building, tower, etc. The A-CPE of the mobile group is installed at the mobile or portable object, such as a car, train, ship, etc. In a relationship between group 1 and group 2, there are two fixed groups, which are overlapping each other; thus the A-BS may allocate different backup channels, for example, backup channel #2 and backup channel #3, to group 1 and group 2, respectively. In a relationship between group 1 and group 3, there are two fixed groups, which are not overlapping each other; thus the A-BS may allocate the same backup channel, for example, backup channel #2, to both group 1 and group 3. In a relationship between group 3 and group 4, there are fixed and mobile groups, which are overlapping each other; thus the A-BS may allocate different backup channels, for example, backup channel #2 and backup channel #3, to group 3 and group 4, respectively. In a relationship between group 2 and group 4, there are fixed and mobile groups, which are not overlapping each other; thus the A-BS may allocate the same backup channel, for example, backup channel #3, to both group 2 and group 4.

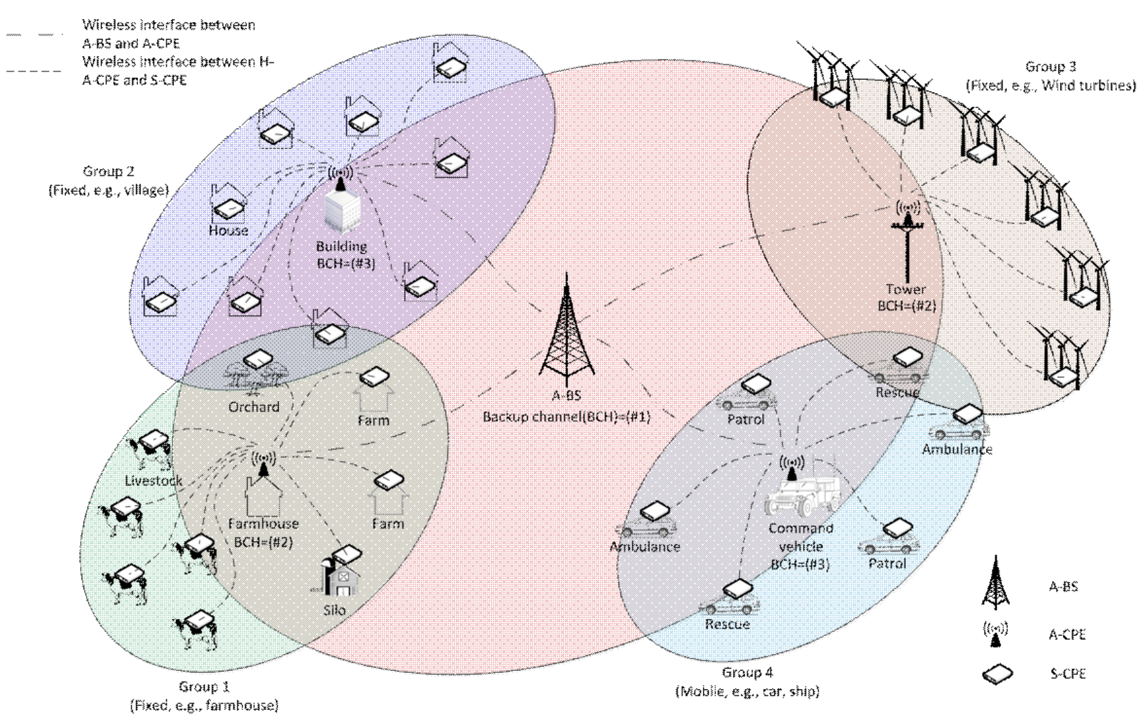


Figure 112l—Example of backup channel selection

Figure 112m shows an example of how the backup channel is decided. When any idle backup channels are not being allocated to other groups, the A-BS allocates the idle backup channels to the target group (1). When there are no idle backup channels to be allocated, the A-BS may first check if any backup channels are allocated to a fixed group. When any backup channels are being allocated to fixed groups, and the target group and fixed group do not overlap, the A-BS allocates the backup channels allocated to the fixed group, to the target group (2). A presence of a backup channel allocated to the fixed group may be first checked since a burden of changing the backup channels may exist when a state of a backup channel being currently allocated to a mobile group is changed to an unavailable backup channel, due to mobility of the mobile group, although it is determined that the allocated backup channel is available. When no backup channels are being allocated to fixed groups, or when any backup channels are being allocated to fixed groups but the target group and the fixed group overlap, the A-BS may check if any backup channels are allocated to a mobile group. When backup channels are being allocated to mobile groups, and the target group and the mobile group do not overlap, the A-BS allocates the backup channels allocated to the mobile group (3). Although backup channels are being allocated to the mobile group, but the mobile group and the target group also overlap, the A-BS allocates the backup channels allocated to the fixed group or the mobile group (4). When also no backup channels are being allocated to mobile groups, the A-BS allocates the backup channels allocated to the A-BS, to the target group (5). When at least two overlapping groups share the backup channels or when the A-BS and some groups share the backup channels, the A-BS may use a mechanism for proper resources sharing between the overlapping groups or the A-BS and some groups after channel switching.

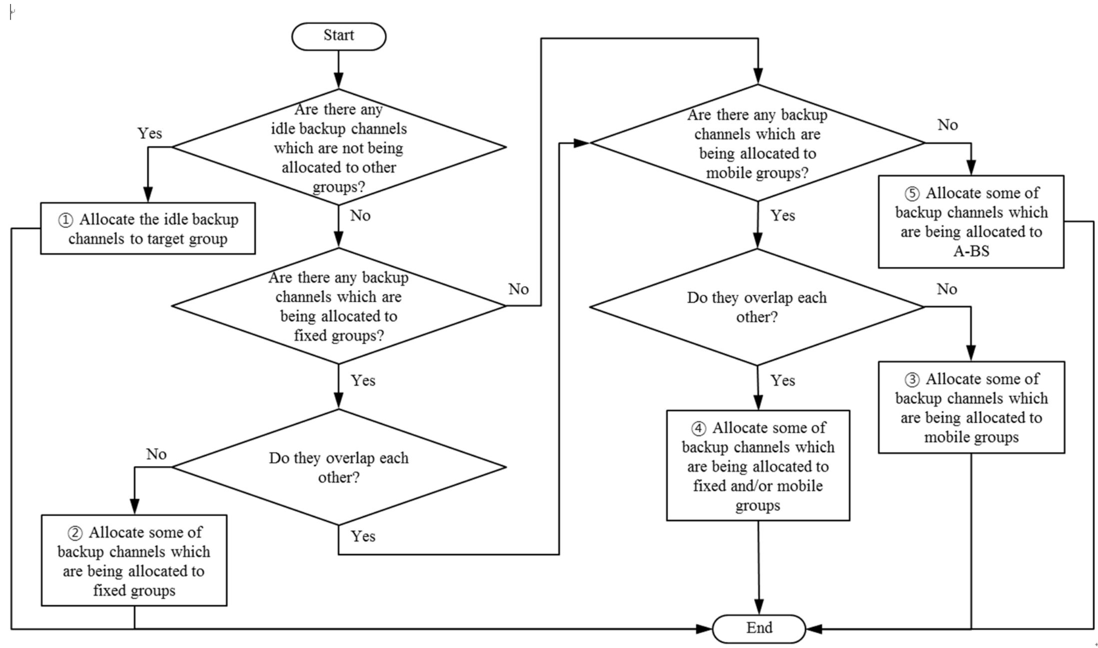


Figure 112m—Example of backup channel decision

8. Security mechanism in IEEE 802.22

Insert the following paragraph after the sixth paragraph in the preliminary text of Clause 8:

The security concepts that are enabled by security sublayers 1 and 2 are also extended to the relay network for both A-CPEs and S-CPEs. The security model in the relay network is end-to-end. Authentication of MAC management and user data sent between the A-BS and S-CPE is handled at each end of the connection, i.e., by the A-BS and S-CPE. Centralized and distributed scheduling A-CPEs are responsible only for authentication of MAC management messages exchanged between them and the A-BS. Centralized and distributed scheduling A-CPEs shall not be involved in initial authentication or reauthentication or keying of attached S-CPEs, other than to forward SCM-REQ/RSP messages between any attached S-CPEs and the A-BS. Centralized and distributed scheduling A-CPEs do not maintain or store any of the authentication information (e.g., AK Context) related to any attached S-CPEs.

8.1 Security Architecture for the Data/Control and Management Planes

8.1.2 Key management and authentication overview

Change the sixth paragraph of 8.1.2 as follows:

The AAA server and a client CPE authenticate each other during the initial authentication exchange. The AAA and CPE present their credentials to each other. Since the AAA and CPE mutually authenticate each other, there is protection against an attacker employing a cloned CPE that masquerades as a legitimate subscriber's CPE. Once authentication is completed, the BS and CPE have keying that is used to protect management messages (e.g., MMP_Key) and keying used in transportation of keys for protection of user data (e.g., KEK). The process related to setting up and maintaining keying to protect user data is known as the TEK Exchange (see 8.2.3) process. During authentication exchange, protection of user data is configured for the CPE.~~if a CPE indicates that it does not support protection of user data, no key exchange and state machines used to maintain keying to protect user data will be executed.~~ The TEK Exchange process shall be engaged by a CPE only if protection of user data has been configured during the authentication exchange.

Insert the following paragraph after the sixth paragraph of 8.1.2:

If an A-CPE is configured to support operation as a distributed or centralized scheduling A-CPE, it shall not initiate TEK Exchange process. Distributed and centralized scheduling A-CPEs shall also not be capable of maintaining/storing the keying material related to S-CPEs that are attached to the A-BS through them.

8.2 SCM protocol

8.2.2 Authentication state machine

Change the preliminary text of 8.2.2 as follows:

The Authentication state machine (ASM) adopts an authentication framework similar to the model specified in IEEE Std 802.16-2009. The ASM incorporates EAP authentication and is made up of four states and thirteen events and messages that are used to communicate with other aspects of the SCM framework. The ASM has to interoperate with the TEK state machine (TSM) (8.2.3) and the EAP Process. In 8.2.2.1 through 8.2.2.7, the term "CPE" refers to S-CPEs as well as A-CPEs.

8.2.2.7 Security capabilities negotiation

Change the ninth paragraph in 8.2.2.7 as follows:

If the SA defines use of ~~authentication only or~~ "no protection" method (e.g., = 0x00) (Table 193), all MAC PDUs sent with FIDs linked to this SA must have the EC bit set to '0' in the generic MAC header. If the SA defines use of any other cryptographic methods (e.g., >= 0x01) (Table 193),~~Otherwise, if only "authentication+encryption" or "encryption only" is supported~~ the EC bit must be set to '1' in the generic MAC header. Other combinations are not allowed; MAC PDUs presenting other combinations should be discarded.

Insert the following paragraph before the last paragraph of 8.2.2.7:

Some rules should be considered for selecting which Cryptographic Suites listed in Table 193 are applicable to CPE:

— Legacy CPEs shall not be capable of being cryptographic Suites that use a 4-byte PN value, e.g., suite 0x0C–0x14.
— A distributed or centralized scheduling A-CPE may make use of cryptographic suites related to DS multicast Group SA (e.g., 0x03, 0x04, 0x0A, 0x0B, 0x0E, 0x0F, 0x13, and 0x14) for MAC management messages sent on the Multicast Management FID.
— A distributed or centralized scheduling A-CPE, S-CPE, or legacy S-CPE shall not be simultaneously configured to use cryptographic suites with 3-byte and 4-byte PNs on the static Null and Primary SAs as well as dynamically allocated Group SAs.
— A distributed or centralized scheduling A-CPE, S-CPE, or legacy S-CPE shall not be simultaneously configured to use cryptographic suites with 4-byte and 8-byte ICVs on the static Null and Primary SAs as well as dynamically allocated Group SAs.

8.2.3 TEK exchange overview

8.2.3.1 TEK exchange overview for PMP topology

Change the first paragraphs in 8.2.3.1 as follows:

~~If the CPE and BS decide “No authentication” as their authentication policy, t~~The CPE and BS shall not perform the Key Request/Key Reply handshake in either of the following cases:~~.~~

— The CPE and BS decide “No authentication” as their authentication policy.
— The A-CPE is configured to operate as a distributed or centralized scheduling A-CPE.

In ~~this~~ the first case, target SAID value, which may be included in DSA-REQ/RSP messages, shall be Null SAID.

8.2.3.2 TEK state machine

Insert the following paragraph at the end of 8.2.3.2:

In 8.2.3.2.1 through 8.2.3.2.5, the term “CPE” refers to legacy CPEs, S-CPEs, and A-CPEs that are not configured to operate as distributed or centralized scheduling A-CPEs.

8.3 Key usage

8.3.1 BS key usage

8.3.1.5 BS usage of TEX and GTEK

Insert the following paragraph after the fifth paragraph (and before Figure 119) in 8.3.1.5:

In Figure 119, “CPE” refers to legacy CPEs, S-CPEs, and A-CPEs that are not configured to operate as Distributed or Centralized scheduling mode.

8.4 Cryptographic methods

8.4.1 Selection of Data Encryption and Authentication methods

Change Table 193 as follows:

Table 193—Cryptographic suite

Cryptographic Suite v~~V~~alue	~~Cryptographic suite~~ Key Type	PN Size (bytes)	ICV Size (bytes)
0x00	No Protection (No Authentication, No Encryption)	0	0
0x01	Authentication only for Unicast, AES-128 key wrap of TEK using KEK, 3-byte PN, 4-byte ICV	3	4
0x02	Authentication and Encryption for Unicast, AES-128 key wrap of TEK using KEK, 3-byte PN, 4-byte ICV	3	4
0x03	Authentication only for Multicast, AES-128 key wrap of GTEK with GKEK, 3-byte PN, 4-byte ICV	3	4
0x04	Authentication and Encryption for Multicast, AES-128 key wrap of GTEK with GKEK, 3-byte PN, 4-byte ICV	3	4
0x05	Encryption only for Unicast, AES-128 key wrap of TEK using KEK, 3-byte PN	3	0
0x06	BS random generation of GKEK and GTEK	N/A	N/A
0x07	Operator-specific function for GKEK and GTEK generation	N/A	N/A
0x08	Authentication only for Unicast, AES-128 key wrap of TEK using KEK, 3-byte PN, 8-byte ICV	3	8
0x09	Authentication and Encryption for Unicast, AES-128 key wrap of TEK using KEK, 3-byte PN, 8-byte ICV	3	8
0x0A	Authentication only for Multicast, AES-128 key wrap of GTEK with GKEK, 3-byte PN, 8-byte ICV	3	8
0x0B	Authentication and Encryption for Multicast, AES-128 key wrap of GTEK with GKEK, 3-byte PN, 8-byte ICV	3	8
0x0C	Authentication only for Unicast, AES-128 key wrap of TEK using KEK, 4-byte PN, 4-byte ICV	4	4
0x0D	Authentication and Encryption for Unicast, AES-128 key wrap of TEK using KEK, 4-byte PN, 4-byte ICV	4	4
0x0E	Authentication only for Multicast, AES-128 key wrap of GTEK with GKEK, 4-byte PN, 4-byte ICV	4	4
0x0F	Authentication and Encryption for Multicast, AES-128 key wrap of GTEK with GKEK, 4-byte PN, 4-byte ICV	4	4
0x10	Encryption only for Unicast, AES-128 key wrap of TEK using KEK, 4-byte PN	4	0
0x11	Authentication only for Unicast, AES-128 key wrap of TEK using KEK, 4-byte PN, 8-byte ICV	4	8

Table 193—Cryptographic suite *(continued)*

Cryptographic Suite v~~V~~alue	~~Cryptographic suite~~ Key Type	PN Size (bytes)	ICV Size (bytes)
0x12	Authentication and Encryption for Unicast, AES-128 key wrap of TEK using KEK, 4-byte PN, 8-byte ICV	4	8
0x13	Authentication only for Multicast, AES-128 key wrap of GTEK with GKEK, 4-byte PN, 8-byte ICV	4	8
0x14	Authentication and Encryption for Multicast, AES-128 key wrap of GTEK with GKEK, 4-byte PN, 8-byte ICV	4	8
~~0x08~~0x15–0xFF	*Reserved*	N/A	N/A

8.4.2 Data Encryption and Authentication with AES GCM

8.4.2.1 PDU format

Change the title of 8.4.2.1.1 as follows:

8.4.2.1.1 Packet number (PN)

Insert the following subclause (8.4.2.1.1.1) immediately after the 8.4.2.1.1 heading:

8.4.2.1.1.1 Overview

A PN is prepended to a MAC PDU payload when a CPE is configured for a cryptographic suite other than x00. The PN value associated with a cryptographic suite selected for an SA can be 3 bytes or 4 bytes. A CPE cannot be configured for a multiple cryptographic suites that support both 3-byte and 4-byte PNs simultaneously across the SAs for which it is configured. Subclause 8.4.2.1.1.2 describes how a CPE and BS handle the operation of a 3-byte PN, and 8.4.2.1.1.3 describes how a CPE and BS handle the operation of 4-byte PN.

Insert the following subclause heading (8.4.2.1.1.2) immediately after the new subclause 8.4.2.1.1.1 (the text formerly in 8.4.2.1.1 is now in 8.4.2.1.1.2), and change the text of 8.4.2.1.1.2 as indicated:

8.4.2.1.1.2 3-byte PN procedure

The MAC PDU payload shall be prefixed with a 3-byte PN ~~(Packet Number)~~, when the cryptographic suite selected for the SA is 0x01–0x05 and 0x08–0x0A. The PN shall be encoded in the MAC PDU least significant byte first. The PN shall not be encrypted.

The PN associated with an SA shall be set to 1 when the SA is established and when a new TEK is installed. Upon completion of initial authentication or reauthentication and after the MMP_KEY ~~has been derived~~ has been derived, the MMP_PN is set to 1. After each PDU transmission made during single channel operation or each PDU transmission to be copied across all active BS/CPE-CHUs during multi-channel operation in Transmit Diversity mode, the PN and MMP_PN shall be incremented by 1. After each unique PDU transmission made on each active BS/CPE-CHU during multi-channel operation in Bulk Transmission mode, the PN and MMP_PN shall be incremented by 1 on each active CHU in succession.

When admitting a CPE to an existing multicast/broadcast group, the BS will take the current value of the PN related to the newest generation of material for that GSA, and increment by 1 when establishing. The maximum number of CPEs that can be admitted to a multicast/broadcast group simultaneously is one half the PN_WINDOW_SIZE (see 8.4.2.3).

On DS connections, the PN shall be XORed with 0x800000 prior to encryption and transmission. This effectively splits the PN space into two ranges for DS (0x000000–0x7FFFFF) and DU (0x800001–0xFFFFFF); thereby avoiding collision of PN values when using a single PN for DS and DU. On DS connections, the PN shall be used without such modification.

Any tuple value of {PN, KEY} ~~shall not be used more than once for the purposes of transmitting data~~ shall be handled as per the receive processing rules for treating the PN value as described in 8.4.2.3. ~~This~~These measures are a known protection against replay attacks.

A new TEK shall be requested and transferred before the PN on either the CPE or BS reaches ~~0x7FFFFFFF~~0x7FFFFF. If the PN in either the CPE or BS reaches ~~0x7FFFFFFF~~0x7FFFFF without new keys being installed, transport communications on that SA shall be halted until new TEKs are installed. In the case of the MMP_KEY, if MMP_PN expires, then the current AK is invalidated and shall start Reauthentication.

Insert the following subclause (8.4.2.1.1.3) after 8.4.2.1.1.2:

8.4.2.1.1.3 4-byte PN procedure

The MAC PDU payload shall be prefixed with a 4-byte PN, when the cryptographic suite selected for the SA is 0x0C–0x14. The PN shall be encoded in the MAC PDU least significant byte first. The PN shall not be encrypted.

The PN associated with an SA shall be set to 1 when the SA is established and when a new TEK is installed. Upon completion of initial authentication or reauthentication and after the MMP_KEY has been derived, the MMP_PN is set to 1. After each PDU transmission made during single channel operation or each PDU transmission to be copied across all active BS/CPE-CHUs during multi-channel operation in Transmit Diversity mode, the PN and MMP_PN shall be incremented by 1. After each unique PDU transmission made on each active BS/CPE-CHU during multi-channel operation in Bulk Transmission mode, the PN and MMP_PN shall be incremented by 1 on each active CHU in succession.

When admitting a CPE to an existing multicast/broadcast group, the BS will take the current value of the PN related to the newest generation of material for that GSA, and increment by 1 when establishing. The maximum number of CPEs that can be admitted to a multicast/broadcast group simultaneously is one half the PN_WINDOW_SIZE (see 8.4.2.3).

On DS connections, the PN shall be XORed with 0x80000000 prior to encryption and transmission. This effectively splits the PN space into two ranges for DS (0x00000000–0x7FFFFFFF) and DU (0x80000001–0xFFFFFFFF); thereby avoiding collision of PN values when using a single PN for DS and DU. On DS connections, the PN shall be used without such modification.

Any tuple value of {PN, KEY} shall be handled as per the receive processing rules for treating the PN value as described in 8.4.2.3. These measures are a known protection against replay attacks.

A new TEK shall be requested and transferred before the PN on either the CPE or BS reaches 0x7FFFFFFF. If the PN in either the CPE or BS reaches 0x7FFFFFFF without new keys being installed, transport communications on that SA shall be halted until new TEKs are installed. In the case of the MMP_KEY, if MMP_PN expires, then the current AK is invalidated and shall start Reauthentication.

8.4.2.1.2 PDU format—Authentication only

Change the text of 8.4.2.1.2 as follows:

The ciphersuites allow for authentication and/or encryption of MAC PDUs. If suite~~s~~ 0x01, ~~or~~ 0x03, 0x08, 0x0A, 0x0C, 0x0E, 0x11, or 0x13 is assigned to the SA, then only authentication is provided for any MAC PDUs transmitted on service flows that are mapped to these SAs.

The AES in GCM protocol is applied in the following manner:

1) The Plaintext Payload is processed, generating an Integrity Check Value (ICV) that is 8 bytes long (i.e., for suites 0x08, 0x0A, 0x11, and 0x13) or 4 bytes long (i.e., for suites 0x01, 0x03, 0x0C, and 0x0E).
2) The PN value is either 4 bytes (i.e., for suites 0x0C, 0x0E, 0x11, and 0x13) or 3 bytes (i.e., for suites 0x01, 0x03, 0x08, and 0x0A). PN Maintenance is described in 8.4.2.1.1.
3) ~~2)~~ Only the ICV is encrypted using the active TEK/GTEK, generating the Ciphertext ICV.
4) ~~3)~~ The Authenticated PDU is formed by prepending the proper PN value to the Plaintext Payload and appending the Ciphertext ICV to the Plaintext Payload from the authenticated PDU (see Figure 120).

This requires the EC bit in the GMH to be set to ~~0~~1. If EC bit is not set to ~~0~~1, the PDU shall be discarded, as this would indicate a conflict between the configured cryptographic suite and how it is being applied.

Figure ~~119~~120 illustrates how MAC PDUs are processed and formatted when suite 0x01, ~~or~~ 0x03, 0x08, 0x0A, 0x0C, 0x0E, 0x11, or 0x13 is configured and the EC bit in GMH is set to ~~0~~1. The Ciphertext ICV is transmitted so that byte index 0 (as enumerated in NIST Special Publication 800-38D) is transmitted first and byte index 7 is transmitted last (i.e., LSB first) for suites 0x08, 0x0A, 0x11, and 0x13. The Ciphertext ICV is transmitted so that byte index 0 (as enumerated in NIST Special Publication 800-38D) is transmitted first and byte index 3 is transmitted last (i.e., LSB first) for suites 0x01, 0x03, 0x0C, and 0x0E.

Replace Figure 120 with the following figure:

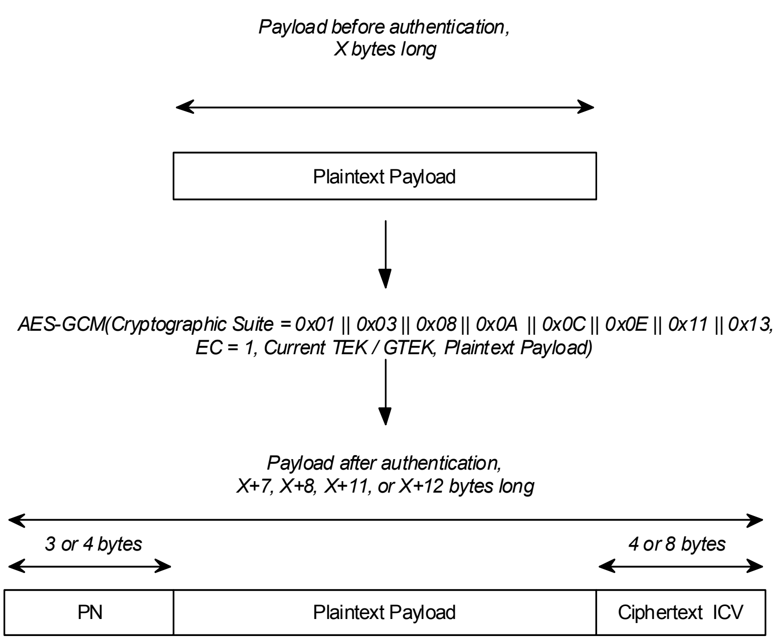


Figure 120—Authentication-only PDU format

8.4.2.1.3 PDU format—Authentication and encryption

Change the text of 8.4.2.1.3 as follows:

The ciphersuites allow for authentication and/or encryption of MAC PDUs. If ~~the~~ suite~~s~~ 0x02, ~~or~~ 0x04, 0x09, 0x0B, 0x0D, 0x0F, 0x12, or 0x14 is assigned to the SA, then authentication and encryption are provided for any MAC PDUs transmitted on service flows that are mapped to these SAs.

The AES in GCM protocol is applied in the following manner:

1) 1) The Plaintext Payload is processed, generating an Integrity Check Value (ICV) that is 8 bytes long (i.e., for suites 0x09, 0x0B, 0x12, and 0x14) or 4 bytes long (i.e., for suites 0x02, 0x04, 0x0D, and 0x0F).
2) The PN value is either 4 bytes (i.e., for suites 0x0D, 0x0F, 0x12, and 0x14) or 3 bytes (i.e., for suites 0x02, 0x04, 0x09, and 0x0B). PN Maintenance is described in 8.4.2.1.1.
3) ~~2)~~ Then the ICV is encrypted using the active TEK/GTEK, generating the Ciphertext ICV.
4) ~~3)~~ Then the Plaintext Payload is encrypted with AES using the active TEK/GTEK, generating a Ciphertext Payload.
5) ~~4)~~ The encrypted PDU is formed by prepending the proper PN value to the Ciphertext Payload and appending the Ciphertext ICV to the Ciphertext Payload (see Figure 121).

This requires the EC bit in the GMH to be set to 1. If EC bit is not set to 1, the PDU shall be discarded, as this would indicate a conflict between the configured cryptographic suite and how it is being applied.

Figure ~~120~~121 illustrates how MAC PDUs are processed and formatted when suite 0x02, ~~or~~ 0x04, 0x09, 0x0B, 0x0D, 0x0F, 0x12, or 0x14 is configured and the EC bit in GMH is set to 1. The Ciphertext ICV is transmitted so that byte index 0 (as enumerated in NIST Special Publication 800-38D) is transmitted first and byte index 7 is transmitted last (i.e., LSB first) for suites 0x09, 0x0B, 0x12, and 0x14. The Ciphertext ICV is transmitted so that byte index 0 (as enumerated in NIST Special Publication 800-38D) is transmitted first and byte index 3 is transmitted last (i.e., LSB first) for suites 0x02, 0x04, 0x0D, and 0x0F.

Replace Figure 121 with the following figure:

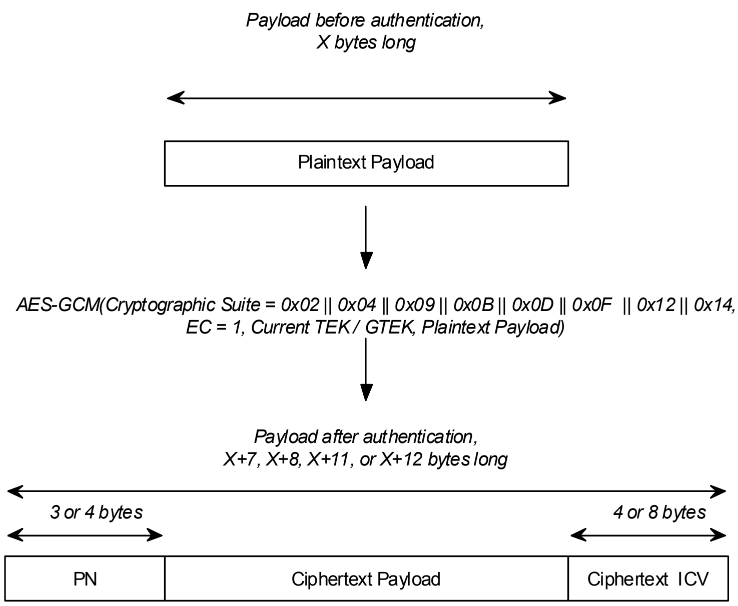


Figure 121—Authenticated + encrypted PDU format

8.4.2.1.4 PDU format—Encryption only

Change the text of 8.4.2.1.5 as follows:

If ~~the~~ suite 0x05 or 0x10 ~~ciphersuite~~ is assigned to an SA, then MAC PDUs associated with service flows mapped to this SA shall only be protected by encryption, and no other cipher suites can be mapped to this SA.

The AES in GCM protocol is applied in the following manner:

1) The Plaintext Payload is processed, generating the Integrity Check Value (ICV), and encrypting the ICV to generate the Ciphertext ICV is skipped.
2) The PN value is either 4 bytes (i.e., for suite 0x10) or 3 bytes (i.e., for suite 0x05). PN Maintenance is described in 8.4.2.1.1.
3) ~~2)~~ Then the Plaintext Payload is encrypted with AES using the active TEK/GTEK, generating a Ciphertext Payload.
4) ~~3)~~ The encrypted PDU is formed ~~from~~ by prepending the proper PN value to the Ciphertext Payload.

This requires the EC bit in the GMH to be set to 1. If the EC bit is not set to 1, the PDU shall be discarded, as this would indicate a conflict between the configured cryptographic suite and how it is being applied.

Figure 122 illustrates how MAC PDUs are processed and formatted when suite ~~0x05~~ 0x10 is configured and the EC bit in GMH is set to 1.

Replace Figure 122 with the following figure:

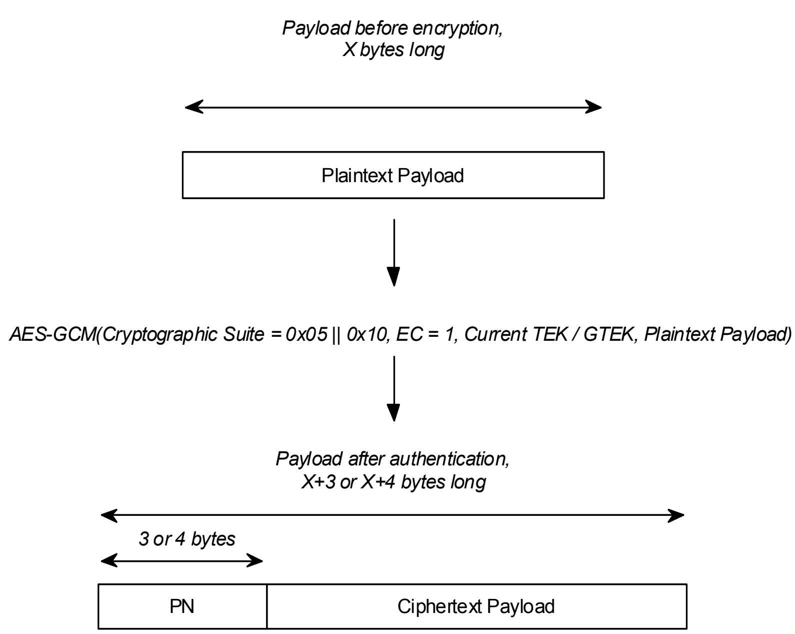


Figure 122—Encryption-only PDU format

8.4.2.2 GCM algorithm constraints

Change 8.4.2.2 as follows:

The GCM specification (NIST SP 800-38D) defines specific values for several parameters.

The additional authenticated data (AAD) to be used in the GCM process shall be the GMH.

T represents the ICV (otherwise known as Message Authentication Code, MAC). This value, as stated in 8.4.2.1, shall be 64 bits (8 octets) long for suites 0x08, 0x09, 0x0A, 0x0B, 0x11, 0x12, 0x13, and 0x14. This value, as stated in 8.4.2.1, shall be 32 bits (4 octets) long for suites 0x01, 0x02, 0x03, 0x04, 0x0C, 0x0D, 0x0E, and 0x0F.

Consistent with the GCM specification, the IV or Initialization Vector is used to initialize the Authenticated Encryption function of GCM. The IV shall be 128 bits (16 octets) long for suites that use a 3-byte PN or 136 bits (17 octets) for suites that use a 4-byte PN. The IV ~~and~~ shall be constructed according to the procedure defined Section 8.2.1 of NIST Special Publication 800-38D. The IV for suites using the 3-byte PN is described in Figure 123. The IV for suites using the 4-byte PN is described in Figure 123a.

IV construction for suites using the 3-byte PN is ordered as follows:

— The IV shall be 16 bytes long.
— Bytes 0 through 3 shall be set to the first 4 bytes of the generic MAC header (thus excluding the HCS). The HCS of the generic MAC header is not included in the IV since it is redundant.
— Bytes 4 through 12 are reserved and shall be set to 0x000000000000.
— Bytes 13 through 15 shall be set to the value of the PN. The PN bytes shall be ordered so that byte 13 shall take the least significant byte and byte 15 shall take the most significant byte.

IV construction for suites using the 4-byte PN is ordered as follows:

— The IV shall be 17 bytes long.
— Bytes 0 through 3 shall be set to the first 4 bytes of the generic MAC header (thus excluding the HCS). The HCS of the generic MAC header is not included in the IV since it is redundant.
— Bytes 4 through 12 are reserved and shall be set to 0x000000000000.
— Bytes 13 through 16 shall be set to the value of the PN. The PN bytes shall be ordered so that byte 13 shall take the least significant byte and byte 16 shall take the most significant byte.

~~The IV shall be 15 bytes long as shown in Figure 123. Bytes 0 through 3 shall be set to the first 4 bytes of the generic MAC header (thus excluding the HCS). The HCS of the generic MAC header is not included in the IV since it is redundant. Bytes 4 through 12 are reserved and shall be set to 0x000000000000. Bytes 13 through 15 shall be set to the value of the PN. The PN bytes shall be ordered so that byte 13 shall take the least significant byte and byte 15 shall take the most significant byte.~~

Field	Fixed Field		Invocation Field
Byte	0 3	4 12	13 15
Data	GMH	*Reserved*	PN
Contents	GMH (without HCS)	0x000000000000000000	3byte PN field from Payload

Figure 123—IV construction for suites with 3-byte PN

Field	Fixed Field		Invocation Field
Byte	0 3	4 12	13 16
Data	GMH	*Reserved*	PN
Contents	GMH (without HCS)	0x000000000000000000	4byte PN field from Payload

Figure 123a—IV construction for suites with 4-byte PN

Consistent with the GCM specification, pre-counter block J_0 is generated using the equations defined in Section 7 of NIST Special Publication 800-38D.

Consistent with the NIST GCM specification, the counter blocks CB_j are formatted as shown in Section 6.5 of NIST Special Publication 800-38D.

8.4.2.3 Receive processing rules

Change 8.4.2.3 as follows.

On receipt of a PDU the receiving CPE or BS shall decrypt and authenticate the PDU consistent with the NIST GCM specification configured as specified in 8.4.2.2.

Packets that are found to be not authentic shall be discarded.

Receiving BS or CPEs shall maintain a record of the highest value PN and MMP_PN received for each SA. The receiver shall maintain a PN window whose size is specified by the PN_WINDOW_SIZE parameter for SAs and management connections as defined in Table 272. The setting of PN_WINDOW_SIZE shall take into account the number of active CPE-CHUs when the network is configured to work in multi-channel operation with Bulk Transmission mode.

When single or multi-channel operation is engaged, a~~A~~ny received PDU with a PN lower than the beginning of the PN window shall be discarded as a replay attempt. The receiver shall track PNs within the PN window.

When the network is configured for single-channel operation, a~~A~~ny PN that is received more than once shall be discarded as a replay attempt. When the network is configured for multi-channel operation in Transmit Diversity mode, any PN that is received more than once on all active CHUs shall be discarded as a replay attempt. When the network is configured for multi-channel operation in Bulk Transmission mode, any PN that is received more than once on one or more of the active CHUs shall be discarded as a replay attempt. Upon reception of a PN, which is greater than the end of the PN window, the PN window shall be advanced to cover this PN.

8.6 Security sublayer 2—Security mechanisms for the cognitive functions

8.6.2 CBP Authentication mechanisms

Insert the following text at the beginning of the fifth paragraph ("The organization of this subclause is as follows"):

In this subclause, "MAC Address" refers to the IEEE 48-bit MAC address that identifies the BS or A-BS for which a CPE is forwarding the CBP MAC PDU.

8.6.2.4 ECQV implicit certificate generation, processing, and validation requirements

8.6.2.4.1 ECQV certificate generation requirements

Change 8.6.2.4.1 as follows:

1) Infrastructure as described in Figure 125 for certificate generation and distribution.
2) Recommended EC domain parameters to be used shall be for binary fields on either 223-bit random or Koblitz curves. Example domain parameters can be found in
   i) K-233 or B-233 elliptic curves defined in [FIPS 186-3].
   ii) sect233k1 and sect233r1 curves defined in SEC2 [B64].
   iii) In the EC domain parameters, elliptic curve points shall be represented in compressed form.
3) BS/A-BS/Distributed scheduling A-CPE shall be identified by its 48-bit MAC Address.
4) 'to -be-signed certificate data', IU construction is as follows:
   — For BSIC: BSIC = I_U || BEU , where I_U = KeyID || ~~BS~~ MAC Address || CA ID || Key Validity Date (Not Before) || Key Validity Date (Not After) || Version, and BEU = BS or A-BS Public Key Reconstruction Data.
   — For CARC: CARC = I_U || BEU, where I_U = KeyID || ~~BS~~ MAC Address || CA ID || Key Validity Date (Not Before) || Key Validity Date (Not After) || Version || EC Domain Parameters, and BEU = CA Public Key Reconstruction Data.
   — NOTE—BS MAC Address comes from the BS, the operator NCMS, or the SCH data in the CBP burst, respectively. In addition the A-BS MAC address comes from the FCH PHY-OM2. The Key ID, Key Validity Date (Not Before), and Key Validity Time Period are assigned by the CA and are contained in the Implicit Certificate.
5) ~~3)~~ The CA shall have a public-key pair that is selected from the EC domain parameters in Requirement 2 and bound to the CA ID. Entities shall have access to the CA implicit certificate (with the CA's public key reconstruction data), but not the private key associated with the implicit certificate.
6) ~~4)~~ SHA-256 shall be used as a Hash function.
7) ~~5)~~ If each operator is allowed to maintain its own BS implicit certificates (i.e., act as its own Certificate Authority),
   — Operator will register its Certificate Authority ID when registering its Operator ID. The mechanism for registration is outside the scope of the standard.
   — Operators may share their own CA Root certificate with other operators that have BSs/A-BSs that border or overlap with BSs/A-BSs in their own network. The mechanism for CA Root Certificate sharing is outside the scope of the standard.

Change all instances of "BS" to "BS/A-BS" in 8.6.2.4.2, 8.6.2.4.3, and 8.6.2.4.4.

8.6.2.5 Signature generation, processing, and validation requirements

Change all instances of "BS" to "BS/A-BS" in 8.6.2.5.1, 8.6.2.5.2, and 8.6.2.5.3.

8.6.2.5.1 Signature generation requirements

Change step 3) in 8.6.2.5.1 as follows:

3) Prior to applying the ECSSR-PV signature scheme to verify a signature in a received CBP MAC PDU (see Table 8 for PHY-OM1 or Table 8a for PHY-OM2), a BS that receives messages shall use the Public Key Reconstruction Data (BEU) (8.6.2.4.1) to reconstruct the public key of each BS implicit certificate that it has installed.

Insert the following list item [step 5)] at the end of 8.6.2.5.1:

5) In this subclause, the “CBP MAC PDU header” can take on different data depending on the PHY operation mode on which the CBP MAC PDU burst is being transmitted. For CBP MAC PDU transmitted on PHY-OM1, the CBP MAC PDU header includes the Length, SCH Data Index, SCH Data, Frame Number, and HCS fields as defined in Table 8. For CBP MAC PDU transmitted on PHY-OM2, the CBP MAC PDU header includes the Length, FCH and Extended FCH Index, FCH and Extended FCH Data, Frame Number, and HCS fields as defined in Table 8a.

8.6.2.6 BS Implicit Certificate Exchange

Change all instances of “BS” to “BS/A-BS” in 8.6.2.6.

Change the title of Clause 9 as follows:

9. PHY Operation Mode 1 (PHY-OM1)

Insert the following paragraph as the second paragraph in the preliminary text of Clause 9:

PHY Operation Mode 1 (PHY-OM1) and PHY Operation Mode 2 (PHY-OM2) are designed to meet the needs required by channel models A and B in [B7a]. In the rare cases where propagation conditions are as severe as those expressed by channel models C and D in [B7a], PHY-OM2 (Clause 9a) may be required to revert to PHY specifications in PHY-OM1 (Clause 9).

Change Table 198 as indicated:

Table 198—System parameters

Parameters	Specifications	Remark
Frequency range	54~862 MHz[a]	
Channel bandwidth	6, 7, or 8 MHz	According to regulatory domain (see Annex A).
Data rate (6 MHz case, 1/16 CP case)	4.54 to 22.69 up to 31.78 Mbit/s (optional) for SISO and single channel operation case 72.59 to 362.96 up to 513.91 Mbit/s for 4 stream MIMO and 4 channel operation case	See Table 202 The single channel and single spatial stream is mandatory. Others cases should be optional.
Spectral Efficiency (6 MHz case, 1/16 CP case)	0.76 to 3.78 up to 5.3 bit/(s·Hz) (optional) for SISO and single channel operation case 3.04 to 15.12 up to 21.2 bit/(s·Hz) for 4 stream MIMO and 4 channel operation case	See Table 202
Payload modulation	QPSK, 16-QAM, 64-QAM, 256-QAM (optional), MD-TCM (optional)	BPSK used for preambles, pilots and CDMA codes.
Transmit EIRP	4W maximum for CPEs. 4W maximum for BSs in the U.S. regulatory domain.	Maximum EIRP for BSs may vary in other regulatory domains.

Table 198—System parameters *(continued)*

Parameters	Specifications	Remark
Multiple Access	OFDMA	
FFT Size (N_{FFT})	2048	
Cyclic Prefix Modes	1/4, 1/8, 1/16, 1/32	
Duplex	TDD	

[a]Frequency range allocated to the Television Broadcasting Service in various parts of the world. See 1239HAnnex A for further details.

9.2 Data rates

Insert the following rows at the end of Table 202:

Table 202—PHY Modes and their related modulations, coding rates and data rates for TCP = TFFT/16

PHY Mode	Modulation	Coding rate	Data rate (Mb/s)	Spectral Efficiency[5] (for 6 MHz bandwidth)
17	256-QAM	1/2	18.16	3.03
18	256-QAM	2/3	24.2	4.033
19	256-QAM	3/4	27.24	4.54
20	256-QAM	5/6	30.24	5.04
21	256-QAM	7/8	31.78	5.30
22	4D-TCM 48QAM	10/11 for two 2D symbols	22.69	3.78
23	4D-TCM 192QAM	14/15 for two 2D symbols	31.78	5.30

Insert the following paragraph and tables after Table 202 in 9.2:

Table 202a through Table 202l give the data rates for the various channel and spatial stream combinations.

Table 202a—Data rate for 1 channel and 1 spatial stream

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6MHz BW				7MHz BW				8MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
5	QPSK	1/2	3.86	4.29	4.54	4.67	4.50	5.00	5.29	5.45	5.14	5.71	6.05	6.23
6	QPSK	2/3	5.14	5.71	6.05	6.23	6.00	6.67	7.06	7.27	6.85	7.61	8.06	8.31
7	QPSK	3/4	5.78	6.43	6.81	7.01	6.75	7.50	7.94	8.18	7.71	8.57	9.07	9.34
8	QPSK	5/6	6.43	7.14	7.56	7.79	7.50	8.33	8.82	9.09	8.57	9.52	10.08	10.38
9	16-QAM	1/2	7.71	8.57	9.07	9.35	9.00	10.00	10.59	10.91	10.28	11.42	12.09	12.46
10	16-QAM	2/3	10.28	11.43	12.10	12.47	12.00	13.33	14.12	14.55	13.70	15.23	16.12	16.61
11	16-QAM	3/4	11.57	12.86	13.61	14.02	13.50	15.00	15.88	16.36	15.42	17.13	18.14	18.69
12	16-QAM	5/6	12.86	14.28	15.12	15.58	15.00	16.67	17.65	18.18	17.13	19.03	20.15	20.76
13	64-QAM	1/2	11.57	12.86	13.61	14.02	13.50	15.00	15.88	16.36	15.42	17.13	18.14	18.69
14	64-QAM	2/3	15.43	17.14	18.15	18.70	18.00	20.00	21.18	21.82	20.56	22.84	24.18	24.92
15	64-QAM	3/4	17.35	19.28	20.42	21.04	20.25	22.50	23.82	24.55	23.13	25.70	27.21	28.03
16	64-QAM	5/6	19.28	21.43	22.69	23.37	22.50	25.00	26.47	27.27	25.70	28.55	30.23	31.15
17	256-QAM	1/2	15.43	17.14	18.15	18.70	18.00	20.00	21.18	21.82	20.56	22.84	24.18	24.92
18	256-QAM	2/3	20.57	22.85	24.20	24.93	24.00	26.67	28.24	29.09	27.41	30.45	32.24	33.22
19	256-QAM	3/4	23.14	25.71	27.22	28.05	27.00	30.00	31.76	32.73	30.83	34.26	36.28	37.37
20	256-QAM	5/6	25.71	28.57	30.25	31.16	30.00	33.33	35.29	36.36	34.26	38.07	40.31	41.53
21	256-QAM	7/8	27.00	30.00	31.76	32.72	31.50	35.00	37.06	38.18	35.97	39.97	42.32	43.60
22	4D-TCM 48QAM	10/11	19.58	21.76	23.04	23.73	22.85	25.39	26.88	27.69	26.09	28.99	30.70	31.63
23	4D-TCM 192QAM	14/15	27.30	30.33	32.12	33.09	31.86	35.40	37.48	38.61	36.38	40.42	42.80	44.10

Table 202b—Data rate for 1 channel and 2 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6MHz BW				7MHz BW				8MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
5	QPSK	1/2	7.71	8.57	9.07	9.35	9.00	10.00	10.59	10.91	10.28	11.42	12.09	12.46
6	QPSK	2/3	10.28	11.43	12.10	12.47	12.00	13.33	14.12	14.55	13.70	15.23	16.12	16.61
7	QPSK	3/4	11.57	12.86	13.61	14.02	13.50	15.00	15.88	16.36	15.42	17.13	18.14	18.69
8	QPSK	5/6	12.86	14.28	15.12	15.58	15.00	16.67	17.65	18.18	17.13	19.03	20.15	20.76
9	16-QAM	1/2	15.43	17.14	18.15	18.70	18.00	20.00	21.18	21.82	20.56	22.84	24.18	24.92
10	16-QAM	2/3	20.57	22.85	24.20	24.93	24.00	26.67	28.24	29.09	27.41	30.45	32.24	33.22
11	16-QAM	3/4	23.14	25.71	27.22	28.05	27.00	30.00	31.76	32.73	30.83	34.26	36.28	37.37
12	16-QAM	5/6	25.71	28.57	30.25	31.16	30.00	33.33	35.29	36.36	34.26	38.07	40.31	41.53
13	64-QAM	1/2	23.14	25.71	27.22	28.05	27.00	30.00	31.76	32.73	30.83	34.26	36.28	37.37
14	64-QAM	2/3	30.85	34.28	36.30	37.40	36.00	40.00	42.35	43.64	41.11	45.68	48.37	49.83
15	64-QAM	3/4	34.71	38.57	40.83	42.07	40.50	45.00	47.65	49.09	46.25	51.39	54.41	56.06
16	64-QAM	5/6	38.57	42.85	45.37	46.75	45.00	50.00	52.94	54.55	51.39	57.10	60.46	62.29
17	256-QAM	1/2	30.85	34.28	36.30	37.40	36.00	40.00	42.35	43.64	41.11	45.68	48.37	49.83
18	256-QAM	2/3	41.14	45.71	48.40	49.86	48.00	53.33	56.47	58.18	54.82	60.91	64.49	66.44
19	256-QAM	3/4	46.28	51.42	54.44	56.09	54.00	60.00	63.53	65.45	61.67	68.52	72.55	74.75
20	256-QAM	5/6	51.42	57.13	60.49	62.33	60.00	66.67	70.59	72.73	68.52	76.13	80.61	83.05
21	256-QAM	7/8	53.99	59.99	63.52	65.44	63.00	70.00	74.12	76.36	71.95	79.94	84.64	87.21
22	4D-TCM 48QAM	10/11	39.16	43.51	46.07	47.47	45.70	50.77	53.76	55.39	52.18	57.98	61.39	63.25
23	4D-TCM 192QAM	14/15	54.60	60.67	64.24	66.19	63.71	70.79	74.96	77.23	72.76	80.85	85.60	88.20

Table 202c—Data rate for 1 channel and 4 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6MHz BW				7MHz BW				8MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
5	QPSK	1/2	15.43	17.14	18.15	18.70	18.00	20.00	21.18	21.82	20.56	22.84	24.18	24.92
6	QPSK	2/3	20.57	22.85	24.20	24.93	24.00	26.67	28.24	29.09	27.41	30.45	32.24	33.22
7	QPSK	3/4	23.14	25.71	27.22	28.05	27.00	30.00	31.76	32.73	30.83	34.26	36.28	37.37
8	QPSK	5/6	25.71	28.57	30.25	31.16	30.00	33.33	35.29	36.36	34.26	38.07	40.31	41.53
9	16-QAM	1/2	30.85	34.28	36.30	37.40	36.00	40.00	42.35	43.64	41.11	45.68	48.37	49.83
10	16-QAM	2/3	41.14	45.71	48.40	49.86	48.00	53.33	56.47	58.18	54.82	60.91	64.49	66.44
11	16-QAM	3/4	46.28	51.42	54.44	56.09	54.00	60.00	63.53	65.45	61.67	68.52	72.55	74.75
12	16-QAM	5/6	51.42	57.13	60.49	62.33	60.00	66.67	70.59	72.73	68.52	76.13	80.61	83.05
13	64-QAM	1/2	46.28	51.42	54.44	56.09	54.00	60.00	63.53	65.45	61.67	68.52	72.55	74.75
14	64-QAM	2/3	61.70	68.56	72.59	74.79	72.00	80.00	84.71	87.27	82.22	91.36	96.73	99.67
15	64-QAM	3/4	69.42	77.13	81.67	84.14	81.00	90.00	95.29	98.18	92.50	102.78	108.83	112.12
16	64-QAM	5/6	77.13	85.70	90.74	93.49	90.00	100.00	105.88	109.09	102.78	114.20	120.92	124.58
17	256-QAM	1/2	61.70	68.56	72.59	74.79	72.00	80.00	84.71	87.27	82.22	91.36	96.73	99.67
18	256-QAM	2/3	82.27	91.41	96.79	99.72	96.00	106.67	112.94	116.36	109.63	121.81	128.98	132.89
19	256-QAM	3/4	92.56	102.84	108.89	112.19	108.00	120.00	127.06	130.91	123.34	137.04	145.10	149.50
20	256-QAM	5/6	102.84	114.27	120.99	124.65	120.00	133.33	141.18	145.45	137.04	152.27	161.22	166.11
21	256-QAM	7/8	107.98	119.98	127.04	130.89	126.00	140.00	148.24	152.73	143.89	159.88	169.28	174.41
22	4D-TCM 48QAM	10/11	78.32	87.02	92.14	94.94	91.39	101.54	107.52	110.78	104.37	115.96	122.79	126.51
23	4D-TCM 192QAM	14/15	109.21	121.34	128.48	132.37	127.43	141.59	149.91	154.46	145.52	161.69	171.20	176.39

Table 202d—Data rate for 2 channels and 1 spatial stream

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6MHz BW				7MHz BW				8MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
5	QPSK	1/2	7.71	8.57	9.07	9.35	9.00	10.00	10.59	10.91	10.28	11.42	12.09	12.46
6	QPSK	2/3	10.28	11.43	12.10	12.47	12.00	13.33	14.12	14.55	13.70	15.23	16.12	16.61
7	QPSK	3/4	11.57	12.86	13.61	14.02	13.50	15.00	15.88	16.36	15.42	17.13	18.14	18.69
8	QPSK	5/6	12.86	14.28	15.12	15.58	15.00	16.67	17.65	18.18	17.13	19.03	20.15	20.76
9	16-QAM	1/2	15.43	17.14	18.15	18.70	18.00	20.00	21.18	21.82	20.56	22.84	24.18	24.92
10	16-QAM	2/3	20.57	22.85	24.20	24.93	24.00	26.67	28.24	29.09	27.41	30.45	32.24	33.22
11	16-QAM	3/4	23.14	25.71	27.22	28.05	27.00	30.00	31.76	32.73	30.83	34.26	36.28	37.37
12	16-QAM	5/6	25.71	28.57	30.25	31.16	30.00	33.33	35.29	36.36	34.26	38.07	40.31	41.53
13	64-QAM	1/2	23.14	25.71	27.22	28.05	27.00	30.00	31.76	32.73	30.83	34.26	36.28	37.37
14	64-QAM	2/3	30.85	34.28	36.30	37.40	36.00	40.00	42.35	43.64	41.11	45.68	48.37	49.83
15	64-QAM	3/4	34.71	38.57	40.83	42.07	40.50	45.00	47.65	49.09	46.25	51.39	54.41	56.06
16	64-QAM	5/6	38.57	42.85	45.37	46.75	45.00	50.00	52.94	54.55	51.39	57.10	60.46	62.29
17	256-QAM	1/2	30.85	34.28	36.30	37.40	36.00	40.00	42.35	43.64	41.11	45.68	48.37	49.83
18	256-QAM	2/3	41.14	45.71	48.40	49.86	48.00	53.33	56.47	58.18	54.82	60.91	64.49	66.44
19	256-QAM	3/4	46.28	51.42	54.44	56.09	54.00	60.00	63.53	65.45	61.67	68.52	72.55	74.75
20	256-QAM	5/6	51.42	57.13	60.49	62.33	60.00	66.67	70.59	72.73	68.52	76.13	80.61	83.05
21	256-QAM	7/8	53.99	59.99	63.52	65.44	63.00	70.00	74.12	76.36	71.95	79.94	84.64	87.21
22	4D-TCM 48QAM	10/11	39.16	43.51	46.07	47.47	45.70	50.77	53.76	55.39	52.18	57.98	61.39	63.25
23	4D-TCM 192QAM	14/15	54.60	60.67	64.24	66.19	63.71	70.79	74.96	77.23	72.76	80.85	85.60	88.20

Table 202e—Data rate for 2 channels and 2 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6MHz BW				7MHz BW				8MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
5	QPSK	1/2	15.43	17.14	18.15	18.70	18.00	20.00	21.18	21.82	20.56	22.84	24.18	24.92
6	QPSK	2/3	20.57	22.85	24.20	24.93	24.00	26.67	28.24	29.09	27.41	30.45	32.24	33.22
7	QPSK	3/4	23.14	25.71	27.22	28.05	27.00	30.00	31.76	32.73	30.83	34.26	36.28	37.37
8	QPSK	5/6	25.71	28.57	30.25	31.16	30.00	33.33	35.29	36.36	34.26	38.07	40.31	41.53
9	16-QAM	1/2	30.85	34.28	36.30	37.40	36.00	40.00	42.35	43.64	41.11	45.68	48.37	49.83
10	16-QAM	2/3	41.14	45.71	48.40	49.86	48.00	53.33	56.47	58.18	54.82	60.91	64.49	66.44
11	16-QAM	3/4	46.28	51.42	54.44	56.09	54.00	60.00	63.53	65.45	61.67	68.52	72.55	74.75
12	16-QAM	5/6	51.42	57.13	60.49	62.33	60.00	66.67	70.59	72.73	68.52	76.13	80.61	83.05
13	64-QAM	1/2	46.28	51.42	54.44	56.09	54.00	60.00	63.53	65.45	61.67	68.52	72.55	74.75
14	64-QAM	2/3	61.70	68.56	72.59	74.79	72.00	80.00	84.71	87.27	82.22	91.36	96.73	99.67
15	64-QAM	3/4	69.42	77.13	81.67	84.14	81.00	90.00	95.29	98.18	92.50	102.78	108.83	112.12
16	64-QAM	5/6	77.13	85.70	90.74	93.49	90.00	100.00	105.88	109.09	102.78	114.20	120.92	124.58
17	256-QAM	1/2	61.70	68.56	72.59	74.79	72.00	80.00	84.71	87.27	82.22	91.36	96.73	99.67
18	256-QAM	2/3	82.27	91.41	96.79	99.72	96.00	106.67	112.94	116.36	109.63	121.81	128.98	132.89
19	256-QAM	3/4	92.56	102.84	108.89	112.19	108.00	120.00	127.06	130.91	123.34	137.04	145.10	149.50
20	256-QAM	5/6	102.84	114.27	120.99	124.65	120.00	133.33	141.18	145.45	137.04	152.27	161.22	166.11
21	256-QAM	7/8	107.98	119.98	127.04	130.89	126.00	140.00	148.24	152.73	143.89	159.88	169.28	174.41
22	4D-TCM 48QAM	10/11	78.32	87.02	92.14	94.94	91.39	101.54	107.52	110.78	104.37	115.96	122.79	126.51
23	4D-TCM 192QAM	14/15	109.21	121.34	128.48	132.37	127.43	141.59	149.91	154.46	145.52	161.69	171.20	176.39

Table 202f—Data rate for 2 channels and 4 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6MHz BW				7MHz BW				8MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
5	QPSK	1/2	30.85	34.28	36.30	37.40	36.00	40.00	42.35	43.64	41.11	45.68	48.37	49.83
6	QPSK	2/3	41.14	45.71	48.40	49.86	48.00	53.33	56.47	58.18	54.82	60.91	64.49	66.44
7	QPSK	3/4	46.28	51.42	54.44	56.09	54.00	60.00	63.53	65.45	61.67	68.52	72.55	74.75
8	QPSK	5/6	51.42	57.13	60.49	62.33	60.00	66.67	70.59	72.73	68.52	76.13	80.61	83.05
9	16-QAM	1/2	61.70	68.56	72.59	74.79	72.00	80.00	84.71	87.27	82.22	91.36	96.73	99.67
10	16-QAM	2/3	82.27	91.41	96.79	99.72	96.00	106.67	112.94	116.36	109.63	121.81	128.98	132.89
11	16-QAM	3/4	92.56	102.84	108.89	112.19	108.00	120.00	127.06	130.91	123.34	137.04	145.10	149.50
12	16-QAM	5/6	102.84	114.27	120.99	124.65	120.00	133.33	141.18	145.45	137.04	152.27	161.22	166.11
13	64-QAM	1/2	92.56	102.84	108.89	112.19	108.00	120.00	127.06	130.91	123.34	137.04	145.10	149.50
14	64-QAM	2/3	123.41	137.12	145.19	149.59	144.00	160.00	169.41	174.55	164.45	182.72	193.47	199.33
15	64-QAM	3/4	138.83	154.26	163.33	168.28	162.00	180.00	190.59	196.36	185.00	205.56	217.65	224.25
16	64-QAM	5/6	154.26	171.40	181.48	186.98	180.00	200.00	211.76	218.18	205.56	228.40	241.84	249.16
17	256-QAM	1/2	123.41	137.12	145.19	149.59	144.00	160.00	169.41	174.55	164.45	182.72	193.47	199.33
18	256-QAM	2/3	164.54	182.83	193.58	199.45	192.00	213.33	225.88	232.73	219.26	243.63	257.96	265.77
19	256-QAM	3/4	185.11	205.68	217.78	224.38	216.00	240.00	254.12	261.82	246.67	274.08	290.20	299.00
20	256-QAM	5/6	205.68	228.53	241.98	249.31	240.00	266.67	282.35	290.91	274.08	304.53	322.45	332.22
21	256-QAM	7/8	215.96	239.96	254.08	261.77	252.00	280.00	296.47	305.45	287.78	319.76	338.57	348.83
22	4D-TCM 48QAM	10/11	156.64	174.05	184.29	189.87	182.78	203.09	215.04	221.55	208.74	231.93	245.57	253.01
23	4D-TCM 192QAM	14/15	218.41	242.68	256.95	264.74	254.85	283.17	299.83	308.91	291.04	323.38	342.40	352.78

Table 202g—Data rate for 3 channels and 1 spatial stream

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6MHz BW				7MHz BW				8MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
5	QPSK	1/2	11.57	12.86	13.61	14.02	13.50	15.00	15.88	16.36	15.42	17.13	18.14	18.69
6	QPSK	2/3	15.43	17.14	18.15	18.70	18.00	20.00	21.18	21.82	20.56	22.84	24.18	24.92
7	QPSK	3/4	17.35	19.28	20.42	21.04	20.25	22.50	23.82	24.55	23.13	25.70	27.21	28.03
8	QPSK	5/6	19.28	21.43	22.69	23.37	22.50	25.00	26.47	27.27	25.70	28.55	30.23	31.15
9	16-QAM	1/2	23.14	25.71	27.22	28.05	27.00	30.00	31.76	32.73	30.83	34.26	36.28	37.37
10	16-QAM	2/3	30.85	34.28	36.30	37.40	36.00	40.00	42.35	43.64	41.11	45.68	48.37	49.83
11	16-QAM	3/4	34.71	38.57	40.83	42.07	40.50	45.00	47.65	49.09	46.25	51.39	54.41	56.06
12	16-QAM	5/6	38.57	42.85	45.37	46.75	45.00	50.00	52.94	54.55	51.39	57.10	60.46	62.29
13	64-QAM	1/2	34.71	38.57	40.83	42.07	40.50	45.00	47.65	49.09	46.25	51.39	54.41	56.06
14	64-QAM	2/3	46.28	51.42	54.44	56.09	54.00	60.00	63.53	65.45	61.67	68.52	72.55	74.75
15	64-QAM	3/4	52.06	57.85	61.25	63.11	60.75	67.50	71.47	73.64	69.38	77.09	81.62	84.09
16	64-QAM	5/6	57.85	64.28	68.06	70.12	67.50	75.00	79.41	81.82	77.09	85.65	90.69	93.44
17	256-QAM	1/2	46.28	51.42	54.44	56.09	54.00	60.00	63.53	65.45	61.67	68.52	72.55	74.75
18	256-QAM	2/3	61.70	68.56	72.59	74.79	72.00	80.00	84.71	87.27	82.22	91.36	96.73	99.67
19	256-QAM	3/4	69.42	77.13	81.67	84.14	81.00	90.00	95.29	98.18	92.50	102.78	108.83	112.12
20	256-QAM	5/6	77.13	85.70	90.74	93.49	90.00	100.00	105.88	109.09	102.78	114.20	120.92	124.58
21	256-QAM	7/8	80.99	89.99	95.28	98.17	94.50	105.00	111.18	114.55	107.92	119.91	126.96	130.81
22	4D-TCM 48QAM	10/11	58.74	65.27	69.11	71.20	68.54	76.16	80.64	83.08	78.28	86.97	92.09	94.88
23	4D-TCM 192QAM	14/15	81.90	91.00	96.36	99.28	95.57	106.19	112.44	115.84	109.14	121.27	128.40	132.29

Table 202h—Data rate for 3 channels and 2 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6MHz BW				7MHz BW				8MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
5	QPSK	1/2	23.14	25.71	27.22	28.05	27.00	30.00	31.76	32.73	30.83	34.26	36.28	37.37
6	QPSK	2/3	30.85	34.28	36.30	37.40	36.00	40.00	42.35	43.64	41.11	45.68	48.37	49.83
7	QPSK	3/4	34.71	38.57	40.83	42.07	40.50	45.00	47.65	49.09	46.25	51.39	54.41	56.06
8	QPSK	5/6	38.57	42.85	45.37	46.75	45.00	50.00	52.94	54.55	51.39	57.10	60.46	62.29
9	16-QAM	1/2	46.28	51.42	54.44	56.09	54.00	60.00	63.53	65.45	61.67	68.52	72.55	74.75
10	16-QAM	2/3	61.70	68.56	72.59	74.79	72.00	80.00	84.71	87.27	82.22	91.36	96.73	99.67
11	16-QAM	3/4	69.42	77.13	81.67	84.14	81.00	90.00	95.29	98.18	92.50	102.78	108.83	112.12
12	16-QAM	5/6	77.13	85.70	90.74	93.49	90.00	100.00	105.88	109.09	102.78	114.20	120.92	124.58
13	64-QAM	1/2	69.42	77.13	81.67	84.14	81.00	90.00	95.29	98.18	92.50	102.78	108.83	112.12
14	64-QAM	2/3	92.56	102.84	108.89	112.19	108.00	120.00	127.06	130.91	123.34	137.04	145.10	149.50
15	64-QAM	3/4	104.13	115.70	122.50	126.21	121.50	135.00	142.94	147.27	138.75	154.17	163.24	168.19
16	64-QAM	5/6	115.70	128.55	136.11	140.24	135.00	150.00	158.82	163.64	154.17	171.30	181.38	186.87
17	256-QAM	1/2	92.56	102.84	108.89	112.19	108.00	120.00	127.06	130.91	123.34	137.04	145.10	149.50
18	256-QAM	2/3	123.41	137.12	145.19	149.59	144.00	160.00	169.41	174.55	164.45	182.72	193.47	199.33
19	256-QAM	3/4	138.83	154.26	163.33	168.28	162.00	180.00	190.59	196.36	185.00	205.56	217.65	224.25
20	256-QAM	5/6	154.26	171.40	181.48	186.98	180.00	200.00	211.76	218.18	205.56	228.40	241.84	249.16
21	256-QAM	7/8	161.97	179.97	190.56	196.33	189.00	210.00	222.35	229.09	215.84	239.82	253.93	261.62
22	4D-TCM 48QAM	10/11	117.48	130.54	138.21	142.40	137.09	152.32	161.28	166.16	156.55	173.95	184.18	189.76
23	4D-TCM 192QAM	14/15	163.81	182.01	192.72	198.56	191.14	212.38	224.87	231.69	218.28	242.54	256.80	264.59

Table 202i—Data rate for 3 channels and 4 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6MHz BW				7MHz BW				8MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
5	QPSK	1/2	46.28	51.42	54.44	56.09	54.00	60.00	63.53	65.45	61.67	68.52	72.55	74.75
6	QPSK	2/3	61.70	68.56	72.59	74.79	72.00	80.00	84.71	87.27	82.22	91.36	96.73	99.67
7	QPSK	3/4	69.42	77.13	81.67	84.14	81.00	90.00	95.29	98.18	92.50	102.78	108.83	112.12
8	QPSK	5/6	77.13	85.70	90.74	93.49	90.00	100.00	105.88	109.09	102.78	114.20	120.92	124.58
9	16-QAM	1/2	92.56	102.84	108.89	112.19	108.00	120.00	127.06	130.91	123.34	137.04	145.10	149.50
10	16-QAM	2/3	123.41	137.12	145.19	149.59	144.00	160.00	169.41	174.55	164.45	182.72	193.47	199.33
11	16-QAM	3/4	138.83	154.26	163.33	168.28	162.00	180.00	190.59	196.36	185.00	205.56	217.65	224.25
12	16-QAM	5/6	154.26	171.40	181.48	186.98	180.00	200.00	211.76	218.18	205.56	228.40	241.84	249.16
13	64-QAM	1/2	138.83	154.26	163.33	168.28	162.00	180.00	190.59	196.36	185.00	205.56	217.65	224.25
14	64-QAM	2/3	185.11	205.68	217.78	224.38	216.00	240.00	254.12	261.82	246.67	274.08	290.20	299.00
15	64-QAM	3/4	208.25	231.39	245.00	252.43	243.00	270.00	285.88	294.55	277.51	308.34	326.48	336.37
16	64-QAM	5/6	231.39	257.10	272.22	280.47	270.00	300.00	317.65	327.27	308.34	342.60	362.75	373.75
17	256-QAM	1/2	185.11	205.68	217.78	224.38	216.00	240.00	254.12	261.82	246.67	274.08	290.20	299.00
18	256-QAM	2/3	246.82	274.24	290.37	299.17	288.00	320.00	338.82	349.09	328.90	365.44	386.94	398.66
19	256-QAM	3/4	277.67	308.52	326.67	336.57	324.00	360.00	381.18	392.73	370.01	411.12	435.30	448.49
20	256-QAM	5/6	308.52	342.80	362.96	373.96	360.00	400.00	423.53	436.36	411.12	456.80	483.67	498.33
21	256-QAM	7/8	323.95	359.94	381.11	392.66	378.00	420.00	444.71	458.18	431.68	479.64	507.85	523.24
22	4D-TCM 48QAM	10/11	234.96	261.07	276.43	284.81	274.17	304.63	322.55	332.33	313.10	347.89	368.36	379.52
23	4D-TCM 192QAM	14/15	327.62	364.02	385.43	397.11	382.28	424.76	449.74	463.37	436.57	485.07	513.61	529.17

Table 202j—Data rate for 4 channels and 1 spatial stream

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6MHz BW				7MHz BW				8MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
5	QPSK	1/2	15.43	17.14	18.15	18.70	18.00	20.00	21.18	21.82	20.56	22.84	24.18	24.92
6	QPSK	2/3	20.57	22.85	24.20	24.93	24.00	26.67	28.24	29.09	27.41	30.45	32.24	33.22
7	QPSK	3/4	23.14	25.71	27.22	28.05	27.00	30.00	31.76	32.73	30.83	34.26	36.28	37.37
8	QPSK	5/6	25.71	28.57	30.25	31.16	30.00	33.33	35.29	36.36	34.26	38.07	40.31	41.53
9	16-QAM	1/2	30.85	34.28	36.30	37.40	36.00	40.00	42.35	43.64	41.11	45.68	48.37	49.83
10	16-QAM	2/3	41.14	45.71	48.40	49.86	48.00	53.33	56.47	58.18	54.82	60.91	64.49	66.44
11	16-QAM	3/4	46.28	51.42	54.44	56.09	54.00	60.00	63.53	65.45	61.67	68.52	72.55	74.75
12	16-QAM	5/6	51.42	57.13	60.49	62.33	60.00	66.67	70.59	72.73	68.52	76.13	80.61	83.05
13	64-QAM	1/2	46.28	51.42	54.44	56.09	54.00	60.00	63.53	65.45	61.67	68.52	72.55	74.75
14	64-QAM	2/3	61.70	68.56	72.59	74.79	72.00	80.00	84.71	87.27	82.22	91.36	96.73	99.67
15	64-QAM	3/4	69.42	77.13	81.67	84.14	81.00	90.00	95.29	98.18	92.50	102.78	108.83	112.12
16	64-QAM	5/6	77.13	85.70	90.74	93.49	90.00	100.00	105.88	109.09	102.78	114.20	120.92	124.58
17	256-QAM	1/2	61.70	68.56	72.59	74.79	72.00	80.00	84.71	87.27	82.22	91.36	96.73	99.67
18	256-QAM	2/3	82.27	91.41	96.79	99.72	96.00	106.67	112.94	116.36	109.63	121.81	128.98	132.89
19	256-QAM	3/4	92.56	102.84	108.89	112.19	108.00	120.00	127.06	130.91	123.34	137.04	145.10	149.50
20	256-QAM	5/6	102.84	114.27	120.99	124.65	120.00	133.33	141.18	145.45	137.04	152.27	161.22	166.11
21	256-QAM	7/8	107.98	119.98	127.04	130.89	126.00	140.00	148.24	152.73	143.89	159.88	169.28	174.41
22	4D-TCM 48QAM	10/11	78.32	87.02	92.14	94.94	91.39	101.54	107.52	110.78	104.37	115.96	122.79	126.51
23	4D-TCM 192QAM	14/15	109.21	121.34	128.48	132.37	127.43	141.59	149.91	154.46	145.52	161.69	171.20	176.39

Table 202k—Data rate for 4 channels and 2 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6MHz BW				7MHz BW				8MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
5	QPSK	1/2	30.85	34.28	36.30	37.40	36.00	40.00	42.35	43.64	41.11	45.68	48.37	49.83
6	QPSK	2/3	41.14	45.71	48.40	49.86	48.00	53.33	56.47	58.18	54.82	60.91	64.49	66.44
7	QPSK	3/4	46.28	51.42	54.44	56.09	54.00	60.00	63.53	65.45	61.67	68.52	72.55	74.75
8	QPSK	5/6	51.42	57.13	60.49	62.33	60.00	66.67	70.59	72.73	68.52	76.13	80.61	83.05
9	16-QAM	1/2	61.70	68.56	72.59	74.79	72.00	80.00	84.71	87.27	82.22	91.36	96.73	99.67
10	16-QAM	2/3	82.27	91.41	96.79	99.72	96.00	106.67	112.94	116.36	109.63	121.81	128.98	132.89
11	16-QAM	3/4	92.56	102.84	108.89	112.19	108.00	120.00	127.06	130.91	123.34	137.04	145.10	149.50
12	16-QAM	5/6	102.84	114.27	120.99	124.65	120.00	133.33	141.18	145.45	137.04	152.27	161.22	166.11
13	64-QAM	1/2	92.56	102.84	108.89	112.19	108.00	120.00	127.06	130.91	123.34	137.04	145.10	149.50
14	64-QAM	2/3	123.41	137.12	145.19	149.59	144.00	160.00	169.41	174.55	164.45	182.72	193.47	199.33
15	64-QAM	3/4	138.83	154.26	163.33	168.28	162.00	180.00	190.59	196.36	185.00	205.56	217.65	224.25
16	64-QAM	5/6	154.26	171.40	181.48	186.98	180.00	200.00	211.76	218.18	205.56	228.40	241.84	249.16
17	256-QAM	1/2	123.41	137.12	145.19	149.59	144.00	160.00	169.41	174.55	164.45	182.72	193.47	199.33
18	256-QAM	2/3	164.54	182.83	193.58	199.45	192.00	213.33	225.88	232.73	219.26	243.63	257.96	265.77
19	256-QAM	3/4	185.11	205.68	217.78	224.38	216.00	240.00	254.12	261.82	246.67	274.08	290.20	299.00
20	256-QAM	5/6	205.68	228.53	241.98	249.31	240.00	266.67	282.35	290.91	274.08	304.53	322.45	332.22
21	256-QAM	7/8	215.96	239.96	254.08	261.77	252.00	280.00	296.47	305.45	287.78	319.76	338.57	348.83
22	4D-TCM 48QAM	10/11	156.64	174.05	184.29	189.87	182.78	203.09	215.04	221.55	208.74	231.93	245.57	253.01
23	4D-TCM 192QAM	14/15	218.41	242.68	256.95	264.74	254.85	283.17	299.83	308.91	291.04	323.38	342.40	352.78

Table 202l—Data rate for 4 channels and 4 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6MHz BW				7MHz BW				8MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
5	QPSK	1/2	61.70	68.56	72.59	74.79	72.00	80.00	84.71	87.27	82.22	91.36	96.73	99.67
6	QPSK	2/3	82.27	91.41	96.79	99.72	96.00	106.67	112.94	116.36	109.63	121.81	128.98	132.89
7	QPSK	3/4	92.56	102.84	108.89	112.19	108.00	120.00	127.06	130.91	123.34	137.04	145.10	149.50
8	QPSK	5/6	102.84	114.27	120.99	124.65	120.00	133.33	141.18	145.45	137.04	152.27	161.22	166.11
9	16-QAM	1/2	123.41	137.12	145.19	149.59	144.00	160.00	169.41	174.55	164.45	182.72	193.47	199.33
10	16-QAM	2/3	164.54	182.83	193.58	199.45	192.00	213.33	225.88	232.73	219.26	243.63	257.96	265.77
11	16-QAM	3/4	185.11	205.68	217.78	224.38	216.00	240.00	254.12	261.82	246.67	274.08	290.20	299.00
12	16-QAM	5/6	205.68	228.53	241.98	249.31	240.00	266.67	282.35	290.91	274.08	304.53	322.45	332.22
13	64-QAM	1/2	185.11	205.68	217.78	224.38	216.00	240.00	254.12	261.82	246.67	274.08	290.20	299.00
14	64-QAM	2/3	246.82	274.24	290.37	299.17	288.00	320.00	338.82	349.09	328.90	365.44	386.94	398.66
15	64-QAM	3/4	277.67	308.52	326.67	336.57	324.00	360.00	381.18	392.73	370.01	411.12	435.30	448.49
16	64-QAM	5/6	308.52	342.80	362.96	373.96	360.00	400.00	423.53	436.36	411.12	456.80	483.67	498.33
17	256-QAM	1/2	246.82	274.24	290.37	299.17	288.00	320.00	338.82	349.09	328.90	365.44	386.94	398.66
18	256-QAM	2/3	329.09	365.65	387.16	398.89	384.00	426.67	451.76	465.45	438.53	487.25	515.92	531.55
19	256-QAM	3/4	370.22	411.36	435.56	448.76	432.00	480.00	508.24	523.64	493.34	548.16	580.40	597.99
20	256-QAM	5/6	411.36	457.07	483.95	498.62	480.00	533.33	564.71	581.82	548.16	609.07	644.89	664.44
21	256-QAM	7/8	431.93	479.92	508.15	523.55	504.00	560.00	592.94	610.91	575.57	639.52	677.14	697.66
22	4D-TCM 48QAM	10/11	313.29	348.10	368.57	379.74	365.56	406.18	430.07	443.10	417.47	463.86	491.14	506.03
23	4D-TCM 192QAM	14/15	436.82	485.36	513.91	529.48	509.71	566.34	599.66	617.83	582.09	646.76	684.81	705.56

9.4 Superframe and frame structure

9.4.1 Preamble

Insert the following subclauses (9.4.1.5 and 9.4.1.6 and their figure and tables) after 9.4.1.4:

9.4.1.5 Local frame preamble

The local frame preamble shall use the T_{CP}=1/4T_{FFT}. Three different preamble carrier sets are defined, differing in the allocation of subcarriers. Those subcarriers are modulated using a boosted BPSK modulation with a specific pseudo-noise (PN) code.

The preamble carrier sets are defined using Equation (4a).

$$PreambleCarrierSet_n = n + 3k \tag{4a}$$

where

$PreambleCarrierSet_n$	specifies all subcarriers allocated to the specific preamble
n	is the designating number of the preamble carrier set indexed 0, 1, and 2
k	is a running index. 0...559

Each start position of segment uses a preamble composed of a single carrier set in the following manner:

- Start position of segment 0 uses preamble carrier set 0 (n =0).
- Start position of segment 1 uses preamble carrier set 1 (n =1).
- Start position of segment 2 uses preamble carrier set 2 (n =2).

For the start position of segment 0, the DC carrier will not be modulated at all, and the appropriate PN will be discarded. Therefore, the DC carrier shall always be zeroed.

Each start position of segment eventually modulates each third subcarrier. As an example, Figure 136a depicts the preamble of start position of segment 0. In this figure, subcarrier 0 corresponds to the first subcarrier used in the preamble symbol.

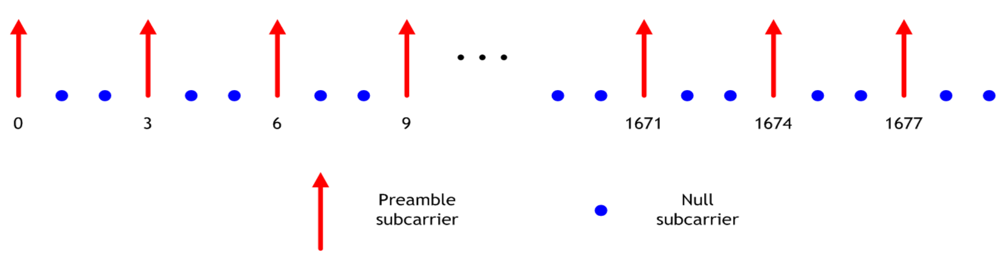


Figure 136a—Example of basic structure of preamble (for the case of *n*=0)

The PN series modulating the preamble carrier set is defined in Table 203a. The series modulated depends on the start position of segment and segment bandwidth used. The defined series shall be mapped onto the preamble subcarriers in ascending order. Table 203a includes the PN sequence in a hexadecimal format. The value of the PN is obtained by converting the series to a binary series (W_k) and mapping the PN starting from the MSB of each symbol to the LSB (0 mapped to +1 and 1 mapped to –1). For example, for Local Frame Preamble 0 (the first row of Table 203a), W_k = 001001010001..., and the mapping shall follow: –1 –1 +1 –1 –1 +1 –1 +1 –1 –1 –1 +1....

For the preamble symbol, there will be 184 guard band subcarriers on each side of the spectrum.

The symbols in the DS preamble shall be modulated according to Equation (4b).

$$\mathrm{Re}\{\mathrm{Pr}\,eambleModulated\} = 2\cdot\sqrt{3}\cdot\left(\frac{1}{2} - W_k\right),\quad \mathrm{Im}\{\mathrm{Pr}\,eambleModulated\} = 0 \tag{4b}$$

Table 203a—Local frame preamble modulation series for segmentation scheme

Preamble Type	Start Position of Segment	Segment Bandwidth	Series to modulate (*W*k)
Local Frame Preamble 0	0	1 segment	0x251D994101EDA04D8BD0B8EA6FA20AE590C2CC199AB083C6AE61F091F2DD41D989EC164B1481D611BE9EA0094AFE9DB56A4763F55B26E54EAB73ACD7D4BBA64C1421BC3EB9D
Local Frame Preamble 1	0	2 segments	0x572B008CAE935937061963E9567C204CB881C66F6C70DC9316A4006F9CDF449C19E5EC29CCFC42786A82330FC7279F99F1DFC4246B1234F792B623341EBA8DBDAC7FD337206
Local Frame Preamble 2	0	3 segments	0x9D7B838B01289DA478424A99E6B5C35E7D6D79FCC9ADEFEE741BFBD48261B9A427AE8994EB230CF27D770B7CDD53A01821C63ADD01236D481BFEF0085FF21DF2044E054E9113
Local Frame Preamble 3	1	1 segment	0xBBF8D4EE09564B33B49FFA37179626165084481424D61EC7592A97D80A66FA6797B1A0C493987566D49A6B2786BC9706F8168264BD24F9A8BD86EEC0211848DFB2B477E2CF3
Local Frame Preamble 4	1	2 segments	0x3A13D1C743143CE5E66B0AC149147AA2E4624EF574EB4D49FC698483BFEB60FB07B286EDB255BC19C0AD0D53669AF9E41E7CF22795EAF0CDB9F1EBAF6979B05A0373A3C7403
Local Frame Preamble 5	2	1 segment	0x9D6E088D4BF521B816766CDD6DEC121DD3C2101F30B8479CADA2EDA38CC97B865D78BDDC1A50843DCC6547D9B4CE4EF1A3E9661C42648013DB35E2E69D7404D52DACA4886F5D

9.4.1.6 Local CBP preamble

The local CBP preamble shall have a duration of 1 OFDM symbol. The preamble structure is used as described in 9.4.1.5. The PN series modulating the local CBP preamble carrier set is defined in Table 203b. The series modulated depends on the start position of segment and segment bandwidth used. The defined series shall be mapped onto the local CBP preamble subcarriers in ascending order. Table 203b includes the PN sequence in a hexadecimal format. The value of the PN is obtained by the same manner as described in 9.4.1.5.

Table 203b—Local CBP preamble modulation series

Preamble Type	Start Position of Segment	Segment Bandwidth	Series to modulate (Wk)
Local CBP Preamble 0	0	1 segment	0xF3E5596544A8D30FF9DAA3AB6CBE5EC769CAB9F0E2F9FF3D1D27619481C8A1A3EC4286F8207F1C69816CC13E995C38C1E4D62AD594B2B02CDEE05A0F1BD18BCA09FC2B1DC72B
Local CBP Preamble 1	0	2 segments	0xFCAEC6B1C7027793A48849AD347AE875408955E7F2AAC5FF9904A2D0D904C931795A1BDA94D9DCABA8A77152A69B89F008680F34505343E591F3EB3CF103BF97DA73BC87FC9
Local CBP Preamble 2	0	3 segments	0x1F6C5C088F9FF6E85171FF5434B95DEB270F1C926F738B8167566D24EC3F7A1BEDC7CC3B913EC2DB60B4103739C07C10DB5D036A9B48223CE4037E148205DD8177084A97E739
Local CBP Preamble 3	1	1 segment	0x1A6988580366EDA426EDA5EC69AEC0B9D77D733AC09338B2E66BCBA5F1960FEE2C08477CB6F80DB152B4EF01E7FBFD5961A16C954EFEB629124F9789B34411713ED05A0EF02C
Local CBP Preamble 4	1	2 segments	0xFA54537894CC41ADE3960B29C89DCAC398CEDFB2AB6BCB61D02B877208A71DD8760FFCABA593996852CAE9AE7E7FF7633EAF24CD2AAC1229E10D9847837CC20C46270E8F824F
Local CBP Preamble 5	2	1 segment	0x8C88EE32C92B5741BBF6A7026E0C268520653A0A948EA318A316508A4602A75DED6AF1D33BCB0B83E8A3C7372E0779FC5C10AA16063AF909031455A18EA324FBD5FECF499D83

9.7 Channel coding

9.7.2 Forward Error Correction (FEC)

9.7.2.1 Binary Convolutional code (BCC) mode (mandatory)

9.7.2.1.2 Puncturing

Change Table 208 as indicated:

Table 208—Puncturing and bit-insertion for the different coding rates

Code rate	1/2	2/3	3/4	5/6	$\underline{7/8}$
Convolutional coder output	A_1B_1	$A_1B_1\cancel{A_2}B_2$	$A_1B_1\cancel{A_2}B_2A_3\cancel{B_3}$	$A_1B_1\cancel{A_2}B_2A_3\cancel{B_3}\cancel{A_4}B_4A_5\cancel{B_5}$	$\underline{A_1B_1\cancel{A_2}B_2\cancel{A_3}B_3\cancel{A_4}B_4A_5\cancel{B_5}\cancel{A_6}B_6A_7\cancel{B_7}}$
Puncturer output/ bit-inserter input	A_1B_1	$A_1B_1B_2$	$A_1B_1B_2A_3$	$A_1B_1B_2A_3B_4A_5$	$\underline{A_1B_1B_2B_3B_4A_5B_6A_7}$
Decoder input	A_1B_1	$A_1B_10B_2$	$A_1B_10B_2A_30$	$A_1B_10B_2A_300B_4A_50$	$\underline{A_1B_10B_20B_30B_4A_500B_6A_70}$

9.7.2.1.3 OFDM slot concatenation

Insert the following rows at the end of Table 209:

Table 209—Concatenation index for different modulations and coding

Modulation and Rate	j
256-QAM 1/2	3
256-QAM 2/3	2
256-QAM 3/4	2
256-QAM 5/6	1
256-QAM 7/8	1
4D-TCM 48QAM	2
4D-TCM 192QAM	1

Change Table 211 as indicated.

Table 211—Useful data payload in bytes for an FEC block

QPSK				16-QAM				64-QAM				256-QAM				
R= 1/2	R= 2/3	R= 3/4	R= 5/6	R= 1/2	R= 2/3	R= 3/4	R= 5/6	R= 1/2	R= 2/3	R= 3/4	R= 5/6	R= 1/2	R= 2/3	R= 3/4	R= 5/6	R= 7/8
3																
	4															
			5													
6				6												
	8				8											
9		9				9		9								
			10				10									
12	12			12					12			12				
15			15								15					
	16				16								16			
18		18		18		18		18						18		
	20		20				20								20	
21																21
24	24			24	24				24			24				
			25													

Table 211—Useful data payload in bytes for an FEC block ***(continued)***

QPSK				**16-QAM**				**64-QAM**				**256-QAM**				
R= 1/2	**R= 2/3**	**R= 3/4**	**R= 5/6**	**R= 1/2**	**R= 2/3**	**R= 3/4**	**R= 5/6**	**R= 1/2**	**R= 2/3**	**R= 3/4**	**R= 5/6**	**R= 1/2**	**R= 2/3**	**R= 3/4**	**R= 5/6**	**R= 7/8**
27		27				27		27		27						
	28															
30			30	30			30				30					
	32				32								32			
33																
			35													
36	36	36		36		36		36	36			36		36		

Insert the following subclause (9.7.2.5 and its subclauses, figures, and tables) after 9.7.2.4:

9.7.2.5 Multidimensional trellis coded modulation (MD-TCM) mode (optional)

9.7.2.5.1 Overview of multidimensional trellis coded modulation (MD-TCM)

Multidimensional trellis coded modulation (MD-TCM) is a combined coding and modulation for band-limited channels by using multiple 2D symbols. In this subclause, four-dimensional TCM (4D-TCM) is applied to achieve additional higher data rate option and peak-to-average power ratio (PAPR) reduction at data mapping. The functional block of the 4D-TCM encoder is illustrated in Figure 149a. 4D-TCM encoder contains the following functions:

- Coset selection
- Region pair selection
- Symbol selection

For 4D-TCM 48QAM, a 4D symbol (equal to two 2D symbols) contains 3 bits for coset selection, 3 bits for region pair selection, and 2x2 bits for symbol selection. In total, it contains 10 bits per 4D symbol, which is equal to 5 bits per 2D symbol (also equal to 5/6-coded 64QAM). For 4D-TCM 48QAM, a 4D symbol (equal to two 2D symbols) contains 3 bits for coset selection, 3 bits for region pair selection, and 2x4 bits for symbol selection. In total, it contains 14 bits per 4D symbol, which is equal to 7 bits per 2D symbol (also equal to 7/8-coded 256 QAM).

Detail structure of each component is described in the following subclauses.

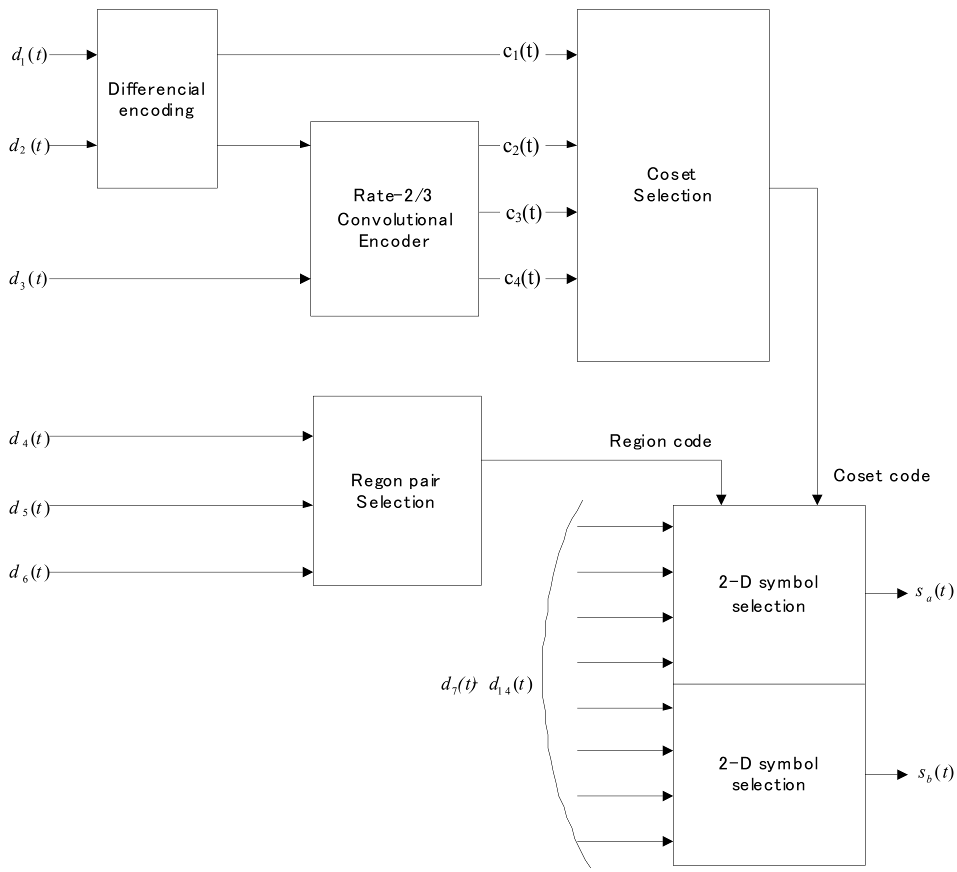


Figure 149a—Structure of multidimensional trellis encoder

9.7.2.5.2 Coset selection

Two bits enter the rate 2/3 convolutional encoder. This encoder generates three-bit output. With one additional bit, a total of four bits are used to choose a pair of signal points illustrated in Figure 149b among the following pairs of signal points:

(A, A), (A, B),(A, C),(A, D),(B, A),(B, B),(B, C),(B, D),(C, A),(C, B),(C, C),(C, D),
(D, A),(D, B),(D, C),(D, D).

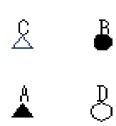


Figure 149b—Signal constellation for coset selection

Bit assignment for coset selection is listed in Table 225a.

Table 225a—Bit assignment for coset selection

Input of coset selection $c_1(t)c_2(t)\ c_3(t)\ c_4(t)$	Output of coset at $s_a(t)$ / $s_b(t)$
0000	A/A
0001	A/C
0010	A/B
0011	A/D
0100	C/A
0101	C/C
0110	C/ B
0111	C/D
1000	B/A
1001	B/C
1010	B/B
1011	B/D
1100	D/A
1101	D/C
1110	D/B
1111	D/D

9.7.2.5.3 Region pair selection

Three bits enter a Region pair selector to select a pair of regions over two 2D symbols. Figure 149c illustrates the sketch of regions. One 2D symbol contains three regions, say I_0, I_1, and O illustrated in Figure 149c. According to the contents of entered three bits, one region pair (R_1, R_2) shall be chosen among the following region pairs:

(I_0, I_0), (I_0, I_1), (I_0, O),(I_1, I_0), (I_1, I_1), (I_1, O), (O, I_0), (O, I_1),

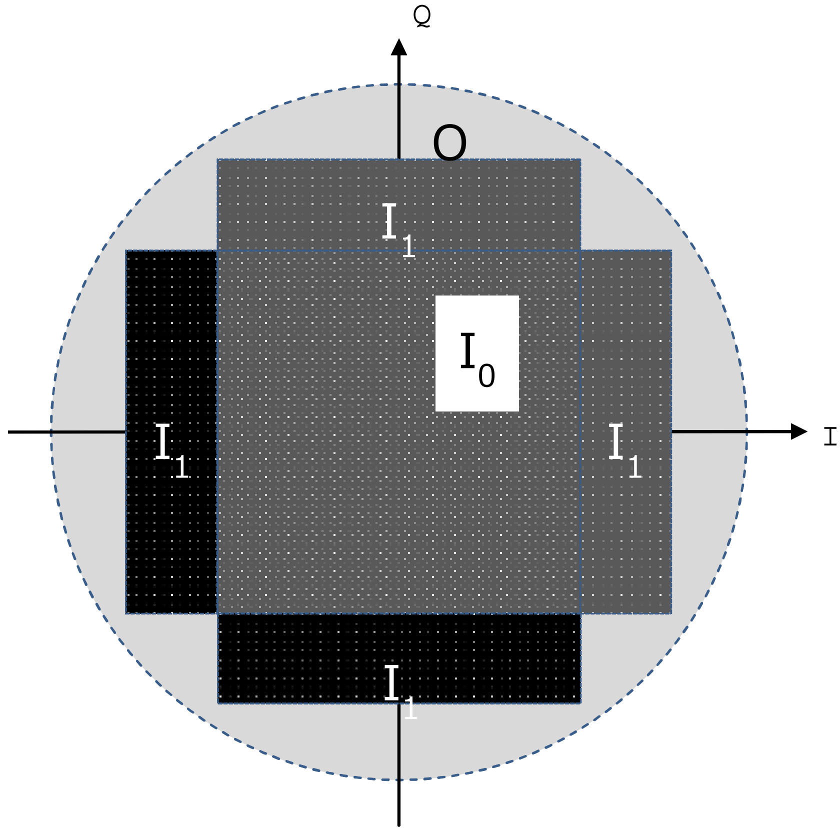


Figure 149c—Sketch of "region" in MD-TCM

Bit assignment of region pair selection is listed in Table 225b.

Table 225b—Region pair selection

$d_4(t)d_5(t)d_6(t)$	Region at $s_a(t)$	Region at $s_b(t)$
000	I_0	I_0
001	I_0	I_1
010	I_0	O
011	I_1	I_0
100	I_1	I_1
101	I_1	O
110	O	I_0
111	O	I_1

9.7.2.5.4 Symbol selection

For MD-TCM 48 QAM, 2-D symbol selection contains QPSK mapper with constellation mapping in Figure 150. For MD-TCM 192 QAM, 2D symbol selection contains 16-QAM mapper with constellation mapping in Figure 151.

9.8 Constellation mapping and modulation

9.8.1 Data modulation

Change the first paragraph in 9.8.1 as follows:

The output of the bit interleaver is entered serially to the constellation mapper. The input data to the mapper is first divided into groups of number of coded bits per carrier, i.e., NCBPC bits and then converted into complex numbers representing QPSK, 16-QAM, ~~or~~ 64-QAM, or 256-QAM constellation points. The mapping for QPSK, 16-QAM, ~~and~~ 64-QAM, and 256-QAM is performed according to Gray-coding constellation mapping, as shown in Figure 150, Figure 151, ~~and~~ Figure 152, and Figure 152a, respectively, where b_0 represents the most significant modulation bit for all constellations.

Insert the following figure (Figure 152a) after Figure 152:

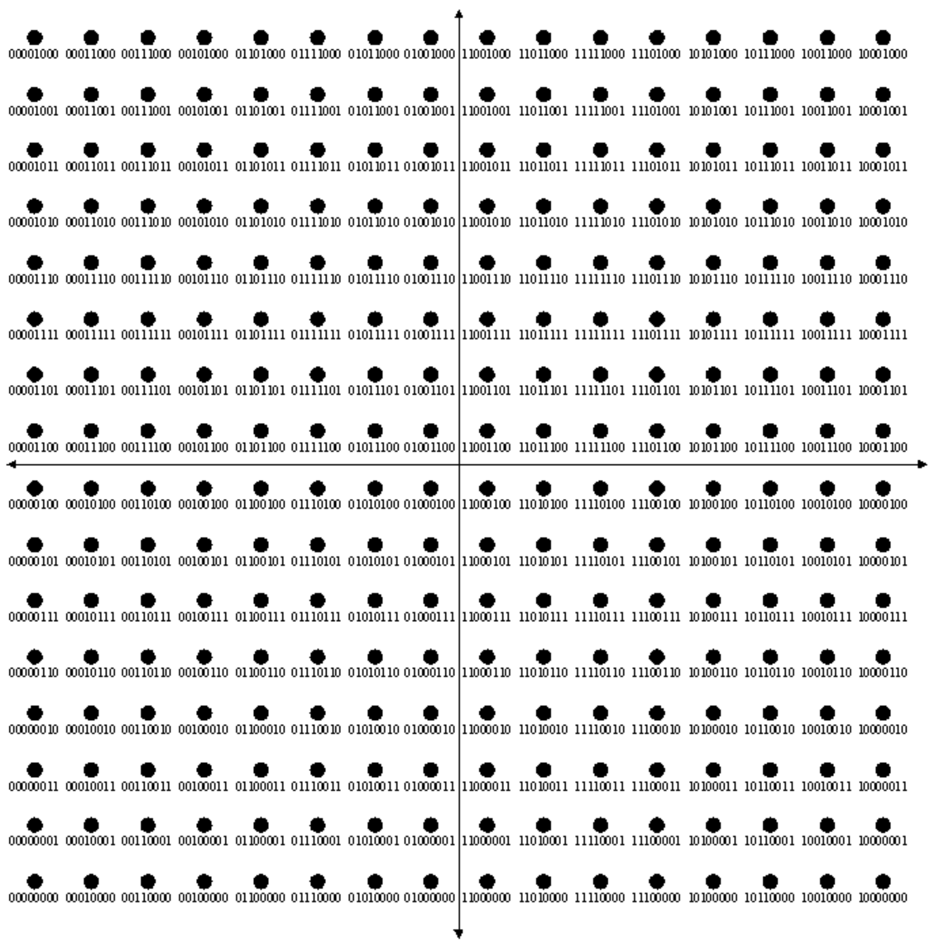


Figure 152a—Gray mapping for 256-QAM

Change Table 226 and Table 227 as indicated:

Table 226—Number of coded bit per carrier and normalization factor for different modulation constellations

Modulation type	N_{CBPC}	K_{MOD}
QPSK	2	$1/\sqrt{2}$
16-QAM	4	$1/\sqrt{10}$
64-QAM	6	$1/\sqrt{42}$
256-QAM	8	$1/\sqrt{170}$
4D-TCM 48QAM	5.5	$1/\sqrt{31.33}$
4D-TCM 192QAM	7.5	$1/\sqrt{122.33}$

Table 227—Number of coded bits per OFDM slot (N_{CBPS}) and corresponding number of data bits for different modulation constellation and coding rate combinations

Constellation type	Coding rate	N_{CBPS}	Corresponding number of data bits
QPSK	1/2	48	24
QPSK	2/3	48	32
QPSK	3/4	48	36
QPSK	5/6	48	40
16-QAM	1/2	96	48
16-QAM	2/3	96	64
16-QAM	3/4	96	72
16-QAM	5/6	96	80
64-QAM	½	144	72
64-QAM	2/3	144	96
64-QAM	3/4	144	108
64-QAM	5/6	144	120
256-QAM	1/2	192	96
256-QAM	2/3	192	128
256-QAM	3/4	192	144
256-QAM	5/6	192	160
256-QAM	7/8	192	168
4D-TCM 48QAM	10/11for 4D symbol	132	120
4D-TCM 192QAM	14/15 for 4D symbol	180	168

Insert the following paragraph and figures (Figure 152b and Figure 152c) after Table 117 in 9.8.1:

The output of the multidimensional trellis encoder is fed to the constellation mapper. The input data to the mapper has represent a group of number of coded bits per two carriers, i.e., NCBPC bits, and that are then converted into complex numbers representing 48-QAM, or 192-QAM constellation points. The mapping for 48-QAM and 192-QAM are performed according to the constellation mapping, as shown in Figure 152b and Figure 152c, respectively.

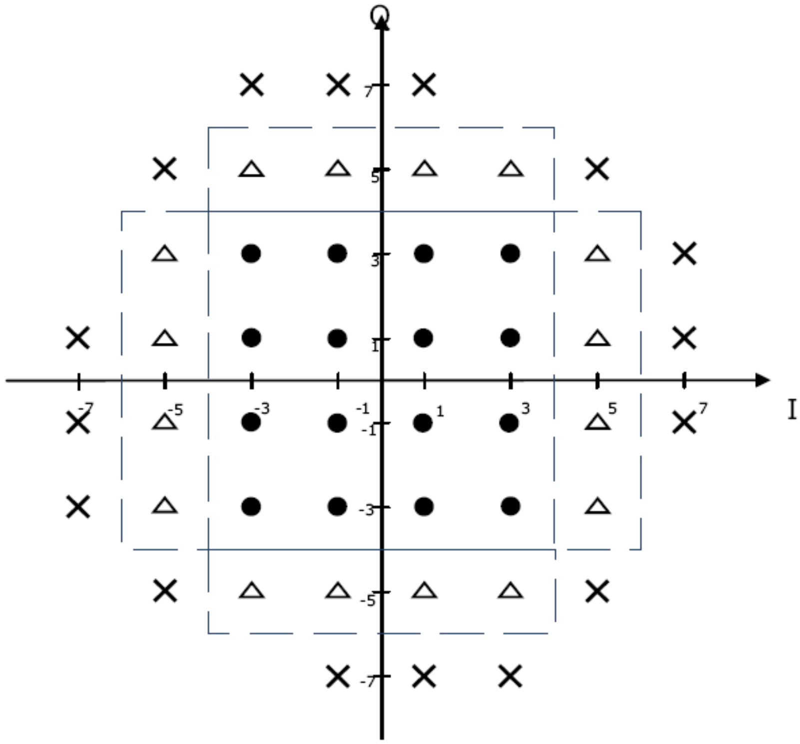


Figure 152b—Constellation of one 2D symbol for MD-TCM 48 QAM

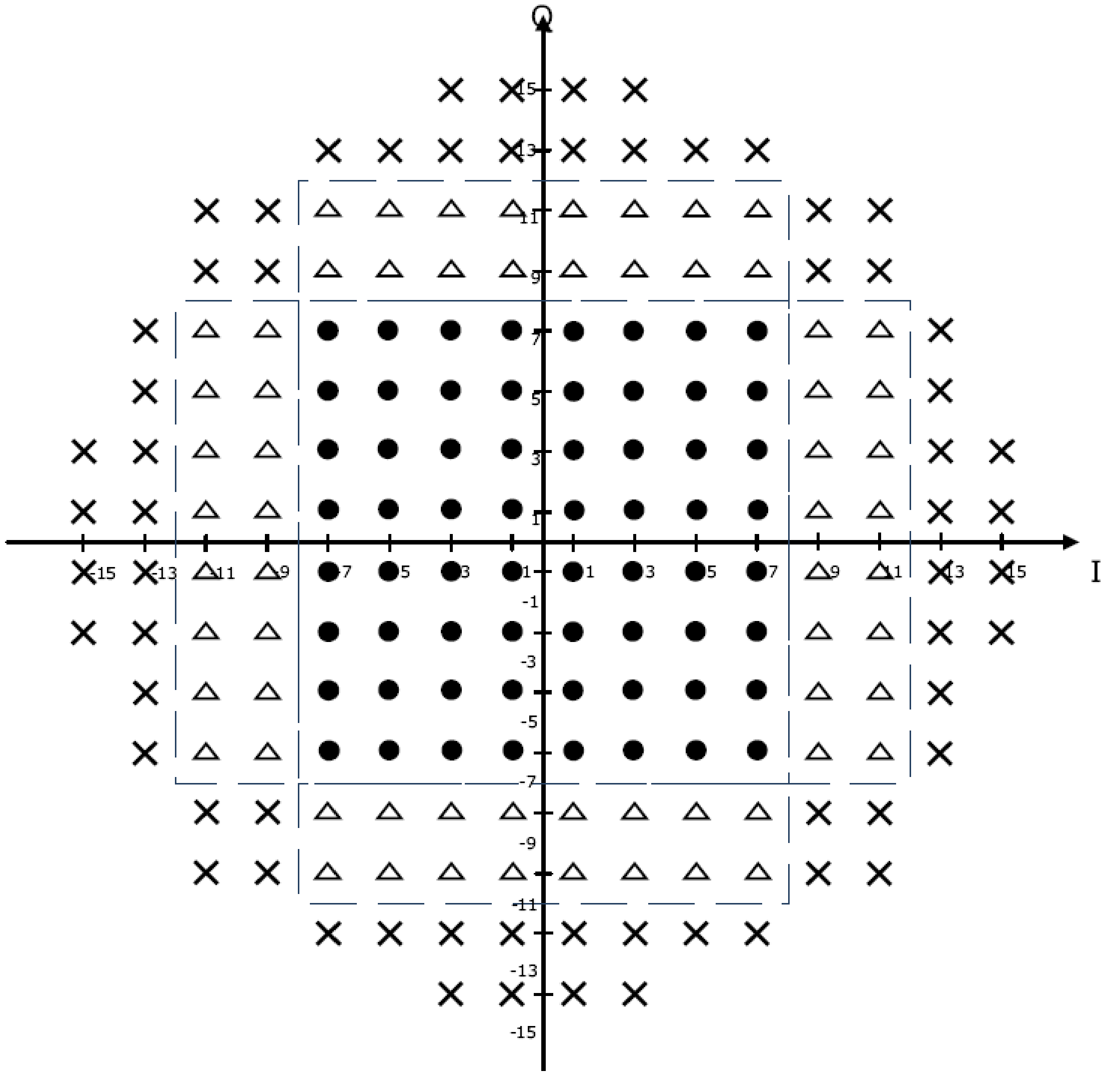


Figure 152c—Constellation of one 2D symbol for MD-TCM 192 QAM

9.9 Control mechanisms

9.9.4 Power control

9.9.4.2 Transmit Power Control mechanism

Change the fifth paragraph in 9.9.4.2 as follows:

This resulting value P_{new} is updated based on the value P_{range} transmitted regularly to the CPE by the BS through the RNG-CMD MAC message (see 7.7.6) to keep the TPC of the RF link up-to-date. The CPE shall be calibrated by the manufacturer so that the actual EIRP density per subcarrier transmitted by the CPE corresponds to the level indicated by the P_{range} variable resulting from the RNG-CMD message (within 0.5 dB). The default normalized CNR values per modulation for the binary convolutional code (BCC) and multidimensional trellis coded modulation (MD-TCM), except for the CDMA code, are given in Table 228. These values may be overridden by the BS by using a dedicated UCD message (see Table 33). The second column is the default value and third column is informative and indicative of the modulation performance in a multipath channel.

Change Table 228 as indicated:

Table 228—Normalized CNR per modulation for BER= 2×10^{-4}

Modulation - FEC rate	Normalized CNR (dB)	
	AWGN (default)	~~Multipath channel~~[20]
CDMA code	1.2	~~5~~
QPSK, rate: 1/2	4.3	~~8.1~~
QPSK, rate: 2/3	6.1	~~11.6~~
QPSK, rate: 3/4	7.1	~~14.0~~
QPSK, rate: 5/6	8.1	~~17.8~~
16-QAM, rate: 1/2	10.2	~~14.8~~
16-QAM, rate: 2/3	12.4	~~20.3~~
16-QAM, rate: 3/4	13.5	~~24.6~~
16-QAM, rate: 5/6	14.8	~~28.6~~
64-QAM, rate: 1/2	15.6	~~20.5~~
64-QAM, rate: 2/3	18.3	~~26.2~~
64-QAM, rate: 3/4	19.7	~~31.8~~
64-QAM, rate: 5/6	20.9	~~40.4~~
256-QAM, rate: 1/2	21.5	
256-QAM, rate: 2/3	25.0	
256-QAM, rate: 3/4	27.2	
256-QAM, rate: 5/6	29.0	
256-QAM, rate: 7/8	31.2	
4D-TCM 48QAM	19.4	
4D-TCM 192 QAM	27.5	

~~[20] The multipath channel used for the calculations is defined on 6 paths as follows: excess delay: –3, 0, 2, 4, 7 and 11 µsec; relative amplitude: –6, 0, –7, –22, –16, and –20 dB; the phase for each path is random. The delay, amplitude and phase are assumed to be constant over the period of one symbol.~~

9.14 Receiver requirements

9.14.1 Receiver minimum sensitivity

Change the following paragraph in the variable list in 9.14.1 as indicated:

Required Signal-to-Noise Ratio = the Reference Normalized SNR as shown in Table 228 for a BER performance of $2x10^{-4}$ where the values include 1.1 dB, 1.3 dB, 1.5 dB, and 1.7 dB decoder implementation margins for QPSK, 16-QAM, ~~and~~ 64-QAM, and 256-QAM modulations, respectively

Insert the following subclause (9.15 and its subclauses, figures, and equations) after 9.14.3:

9.15 Multiple-input, multiple-output (MIMO)

9.15.1 Overview

Multiple-input, multiple-output (MIMO) system has attracted a great deal of attention since the mid-1990's. It consists of multiple antennas at both transmitter and receiver, and are a breakthrough in wireless communication system design. Not limited to time and frequency dimensions, MIMO exploits the spatial dimension created by multiple antennas to achieve improvements in capacity and reliability. Moreover, the improvements come with neither addition of bandwidth nor increment of power, therefore, making MIMO a highly spectral efficient and reliable technique.

The MIMO channel can be made more robust against fading channels than each of its single-input-single-output (SISO) components by exploiting spatial diversity. Furthermore, MIMO channel creates the possibility to increase the transmission rate compared to SISO channel through spatial multiplexing; however, these two features cannot be fully exploited at the same time. A fundamental trade-off between rate increment and robustness against fading exists and must be decided according to the users needs.

The MIMO technique described hereafter is more appropriate for the link between A-BS and A-CPEs existing in the wireless network backbone of A-WRAN systems. On the other hand, implementing MIMO on the links between A-BS and S-CPEs or A-CPEs and S-CPEs is technically more challenging. This is due to the fact that the lower operating frequencies inherent to the TVWS bands require antennas with bigger physical sizes than the ones required by existing wireless communication systems operating at higher parts of the frequency spectrum.

9.15.2 MIMO pilot allocation

9.15.2.1 Overview

The pilot insertion pattern for two antennas and four antennas is shown in Figure 160a and Figure 106b, respectively. The pilot pattern shall be repeated every 7 OFDM symbols and 7 subcarriers in the time and frequency domains, respectively. The pilot pattern is always the same, independent of the channel bandwidth. The pilot pattern shall also be the same for the DS and US.

9.15.2.2 Pilot allocation for two antennas

The pilot insertion pattern for two antennas is shown in Figure 160a. The following physical pilot indices, P_k, after the last frame preamble in every DS subframe, shall be used instead of the logical indices 0, 1, …, 6.

$$P_k = -840 + 7k + pilot\_subcarrier\_offset + DC\_flag, \quad k = 0,1,2,...,239$$

where

k	is the running subcarrier index from 0 to 239.
pilot_subcarrier_offset	is the subcarrier offset to control the beginning of first pilot subcarrier within each OFDM symbol. The *pilot_subcarrier_offset* for antenna 0 is 0, 3, 5, and 1 for (*OFDM_symbol_index mod 7*) = 0, 2, 4, and 6, respectively. The *pilot_subcarrier_offset* for antenna 1 is 2, 6, and 4 for (*OFDM_symbol_index mod 7*) = 1, 3, and 5, respectively. The OFDMA symbol of index 0 should be the first OFDMA symbol in every DS or US subframes.
DC_flag	is used to count the DC subcarrier in the calculation of pilot subcarrier index. When *k* is equal or larger than 120, the value is set to 1.

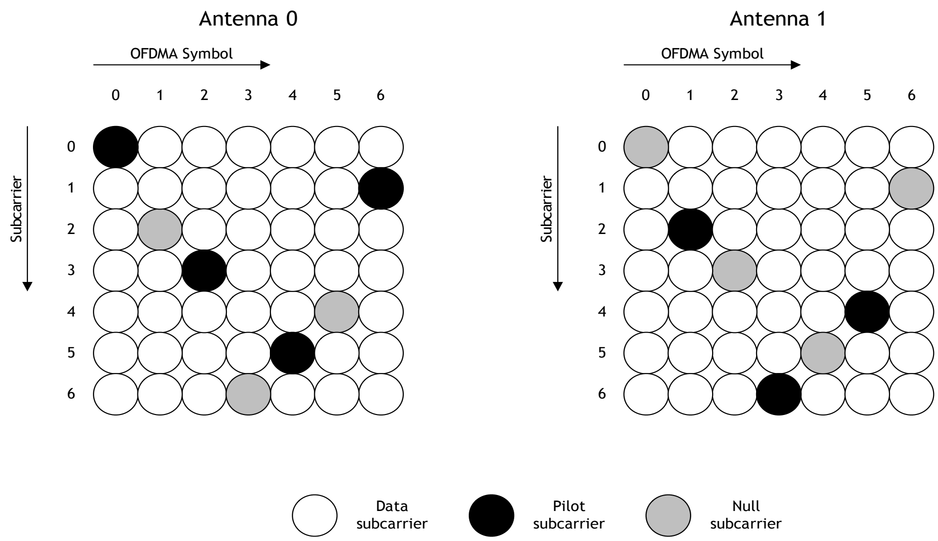


Figure 160a—Pilot pattern for two TX antennas

9.15.2.3 Pilot allocation for four antennas

The pilot insertion pattern for four antennas is shown in Figure 106b. The following physical pilot indices, P_k, after the last frame preamble in every DS subframe, shall be used instead of the logical indices 0, 1, …, 6.

$$P_k = -840 + 7k + pilot\_subcarrier\_offset + DC\_flag, \quad k = 0,1,2,...,239$$

where

k	is the running subcarrier index from 0 to 239.
pilot_subcarrier_offset	is the subcarrier offset to control the beginning of first pilot subcarrier within each OFDM symbol. The *pilot_subcarrier_offset* for antenna 0 is 0 and 3 for (*OFDM_symbol_index mod 7*)= 0 and 4, respectively. The *pilot_subcarrier_offset* for antenna 1 is 1 and 4 for (*OFDM_symbol_index mod 7*) = 1 and 5, respectively. The *pilot_subcarrier_offset* for antenna 2 is 2 and 5 for (*OFDM_symbol_index mod 7*) = 2 and 6, respectively. The OFDMA symbol of index 0 should be the first OFDMA symbol in every DS or US subframes.

DC_flag is used to count the DC subcarrier in the calculation of pilot subcarrier index.When k is equal or larger than 120, the value is set to 1.

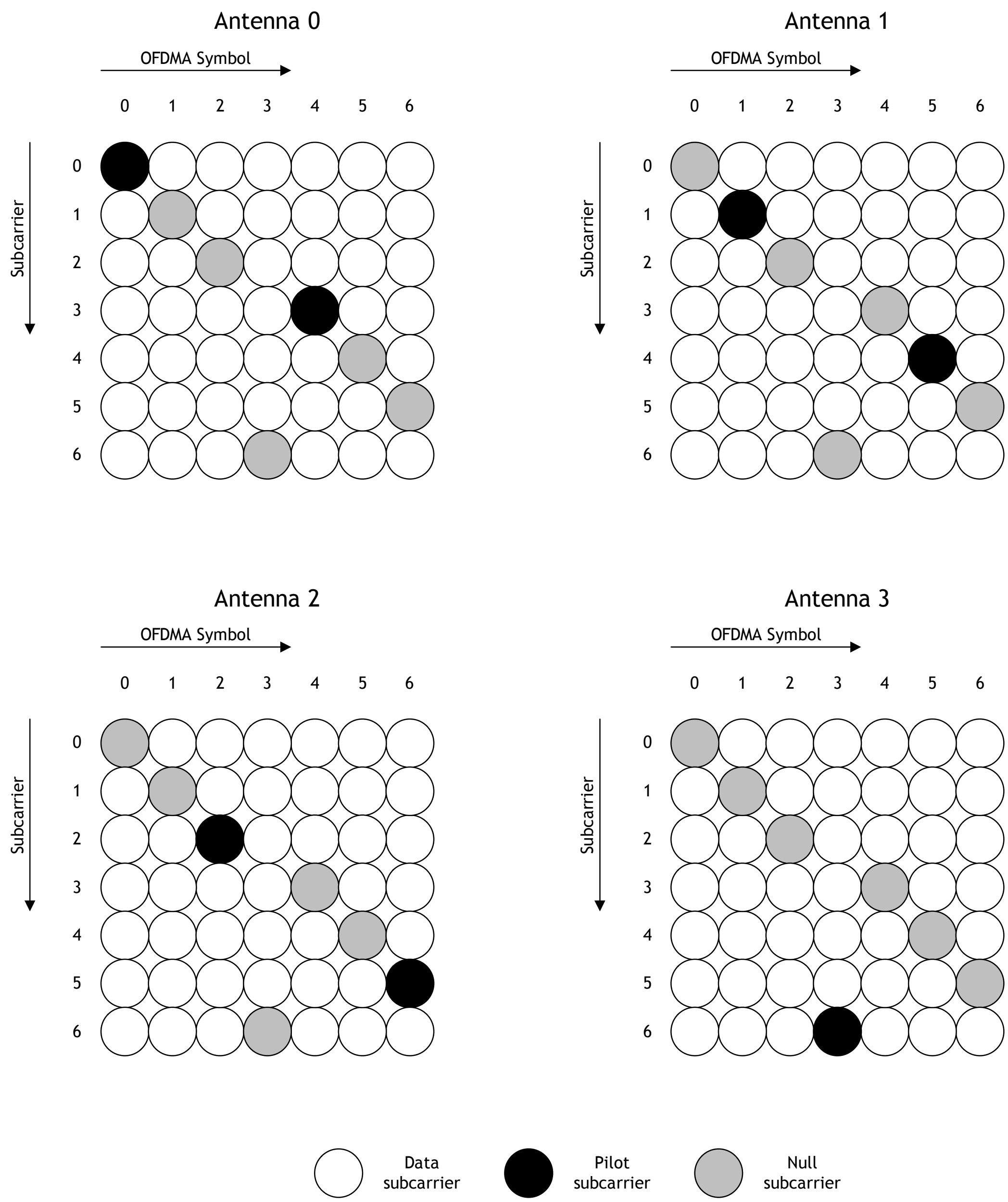


Figure 106b—Pilot pattern for four TX antennas

9.15.3 Space time coding (STC)

9.15.3.1 Overview

The MIMO technique described in this clause is common to both PHY-OM1 (Clause 9) and PHY-OM2 (Clause 9a) of the PHY considered in this standard.

9.15.3.2 Transmit diversity using two antennas (Alamouti O-STBC)

Improvement in wireless link robustness against the deleterious effects of fading is achieved by the use of Orthogonal Space-Time Block Codes (O-STBCs) through exploitation of the extra degrees of freedom provided by the multi-input, multi-output (MIMO) channel.

Let us consider a wireless communications system with two antennas at the transmitter side and a single antenna at the receiver side. Additionally, let both transmit antennas, namely antenna one and two, be spaced at least half-wave length from each other and from which two symbols s_1 and s_2 are respectively transmitted (simultaneously) at a given symbol period *T*. If during the following symbol period $-s_2^*$ and s_1^*, where * represents complex conjugation operation, are now transmitted respectively from antenna one and two, we can represent the encoding scheme in the following manner:

$$G_2 = \begin{bmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{bmatrix}, \tag{16}$$

where the columns of the above encoding matrix represent the transmit antennas, the rows correspond to the symbol periods and s_n is the symbol taken from a complex constellation *C* with $n \in \{1,2\}$.

Considering that the channel remains constant across two consecutive symbol periods, i.e., a block fading channel, we can write

$$h_1(t) = h_1(t+T) = h_1 \tag{17}$$

$$h_2(t) = h_2(t+T) = h_2$$

where

T	is the symbol period
h_1 and h_2	are the channel paths between the transmit antenna and the receive antenna

Thus received signals are expressed by

$$r_1 = h_1 s_1 + h_2 s_2 + n_1$$

$$r_2 = h_1 s_2 + h_2 s_1 + n_2$$

Here, n_1 and n_2 are zero-mean white complex Gaussian distributed noise values with variance $\sigma^2_n/2$ per dimension.

9.15.3.3 Transmit diversity with array-interference gain

9.15.3.3.1 Overview

The technique disclosed in this subclause is full rate based on array-interference constructive aggregation. Its objective is to improve the link reliability over conventional transmit diversity, i.e., Space-Time Block Codes (STBC). This technique intentionally creates aligned array interference so as to exploit its energy in the form of added array gain. As a result, the overall gain (diversity gain + array gain) reduces the bit-error probability (BEP) as compared to the diversity gain only yielded by conventional STBCs based systems.

9.15.3.3.2 Transmit diversity with array-interference gain for two antennas

9.15.3.3.2.1 Overview

In this subclause we describe the structure of a 2 transmit (TX) antennas ($n_t = 2$) transmit diversity TDD system exploiting transmit array interference. Since the system is based on TDD, both transmitter and receiver operate in the same frequency channel, however, in different time-slots. In addition, in a TDD communication system, transmitter and receiver alternate their roles, i.e., the transmitter in time "T_n" is the receiver in the consecutive time "T_{n+1}". A direct consequence of the aforementioned is that both transmitter and receiver can estimate the wireless channel **H** during the time in which they are acting as receiver.

The vector $\mathbf{H} = [h_1\ h_2]$ represents the multiple-input-single-output (MISO) channel between the base station and the single antennae receiver (RX) white space device. In the analyses presented hereafter, **H** is considered to be quasi-static.

Symbols vectors are transmitted through **H** and noise is added at the receiver as shown in Figure 160c. The transmitter is composed of two blocks, namely, "array gain maximization" and "transmit vector selector." The aforementioned blocks are described in the following subclauses.

In two TX antenna systems, a total of two unique transmit vectors G_m, for $m \in \{0,1\}$ exists. Each G_m yields a single interference, which is aligned to the original signal thus improving system robustness towards fading. The total interference has components coming from all antennas in the array thus it is hereafter called aligned array interference I_{Am}. It should be noted that I_{Am}, where $m \in \{0,1\}$, are functions of the fading channel **H**, and both TX and RX can estimate **H** due to the reciprocity of uplink/downlink.

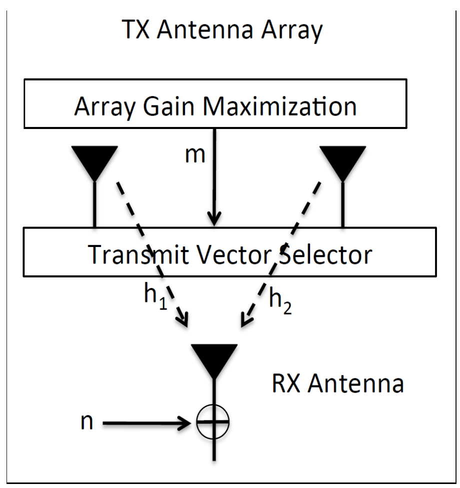


Figure 160c—Transmit diversity with array-interference gain for two TX antennas (TX side)

Channel estimation is performed by the channel estimator block (see . for implementation of the receiver side) based on pilots. The estimation is then provided to the array gain maximization block.

The array gain maximization block in TX performs

$$\arg\max_{m}(I_{Am}), \forall m \in \{0,1\}$$

in order to compare all the I_{Am} and selects the one that has the maximum value.

Then, the array gain maximization block at the transmitter sends *m* inherent to the maximum array interference to the transmit vector selector block, which selects G_m to be transmitted over the channel **H** since G_m will yield the maximum array gain.

9.15.3.3.2.2 Array gain maximization block

In the array gain maximization block, the array interference I_{Am} is stored as a function of **H.**

— Array Interference I_{A0}

$$I_{A0} = h_1^* h_2 + h_1 h_2^*$$

— Array Interference I_{A1}

$$I_{A1} = -h_1^* h_2 - h_1 h_2^*$$

In order to select the most aligned interference, the array gain maximization block performs

$$\arg\max_m (I_{Am}), \forall m \in \{0,1\}$$

The array gain maximization block at the TX directly sends *m* to the collocated transmit vector selector block. For the following implementation examples, consider that *m* is represented by 3 bits.

9.15.3.3.2.3 Transmit vector selector block

— Transmit $G_0 = [\text{ s } \text{ s}]$ if *m* is '000'

— Transmit $G_1 = [\text{ s -s}]$ if *m* is '001'

where

s is a symbol taken from a complex constellation *C*

9.15.3.3.3 Transmit diversity with array-interference gain for four antennas

9.15.3.3.3.1 Array gain maximization block

For four TX antennas, there are eight unique G_m together with their respective I_{Am} as well as w_m, m {0,1,2,3,4,5,6,7}.

$$I_{A0} = h_1^* h_2 + h_1 h_2^* + h_1^* h_3 + h_1 h_3^* + h_1^* h_4 + h_1 h_4^* + h_2^* h_3 + h_2 h_3^* + h_2^* h_4 + h_2 h_4^* + h_3^* h_4 + h_3 h_4^*$$
$$I_{A1} = -h_1^* h_2 - h_1 h_2^* - h_1^* h_4 - h_1 h_4^* - h_2^* h_3 - h_2 h_3^* - h_3^* h_4 - h_3 h_4^* + h_1^* h_3 + h_1 h_3^* + h_2^* h_4 + h_2 h_4^*$$
$$I_{A2} = -h_1^* h_3 - h_1 h_3^* - h_1^* h_4 - h_1 h_4^* - h_2^* h_3 - h_2 h_3^* - h_2^* h_4 - h_2 h_4^* + h_1^* h_2 + h_1 h_2^* + h_3^* h_4 + h_3 h_4^*$$
$$I_{A3} = -h_1^* h_2 - h_1 h_2^* - h_1^* h_3 - h_1 h_3^* - h_2^* h_4 - h_2 h_4^* - h_3^* h_4 - h_3 h_4^* + h_1^* h_4 + h_1 h_4^* + h_2^* h_3 + h_2 h_3^*$$
$$I_{A4} = -h_1^* h_4 - h_1 h_4^* - h_2^* h_4 - h_2 h_4^* - h_3^* h_4 - h_3 h_4^* + h_1^* h_2 + h_1 h_2^* + h_1^* h_3 + h_1 h_3^* + h_2^* h_3 + h_2 h_3^*$$
$$I_{A5} = -h_1^* h_3 - h_1 h_3^* - h_2^* h_3 - h_2 h_3^* - h_3^* h_4 - h_3 h_4^* + h_1^* h_2 + h_1 h_2^* + h_1^* h_4 + h_1 h_4^* + h_2^* h_4 + h_2 h_4^*$$
$$I_{A6} = -h_1^* h_2 - h_1 h_2^* - h_2^* h_3 - h_2 h_3^* - h_2^* h_4 - h_2 h_4^* + h_1^* h_3 + h_1 h_3^* + h_1^* h_4 + h_1 h_4^* + h_3^* h_4 + h_3 h_4^*$$
$$I_{A7} = -h_1^* h_2 - h_1 h_2^* - h_1^* h_3 - h_1 h_3^* - h_1^* h_4 - h_1 h_4^* + h_2^* h_3 + h_2 h_3^* + h_2^* h_4 + h_2 h_4^* + h_3^* h_4 + h_3 h_4^*$$

In order to select the most aligned interference, the array gain maximization block performs

$$\arg\max_m (I_{Am}), \forall m \in \{0,1,2,3,4,5,6,7\}$$

The array gain maximization block at the transmitter sends *m* to the transmit vector selector block collocated at the transmitter.

9.15.3.3.3.2 Transmit vector selector block

- Transmit $G_0 = [\text{ s s s s}]$ if *m* is '000';
- Transmit $G_1 = [\text{ s -s s -s}]$ if *m* is '001';
- Transmit $G_2 = [\text{ s s -s -s}]$ if *m* is '010';
- Transmit $G_3 = [\text{ s -s -s s}]$ if *m* is '011';
- Transmit $G_4 = [\text{ s s s -s}]$ if *m* is '100';
- Transmit $G_5 = [\text{ s s -s s}]$ if m is '101';
- Transmit $G_6 = [\text{ s -s s s}]$ if *m* is '110';
- Transmit $G|_7 = [\text{-s s s s}]$ if *m* is '111';

The above procedure partially (transmitter side only) describes how to obtain diversity added with array gain for systems with multiple antennas at the transmitter side. Note that the transmitter steps described here must be followed by the receiver steps described in H.1.2.

If more than one antenna is available in the receiver terminal, maximum ratio combining (MRC) can be utilized to significantly enhance link reliability. For simplicity, in the following example consider that the number of antennas available at the receiver is 2. The technique, however, can be utilized for any number of receive antennas.

In order to use MRC, little modification is necessary to what has been presented. The array gain maximization block, now, performs

$$\arg\max_m (I_{Am} + I'_{Am}), \forall m \in \{0,1\}$$

for two TX antennas, and

$$\arg\max_m (I_{Am} + I'_{Am}), \forall m \in \{0,1,2,3,4,5,6,7\}$$

for four TX antennas. Here, I_{Am} is the array interference in the first RX antenna, given in the previous clauses and I'_{Am} represents the array interferences in the second RX antenna. Since the channel to the second RX antenna is given by **H** = [h_3 h_4], for two TX antennas, and **H** = [h_5 h_6 h_7 h_8], for four TX antennas, I'_{Am} becomes

$$I_{A0} = h_3^* h_4 + h_3 h_4^*$$
$$I_{A1} = -h_3^* h_4 - h_3 h_4^*$$

or

$$I_{A0} = h_5^* h_6 + h_5 h_6^* + h_5^* h_7 + h_5 h_7^* + h_5^* h_8 + h_5 h_8^* + h_6^* h_7 + h_6 h_7^* + h_6^* h_8 + h_6 h_8^* + h_7^* h_8 + h_7 h_8^*$$
$$I_{A1} = -h_5^* h_6 - h_5 h_6^* - h_5^* h_8 - h_5 h_8^* - h_6^* h_7 - h_6 h_7^* - h_7^* h_8 - h_7 h_8^* + h_5^* h_7 + h_5 h_7^* + h_6^* h_8 + h_6 h_8^*$$
$$I_{A2} = -h_5^* h_7 - h_5 h_7^* - h_5^* h_8 - h_5 h_8^* - h_6^* h_7 - h_6 h_7^* - h_6^* h_8 - h_6 h_8^* + h_5^* h_6 + h_5 h_6^* + h_7^* h_8 + h_7 h_8^*$$
$$I_{A3} = -h_5^* h_6 - h_5 h_6^* - h_5^* h_7 - h_5 h_7^* - h_6^* h_8 - h_6 h_8^* - h_7^* h_8 - h_7 h_8^* + h_5^* h_8 + h_5 h_8^* + h_6^* h_7 + h_6 h_7^*$$
$$I_{A4} = -h_5^* h_8 - h_5 h_8^* - h_6^* h_8 - h_6 h_8^* - h_7^* h_8 - h_7 h_8^* + h_5^* h_6 + h_5 h_6^* + h_5^* h_7 + h_5 h_7^* + h_6^* h_7 + h_6 h_7^*$$
$$I_{A5} = -h_5^* h_7 - h_5 h_7^* - h_6^* h_7 - h_6 h_7^* - h_7^* h_8 - h_7 h_8^* + h_5^* h_6 + h_5 h_6^* + h_5^* h_8 + h_5 h_8^* + h_6^* h_8 + h_6 h_8^*$$
$$I_{A6} = -h_5^* h_6 - h_5 h_6^* - h_6^* h_7 - h_6 h_7^* - h_6^* h_8 - h_6 h_8^* + h_5^* h_7 + h_5 h_7^* + h_5^* h_8 + h_5 h_8^* + h_7^* h_8 + h_7 h_8^*$$
$$I_{A7} = -h_5^* h_6 - h_5 h_6^* - h_5^* h_7 - h_5 h_7^* - h_5^* h_8 - h_5 h_8^* + h_6^* h_7 + h_6 h_7^* + h_6^* h_8 + h_6 h_8^* + h_7^* h_8 + h_7 h_8^*$$

The array gain maximization block at the transmitter sends m to the collocated transmit vector selector block.

9.15.4 Spatial multiplexing

9.15.4.1 Overview

The MIMO technique described in this clause is common to both Mode 1 (Clause 9) and PHY-OM2 (Clause 9a) of the PHY considered in this standard.

9.15.4.2 Spatial multiplexing using two antennas

Previous subclauses have described methods to improve wireless link robustness against the deleterious effects of fading. Two spatial diversity techniques were described, namely Alamouti Code and a form of transmit diversity, which exploits the antenna array interference to obtain extra diversity gain. One application example of the aforementioned techniques is link-range extension between CPEs in order to service a wider geographical area. This is fundamental whenever the antennas of both CPEs are positioned relatively low due to the strong signal attenuation characteristic to near ground wave propagation.

This subclause, however, describes a highly spectral efficient technique that significantly enhances the A-WRAN system throughput. Spatial multiplexing transmits independent and separately encoded signals, i.e., streams, from each transmit antenna, therefore reusing (or multiplexing) the space dimension. In A-WRAN systems, enhanced data rate enables CPEs with bandwidth-hungry applications, e.g., such as wireless video transmissions for monitoring purposes, or it can increase the density of CPEs with data rate comparable to legacy IEEE 802.22 standard.

Let us consider the 2x2 wireless communications depicted in Figure 160d. The channel gains between the ith transmit antenna and the jth receive antenna $h_{j,i}$ is represented by the MIMO channel matrix

$$\boldsymbol{H} = \begin{bmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{bmatrix}.$$

Additionally, let both transmit antennas, namely antenna one and two, be spaced at least half-wave length from each other and from which two symbols s_1 and s_2, taken from an arbitrary complex constellation C, are simultaneously transmitted. Representing the transmitted symbols by the vector $\boldsymbol{s} = [s_1\ s_2]^T$ and the noise at the receive antennas by $\boldsymbol{n} = [n_1\ n_2]^T$, also illustrated in Figure 160d, we can represent the received signals as

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{bmatrix} \cdot \begin{bmatrix} s_1 \\ s_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \tag{18}$$

or

$$\mathbf{y} = \mathbf{H}^{\cdot}\mathbf{s} + \mathbf{n} \tag{19}$$

Here, n_j is the zero-mean white complex Gaussian distributed noise with variance $\sigma^2_n/2$ per dimension and ^{T} denotes transpose operation.

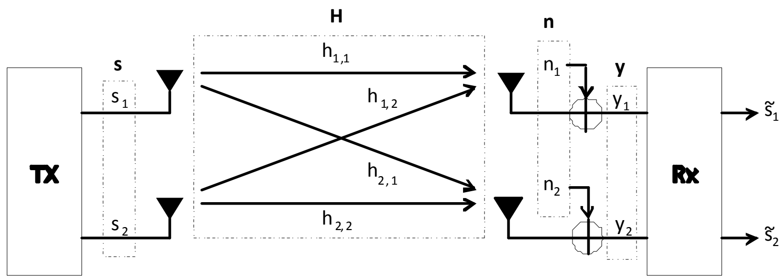


Figure 160d—Schematic representation of spatial multiplexing technique

9.15.4.3 Spatial multiplexing using four antennas

Previous subclauses have described spatial multiplexing with two Tx and two RX antennas. This subclause illustrates the same technique, however, for four Tx and four RX antennas.

Consider a 4x4 wireless communications system. The channel gains between the ith transmit antenna and the jth receive antenna $h_{j,i}$ is represented by the MIMO channel matrix

$$\boldsymbol{H} = \begin{bmatrix} h_{1,1} & h_{1,2} & h_{1,3} & h_{1,4} \\ h_{2,1} & h_{2,2} & h_{2,3} & h_{2,4} \\ h_{3,1} & h_{3,2} & h_{3,3} & h_{3,4} \\ h_{4,1} & h_{4,2} & h_{4,3} & h_{4,4} \end{bmatrix}$$

Similarly to the 2x2 case, let all antennas be spaced at least half-wave length from each other from where four symbols s_1, s_2, s_3, s_4, taken from the arbitrary complex constellation C are simultaneously transmitted. The transmitted symbols vector is $\boldsymbol{s} = [s_1\ s_2\ s_3\ s_4]^T$ and the noise at the receive antennas is $\boldsymbol{n} = [w_1\ w_2\ w_3\ w_4]^T$ with the received signals also given by $\boldsymbol{y} = \boldsymbol{H}^{\cdot}\boldsymbol{s} + \boldsymbol{n}$.

Insert the new Clause 9a after Clause 9:

9a. PHY Operation Mode 2 (PHY-OM2)

This clause specifies the basic technologies for the standardization of the PHY for A-WRAN systems. The specification is for a system that uses vacant channels to provide wireless communication.

The system reference frequency is the center frequency of the channel in which the transmitter and the receiver equipment operates. Annex A lists the frequencies corresponding to the channels used for A-WRAN operation in various regulatory domains.

The PHY specification is based on an OFDMA scheme where information to (DS) or from (US) multiple CPEs are modulated on orthogonal subcarriers using Inverse Fourier Transforms. The main system parameters are provided in Table 231a.

Table 231a—System parameters for A-WRAN

Parameters	Specifications	Remark
Frequency range	54~862 MHz	
Channel bandwidth	6, 7, or 8 MHz	According to regulatory domain (see Annex A).
Data rate (6 MHz case, 1/16 CP case)	3.61 to 18.05 up to 25.27 Mbit/s for SISO and single channel operation case 57.77 to 288.85 up to 404.39 Mbit/s for 4 stream MIMO and 4 channel operation case	See Table 231e. The single channel and single spatial stream is mandatory. Others cases should be optional.
Spectral Efficiency (6 MHz case, 1/16 CP case)	0.60 to 3.01 up to 4.21 bit/(s·Hz) for SISO and single channel operation case 2.41 to 12.05 up to 16.85 bit/(s·Hz) for 4 stream MIMO and 4 channel operation case	See Table 231e.
Payload modulation	QPSK, 16-QAM, 64-QAM, 256-QAM (optional), MD-TCM (optional)	BPSK used for preambles, pilots, and CDMA codes.
Transmit EIRP	4W maximum for CPEs. 4W maximum for BSs in the USA regulatory domain.	Maximum EIRP for BSs may vary in other regulatory domains.
Multiple Access	OFDMA	
FFT Size (N_{FFT})	1024	
Cyclic Prefix Modes	1/4, 1/8, 1/16, 1/32	
Duplex	TDD	

The following subclauses provide details on the various aspects of the PHY specifications.

9a.1 Symbol description

9a.1.1 OFDM symbol mathematical representation

The RF signal transmitted during any OFDM symbol duration can be represented mathematically as follows:

$$s(t) = \mathrm{Re}\left\{ e^{j2\pi f_c t} \sum_{\substack{k=-N_T/2 \\ k\neq 0}}^{N_T/2} c_k e^{j2\pi k\Delta f (t - T_{CP})} \right\}$$

where

- t is the time elapsed since the beginning of the current symbol, with $0<t<T_{SYM}$
- T_{SYM} is the symbol duration, including cyclic prefix duration
- *Re(.)* is the real part of the signal
- f_c is the carrier frequency
- C_k is a complex number; the data to be transmitted on the subcarrier whose frequency offset index is k, during the current symbol. It specifies a point in a QAM constellation.
- Δf is the subcarrier frequency spacing

T_{CP} is the time duration of cyclic prefix

N_T is the number of used subcarriers (not including DC subcarrier)

9a.1.1.1 Time domain description

The time domain signal is generated by taking the inverse Fourier transform of the length NFFT vector. The vector is formed by taking the constellation mapper output and inserting pilot and guard tones. At the receiver, the time domain signal is transformed to the frequency domain representation by using a Fourier transform.

Let T_{FFT} represent the time duration of the IFFT output signal. The OFDM symbol is formed by inserting a cyclic prefix of time duration T_{CP} (shown in Figure 160e), resulting in a symbol duration of $T_{SYM} = T_{FFT} + T_{CP}$.

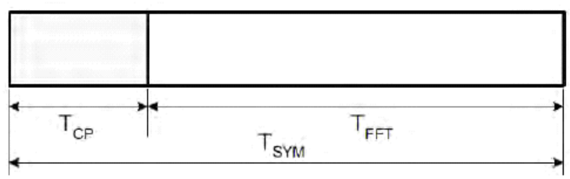


Figure 160e—OFDM symbol format

The specific values for T_{FFT}, T_{CP}, and T_{SYM} are given in 9a.1.2. The BS determines these parameters and conveys the T_{CP}-to-T_{FFT} ratio to the CPEs using the FCH.

The time at which the FFT window starts within the symbol period for reception at the CPE is determined by the local synchronization strategy to minimize inter-symbol interference due to pre- and post-echoes and any synchronization error; therefore, it is implementation dependent.

9a.1.1.2 Frequency domain description

In the frequency domain, an OFDM symbol is defined in terms of its subcarriers, which are classified as follows: data subcarriers, pilot subcarriers, and guard and null (including DC) subcarriers. The classification is based on the functionality of the subcarriers. The DS and US may have different allocations of subcarriers. The total number of subcarriers is determined by the FFT/IFFT size. The pilot subcarriers are distributed across the bandwidth. The exact location of the pilot and data subcarriers and the symbol's subchannel allocation is determined by the particular configuration used. All the remaining guard/null subcarriers carry no energy and are located at the center frequency of the channel (DC subcarrier) and at both edges of the channel (guard subcarriers).

9a.1.2 Symbol parameters

9a.1.2.1 Subcarrier spacing

The BS and CPEs shall use the 1024 FFT mode with the subcarriers spacing specified in Table 231b. The subcarrier spacing, ΔF, is dependent on the bandwidth of the channel (6 MHz, 7 MHz, or 8 MHz). Table 231b shows the subcarrier spacing and the corresponding FFT/IFFT period (T_{FFT}) values for the different channel bandwidth options.

Table 231b—Subcarrier spacing and FFT/IFFT period values for different bandwidth options

	6 MHz based channels	7 MHz based channels	8 MHz based channels
Basic sampling frequency, F_s (MHz)	5.6	6.53	7.46
Inter-carrier spacing ΔF (Hz)= F_s /1024	5468.75	6380.208…	7291.6…
FFT/IFFT period, T_{FFT}(μs)=1/ ΔF	182.857…	156.734…	137.142…
Time Unit (ns) TU=T_{FFT}/1024	178.571…	153.061…	133.928…

9a.1.2.2 Symbol duration for different cyclic prefix modes

The cyclic prefix duration, T_{CP}, could be one of the following derived values: $T_{FFT}/32$, $T_{FFT}/16$, $T_{FFT}/8$, and $T_{FFT}/4$. The OFDM symbol duration for different values of cyclic prefix is given in Table 231c.

Table 231c—Symbol duration for different cyclic prefixes and bandwidth options

		CP=T_{FFT}/32	CP=T_{FFT}/16	CP=T_{FFT}/8	CP=T_{FFT}/4
T_{SYM} =T_{FFT}+T_{CP} (μs)	6 MHz	188.571…	194.285…	205.714…	228.571…
	7 MHz	161.632…	166.530…	176.326…	195.918…
	8 MHz	141.428…	145.714…	154.285…	171.428..

9a.1.2.3 Transmission parameters

Table 231d shows the different parameters and their values for the three bandwidths..

Table 231d—OFDM parameters for the three channel bandwidths

TV channel bandwidth (MHz)	6	7	8
Total number of subcarriers, N_{FFT}	1024		
Number of guard subcarriers, N_G (L, DC, R)	192 (96,1,95) for DS 184 (92,1,91) for US		
Number of used subcarriers N_T= N_D+ N_P	832 for DS 840 for US		
Number of data subcarriers, N_D	832 or 416 for DS 840 or 420 for US		
Number of pilot subcarriers, N_P	0 or 416 for DS 0 or 420 for US		

9a.1.3 OFDMA basic terms definition

9a.1.3.1 Tile, slot, and data region

In DS, a tile consists of 4 successive active subcarriers and 4 OFDM symbols as shown in Figure 160f. In US, a tile consists of 4 successive active subcarriers and 7 OFDM symbols as shown in Figure 160g.

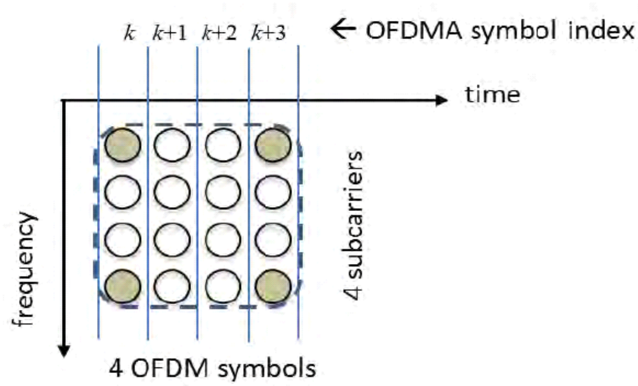


Figure 160f—Tile configuration for DS

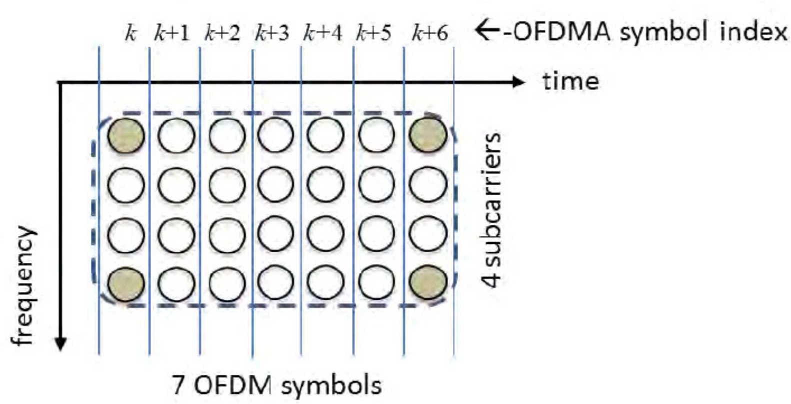


Figure 160g—Tile configuration for US

A slot is the minimum possible data allocation unit. A slot requires both a time and subchannel dimension. In DS, a slot consists of 16 subcarriers and 4 OFDM symbols (or 4 DS tiles) as shown in Figure 160h. In US, a tile consists of 8 subcarriers and 7 OFDM symbols (or 2 US tiles) as shown in Figure 160i.

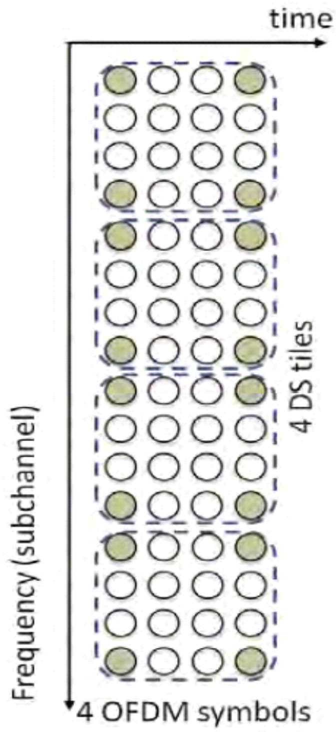


Figure 160h—Slot configuration for DS

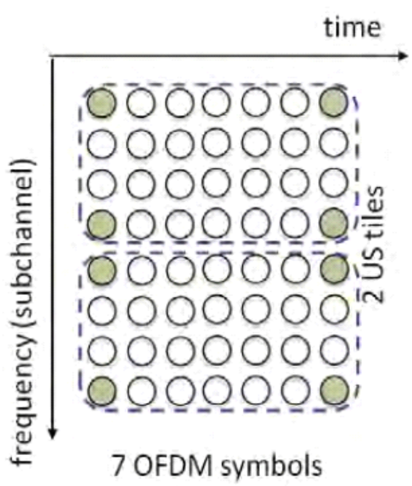


Figure 160i—Slot configuration for US

A data region is a 2D allocation of a group of contiguous subchannels, in a group of contiguous OFDMA symbols. All the allocations refer to logical subchannels. A 2D allocation may be visualized as a rectangle, such as the 8x5 rectangles shown in Figure 160j.

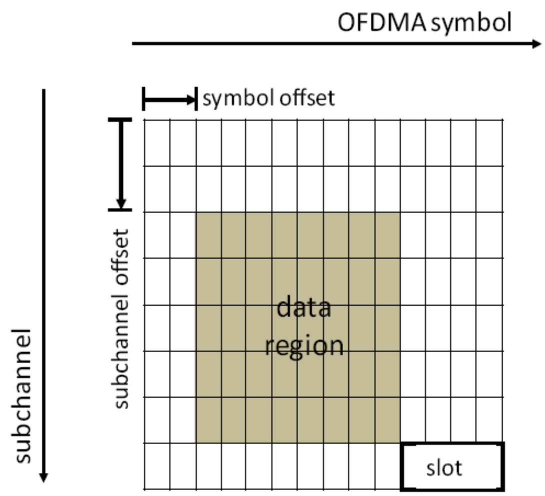


Figure 160j—Example of a data region that defines an OFDMA allocation (DS)

9a.1.3.2 Data mapping

MAC data shall be processed as described in 9a.7 and shall be mapped to a data region (see 9a.1.3.1) for DS and US using the algorithms defined below.

a) **DS:**
   1) Segment the data into blocks sized to fit into one slot.
   2) Each slot shall span one subchannel in the subchannel axis and 4 OFDM symbols in the time axis, as per the slot definition in 9a.1.3.1. Map the slots so that the lowest numbered slot occupies the lowest numbered subchannel in the lowest numbered symbol.
   3) Continue the mapping so that the subchannel index is increased. When the edge of the data region is reached, continue the mapping from the lowest numbered subchannel in the next available symbol.

   Figure 160k illustrates the order in which OFDMA slots are mapped to subchannels and OFDMA symbols in DS.

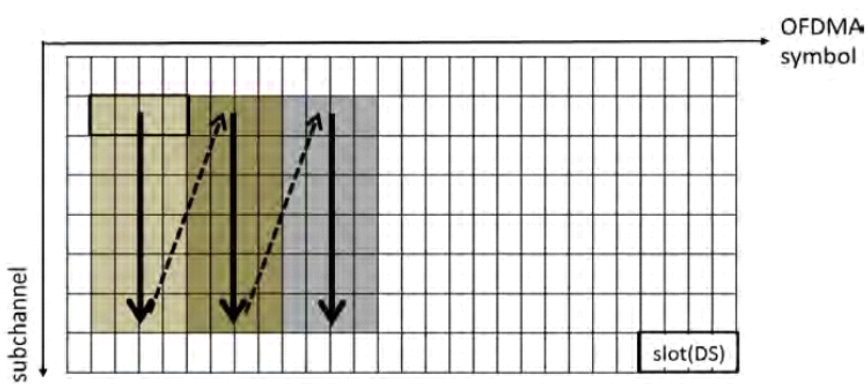


Figure 160k—Procedure of slot allocation to the burst (data region) in DS

b) **US:** The US mapping consists of two steps. In the first step, the slots allocated to each burst (a data region) are selected. In the second step, the allocated slots are mapped.

   1) Allocate slots to bursts.

      i) Segment the data into blocks sized to fit into one slot.

      ii) Each slot shall span one subchannel in the subchannel axis and 7 OFDM symbols in the time axis, as per the slot definition in Figure 160i. Allocate the slots so that the lowest numbered slot occupies the lowest numbered symbol in the lowest numbered subchannel.

      iii) Continue allocating so that the OFDMA symbol index is increased. When the edge of the allocated data region is reached, continue allocating from the lowest numbered symbol in the next available subchannel.

      iv) An US allocation is created by selecting an integer number of contiguous slots, according to the ordering of sub-steps i) through iii). This results in the general burst structure shown by the gray area in Figure 160l.

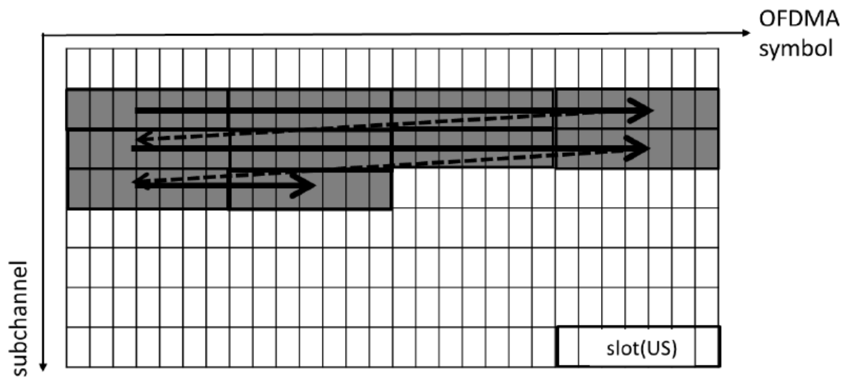


Figure 160l—Slot allocation to the allocated data region (burst) in US

   2) Map slots within the UL allocation.

      i) Map the slots so that the lowest numbered slot occupies the lowest numbered subchannel in the lowest numbered OFDMA symbol.

      ii) Continue the mapping so that the subchannel index is increased. When the last subchannel is reached, continue the mapping from the lowest numbered subchannel in the next OFDMA symbol that belongs to the UL allocation. The resulting order is shown by the arrows in Figure 160m.

   Figure 160m illustrates the order in which OFDMA slots are mapped to subchannels and OFDMA symbols in US.

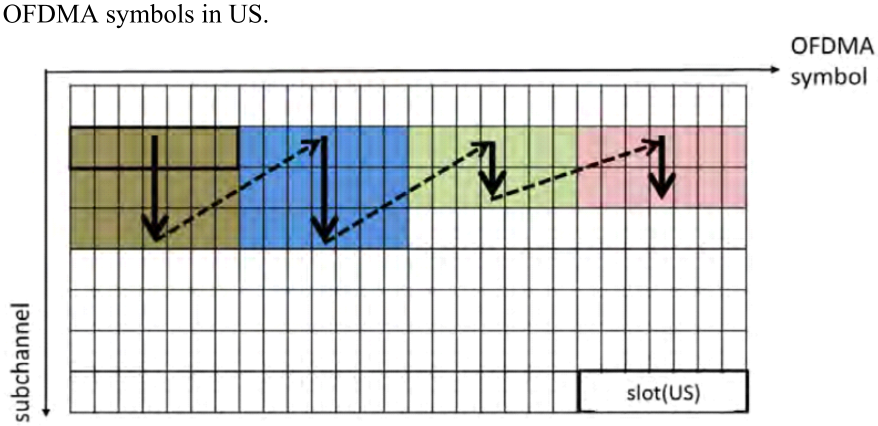


Figure 160m—Example of mapping slots to subchannels and symbols in the US

The subchannels referred to in this subclause are logical subchannels.

9a.2 Data rates

Table 231e defines the different PHY modulation and encoding modes with their associated parameters along with an example of the resulting gross data rates for the 6 MHz channel bandwidth.

Table 231e—PHY modes and their related modulations, coding rates, and data rates for $T_{CP} = T_{FFT}/16$

PHY mode	Modulation	Coding rate	Data rate (Mb/s)	Spectral efficiency[3] (for 6 MHz bandwidth)
1[1]	BPSK	Uncoded	4	4
2[2]	QPSK	1/2Repetition: 4	4	4
3	QPSK	1/2	3.61	0.60
4	QPSK	2/3	4.81	0.80
5	QPSK	3/4	5.42	0.90
6	QPSK	5/6	6.02	1.00
7	16-QAM	1/2	7.22	1.20
8	16-QAM	2/3	9.63	1.60
9	16-QAM	3/4	10.83	1.81
10	16-QAM	5/6	12.04	2.01
11	64-QAM	1/2	10.83	1.81
12	64-QAM	2/3	14.44	2.41
13	64-QAM	3/4	16.25	2.71
14	64-QAM	5/6	18.05	3.01
15	256-QAM	1/2	14.44	2.41
16	256-QAM	2/3	19.26	3.21
17	256-QAM	3/4	21.66	3.61
18	256-QAM	5/6	24.07	4.01
19	256-QAM	7/8	25.27	4.21
20	4D-TCM 48 QAM	10/11	18.05	3.01
21	4D-TCM 192 QAM	14/15	25.27	4.21

NOTE 1: Mode 1 is used only for CDMA opportunistic bursts.
NOTE 2: Mode 2 is used only for FCH and DRZ-FCH transmission.
NOTE 3: Spectral efficiency informative values are calculated assuming continuous stream for the given modulation and FEC modes (i.e., assuming no TTG, RTG, or frame headers).
NOTE 4: These modes are for control signal transmissions, and there is no need to specify data rate or spectral efficiency.

Table 202a through Table 202l give the data rates for the various channel and spatial stream combinations.

Table 231f—Data rate for 1 channel and 1 spatial stream

MODE	Modulation	Coding Rate	Data rate (Mbits/s)				Data rate (Mbits/s)				Data rate (Mbits/s)			
			6 MHz BW				7 MHz BW				8 MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
3	QPSK	1/2	3.07	3.41	3.61	3.72	3.58	3.98	4.21	4.34	4.09	4.55	4.81	4.96
4	QPSK	2/3	4.09	4.55	4.81	4.96	4.77	5.30	5.62	5.79	5.46	6.06	6.42	6.61
5	QPSK	3/4	4.60	5.11	5.42	5.58	5.37	5.97	6.32	6.51	6.14	6.82	7.22	7.44
6	QPSK	5/6	5.11	5.68	6.02	6.20	5.97	6.63	7.02	7.23	6.82	7.58	8.02	8.27
7	16-QAM	1/2	6.14	6.82	7.22	7.44	7.16	7.96	8.42	8.68	8.18	9.09	9.63	9.92
8	16-QAM	2/3	8.18	9.09	9.63	9.92	9.55	10.61	11.23	11.57	10.91	12.12	12.84	13.23
9	16-QAM	3/4	9.21	10.23	10.83	11.16	10.74	11.93	12.64	13.02	12.28	13.64	14.44	14.88
10	16-QAM	5/6	10.23	11.37	12.04	12.40	11.93	13.26	14.04	14.47	13.64	15.16	16.05	16.53
11	64-QAM	1/2	9.21	10.23	10.83	11.16	10.74	11.93	12.64	13.02	12.28	13.64	14.44	14.88
12	64-QAM	2/3	12.28	13.64	14.44	14.88	14.32	15.91	16.85	17.36	16.37	18.19	19.26	19.84
13	64-QAM	3/4	13.81	15.34	16.25	16.74	16.11	17.90	18.96	19.53	18.41	20.46	21.66	22.32
14	64-QAM	5/6	15.34	17.05	18.05	18.60	17.90	19.89	21.06	21.70	20.46	22.73	24.07	24.80
15	256-QAM	1/2	12.28	13.64	14.44	14.88	14.32	15.91	16.85	17.36	16.37	18.19	19.26	19.84
16	256-QAM	2/3	16.37	18.19	19.26	19.84	19.10	21.22	22.47	23.15	21.82	24.25	25.68	26.45
17	256-QAM	3/4	18.41	20.46	21.66	22.32	21.48	23.87	25.27	26.04	24.55	27.28	28.88	29.76
18	256-QAM	5/6	20.46	22.73	24.07	24.80	23.87	26.52	28.08	28.93	27.28	30.31	32.09	33.07
19	256-QAM	7/8	21.48	23.87	25.27	26.04	25.06	27.85	29.49	30.38	28.64	31.83	33.70	34.72
20	4D-TCM 48QAM	10/11	15.34	17.05	18.05	18.60	17.90	19.89	21.06	21.70	20.46	22.73	24.07	24.80
21	4D-TCM 192QAM	14/15	21.48	23.87	25.27	26.04	25.06	27.85	29.49	30.38	28.64	31.83	33.70	34.72

Table 231g—Data rate for 1 channel and 2 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6 MHz BW				7 MHz BW				8 MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
3	QPSK	1/2	6.14	6.82	7.22	7.44	7.16	7.96	8.42	8.68	8.18	9.09	9.63	9.92
4	QPSK	2/3	8.18	9.09	9.63	9.92	9.55	10.61	11.23	11.57	10.91	12.12	12.84	13.23
5	QPSK	3/4	9.21	10.23	10.83	11.16	10.74	11.93	12.64	13.02	12.28	13.64	14.44	14.88
6	QPSK	5/6	10.23	11.37	12.04	12.40	11.93	13.26	14.04	14.47	13.64	15.16	16.05	16.53
7	16-QAM	1/2	12.28	13.64	14.44	14.88	14.32	15.91	16.85	17.36	16.37	18.19	19.26	19.84
8	16-QAM	2/3	16.37	18.19	19.26	19.84	19.10	21.22	22.47	23.15	21.82	24.25	25.68	26.45
9	16-QAM	3/4	18.41	20.46	21.66	22.32	21.48	23.87	25.27	26.04	24.55	27.28	28.88	29.76
10	16-QAM	5/6	20.46	22.73	24.07	24.80	23.87	26.52	28.08	28.93	27.28	30.31	32.09	33.07
11	64-QAM	1/2	18.41	20.46	21.66	22.32	21.48	23.87	25.27	26.04	24.55	27.28	28.88	29.76
12	64-QAM	2/3	24.55	27.28	28.88	29.76	28.64	31.83	33.70	34.72	32.74	36.37	38.51	39.68
13	64-QAM	3/4	27.62	30.69	32.50	33.48	32.22	35.80	37.91	39.06	36.83	40.92	43.33	44.64
14	64-QAM	5/6	30.69	34.10	36.11	37.20	35.80	39.78	42.12	43.40	40.92	45.47	48.14	49.60
15	256-QAM	1/2	24.55	27.28	28.88	29.76	28.64	31.83	33.70	34.72	32.74	36.37	38.51	39.68
16	256-QAM	2/3	32.74	36.37	38.51	39.68	38.19	42.44	44.93	46.29	43.65	48.50	51.35	52.91
17	256-QAM	3/4	36.83	40.92	43.33	44.64	42.97	47.74	50.55	52.08	49.10	54.56	57.77	59.52
18	256-QAM	5/6	40.92	45.47	48.14	49.60	47.74	53.04	56.16	57.87	54.56	60.62	64.19	66.13
19	256-QAM	7/8	42.97	47.74	50.55	52.08	50.13	55.70	58.97	60.76	57.29	63.65	67.40	69.44
20	4D-TCM 48QAM	10/11	30.69	34.10	36.11	37.20	35.80	39.78	42.12	43.40	40.92	45.47	48.14	49.60
21	4D-TCM 192QAM	14/15	42.97	47.74	50.55	52.08	50.13	55.70	58.97	60.76	57.29	63.65	67.40	69.44

Table 231h—Data rate for 1 channel and 4 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6 MHz BW				7 MHz BW				8 MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
3	QPSK	1/2	12.28	13.64	14.44	14.88	14.32	15.91	16.85	17.36	16.37	18.19	19.26	19.84
4	QPSK	2/3	16.37	18.19	19.26	19.84	19.10	21.22	22.47	23.15	21.82	24.25	25.68	26.45
5	QPSK	3/4	18.41	20.46	21.66	22.32	21.48	23.87	25.27	26.04	24.55	27.28	28.88	29.76
6	QPSK	5/6	20.46	22.73	24.07	24.80	23.87	26.52	28.08	28.93	27.28	30.31	32.09	33.07
7	16-QAM	1/2	24.55	27.28	28.88	29.76	28.64	31.83	33.70	34.72	32.74	36.37	38.51	39.68
8	16-QAM	2/3	32.74	36.37	38.51	39.68	38.19	42.44	44.93	46.29	43.65	48.50	51.35	52.91
9	16-QAM	3/4	36.83	40.92	43.33	44.64	42.97	47.74	50.55	52.08	49.10	54.56	57.77	59.52
10	16-QAM	5/6	40.92	45.47	48.14	49.60	47.74	53.04	56.16	57.87	54.56	60.62	64.19	66.13
11	64-QAM	1/2	36.83	40.92	43.33	44.64	42.97	47.74	50.55	52.08	49.10	54.56	57.77	59.52
12	64-QAM	2/3	49.10	54.56	57.77	59.52	57.29	63.65	67.40	69.44	65.47	72.75	77.03	79.36
13	64-QAM	3/4	55.24	61.38	64.99	66.96	64.45	71.61	75.82	78.12	73.66	81.84	86.65	89.28
14	64-QAM	5/6	61.38	68.20	72.21	74.40	71.61	79.57	84.25	86.80	81.84	90.93	96.28	99.20
15	256-QAM	1/2	49.10	54.56	57.77	59.52	57.29	63.65	67.40	69.44	65.47	72.75	77.03	79.36
16	256-QAM	2/3	65.47	72.75	77.03	79.36	76.38	84.87	89.86	92.59	87.30	97.00	102.70	105.81
17	256-QAM	3/4	73.66	81.84	86.65	89.28	85.93	95.48	101.10	104.16	98.21	109.12	115.54	119.04
18	256-QAM	5/6	81.84	90.93	96.28	99.20	95.48	106.09	112.33	115.73	109.12	121.24	128.38	132.27
19	256-QAM	7/8	85.93	95.48	101.10	104.16	100.25	111.39	117.95	121.52	114.58	127.31	134.80	138.88
20	4D-TCM 48QAM	10/11	61.38	68.20	72.21	74.40	71.61	79.57	84.25	86.80	81.84	90.93	96.28	99.20
21	4D-TCM 192QAM	14/15	85.93	95.48	101.10	104.16	100.25	111.39	117.95	121.52	114.58	127.31	134.80	138.88

Table 231i—Data rate for 2 channels and 1 spatial stream

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6 MHz BW				7 MHz BW				8 MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
3	QPSK	1/2	6.14	6.82	7.22	7.44	7.16	7.96	8.42	8.68	8.18	9.09	9.63	9.92
4	QPSK	2/3	8.18	9.09	9.63	9.92	9.55	10.61	11.23	11.57	10.91	12.12	12.84	13.23
5	QPSK	3/4	9.21	10.23	10.83	11.16	10.74	11.93	12.64	13.02	12.28	13.64	14.44	14.88
6	QPSK	5/6	10.23	11.37	12.04	12.40	11.93	13.26	14.04	14.47	13.64	15.16	16.05	16.53
7	16-QAM	1/2	12.28	13.64	14.44	14.88	14.32	15.91	16.85	17.36	16.37	18.19	19.26	19.84
8	16-QAM	2/3	16.37	18.19	19.26	19.84	19.10	21.22	22.47	23.15	21.82	24.25	25.68	26.45
9	16-QAM	3/4	18.41	20.46	21.66	22.32	21.48	23.87	25.27	26.04	24.55	27.28	28.88	29.76
10	16-QAM	5/6	20.46	22.73	24.07	24.80	23.87	26.52	28.08	28.93	27.28	30.31	32.09	33.07
11	64-QAM	1/2	18.41	20.46	21.66	22.32	21.48	23.87	25.27	26.04	24.55	27.28	28.88	29.76
12	64-QAM	2/3	24.55	27.28	28.88	29.76	28.64	31.83	33.70	34.72	32.74	36.37	38.51	39.68
13	64-QAM	3/4	27.62	30.69	32.50	33.48	32.22	35.80	37.91	39.06	36.83	40.92	43.33	44.64
14	64-QAM	5/6	30.69	34.10	36.11	37.20	35.80	39.78	42.12	43.40	40.92	45.47	48.14	49.60
15	256-QAM	1/2	24.55	27.28	28.88	29.76	28.64	31.83	33.70	34.72	32.74	36.37	38.51	39.68
16	256-QAM	2/3	32.74	36.37	38.51	39.68	38.19	42.44	44.93	46.29	43.65	48.50	51.35	52.91
17	256-QAM	3/4	36.83	40.92	43.33	44.64	42.97	47.74	50.55	52.08	49.10	54.56	57.77	59.52
18	256-QAM	5/6	40.92	45.47	48.14	49.60	47.74	53.04	56.16	57.87	54.56	60.62	64.19	66.13
19	256-QAM	7/8	42.97	47.74	50.55	52.08	50.13	55.70	58.97	60.76	57.29	63.65	67.40	69.44
20	4D-TCM 48QAM	10/11	30.69	34.10	36.11	37.20	35.80	39.78	42.12	43.40	40.92	45.47	48.14	49.60
21	4D-TCM 192QAM	14/15	42.97	47.74	50.55	52.08	50.13	55.70	58.97	60.76	57.29	63.65	67.40	69.44

Table 231j—Data rate for 2 channels and 2 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6 MHz BW				7 MHz BW				8 MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
3	QPSK	1/2	12.28	13.64	14.44	14.88	14.32	15.91	16.85	17.36	16.37	18.19	19.26	19.84
4	QPSK	2/3	16.37	18.19	19.26	19.84	19.10	21.22	22.47	23.15	21.82	24.25	25.68	26.45
5	QPSK	3/4	18.41	20.46	21.66	22.32	21.48	23.87	25.27	26.04	24.55	27.28	28.88	29.76
6	QPSK	5/6	20.46	22.73	24.07	24.80	23.87	26.52	28.08	28.93	27.28	30.31	32.09	33.07
7	16-QAM	1/2	24.55	27.28	28.88	29.76	28.64	31.83	33.70	34.72	32.74	36.37	38.51	39.68
8	16-QAM	2/3	32.74	36.37	38.51	39.68	38.19	42.44	44.93	46.29	43.65	48.50	51.35	52.91
9	16-QAM	3/4	36.83	40.92	43.33	44.64	42.97	47.74	50.55	52.08	49.10	54.56	57.77	59.52
10	16-QAM	5/6	40.92	45.47	48.14	49.60	47.74	53.04	56.16	57.87	54.56	60.62	64.19	66.13
11	64-QAM	1/2	36.83	40.92	43.33	44.64	42.97	47.74	50.55	52.08	49.10	54.56	57.77	59.52
12	64-QAM	2/3	49.10	54.56	57.77	59.52	57.29	63.65	67.40	69.44	65.47	72.75	77.03	79.36
13	64-QAM	3/4	55.24	61.38	64.99	66.96	64.45	71.61	75.82	78.12	73.66	81.84	86.65	89.28
14	64-QAM	5/6	61.38	68.20	72.21	74.40	71.61	79.57	84.25	86.80	81.84	90.93	96.28	99.20
15	256-QAM	1/2	49.10	54.56	57.77	59.52	57.29	63.65	67.40	69.44	65.47	72.75	77.03	79.36
16	256-QAM	2/3	65.47	72.75	77.03	79.36	76.38	84.87	89.86	92.59	87.30	97.00	102.70	105.81
17	256-QAM	3/4	73.66	81.84	86.65	89.28	85.93	95.48	101.10	104.16	98.21	109.12	115.54	119.04
18	256-QAM	5/6	81.84	90.93	96.28	99.20	95.48	106.09	112.33	115.73	109.12	121.24	128.38	132.27
19	256-QAM	7/8	85.93	95.48	101.10	104.16	100.25	111.39	117.95	121.52	114.58	127.31	134.80	138.88
20	4D-TCM 48QAM	10/11	61.38	68.20	72.21	74.40	71.61	79.57	84.25	86.80	81.84	90.93	96.28	99.20
21	4D-TCM 192QAM	14/15	85.93	95.48	101.10	104.16	100.25	111.39	117.95	121.52	114.58	127.31	134.80	138.88

Table 231k—Data rate for 2 channels and 4 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6 MHz BW				7 MHz BW				8 MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
3	QPSK	1/2	24.55	27.28	28.88	29.76	28.64	31.83	33.70	34.72	32.74	36.37	38.51	39.68
4	QPSK	2/3	32.74	36.37	38.51	39.68	38.19	42.44	44.93	46.29	43.65	48.50	51.35	52.91
5	QPSK	3/4	36.83	40.92	43.33	44.64	42.97	47.74	50.55	52.08	49.10	54.56	57.77	59.52
6	QPSK	5/6	40.92	45.47	48.14	49.60	47.74	53.04	56.16	57.87	54.56	60.62	64.19	66.13
7	16-QAM	1/2	49.10	54.56	57.77	59.52	57.29	63.65	67.40	69.44	65.47	72.75	77.03	79.36
8	16-QAM	2/3	65.47	72.75	77.03	79.36	76.38	84.87	89.86	92.59	87.30	97.00	102.70	105.81
9	16-QAM	3/4	73.66	81.84	86.65	89.28	85.93	95.48	101.10	104.16	98.21	109.12	115.54	119.04
10	16-QAM	5/6	81.84	90.93	96.28	99.20	95.48	106.09	112.33	115.73	109.12	121.24	128.38	132.27
11	64-QAM	1/2	73.66	81.84	86.65	89.28	85.93	95.48	101.10	104.16	98.21	109.12	115.54	119.04
12	64-QAM	2/3	98.21	109.12	115.54	119.04	114.58	127.31	134.80	138.88	130.94	145.49	154.05	158.72
13	64-QAM	3/4	110.48	122.76	129.98	133.92	128.90	143.22	151.64	156.24	147.31	163.68	173.31	178.56
14	64-QAM	5/6	122.76	136.40	144.42	148.80	143.22	159.13	168.49	173.60	163.68	181.87	192.56	198.40
15	256-QAM	1/2	98.21	109.12	115.54	119.04	114.58	127.31	134.80	138.88	130.94	145.49	154.05	158.72
16	256-QAM	2/3	130.94	145.49	154.05	158.72	152.77	169.74	179.73	185.17	174.59	193.99	205.40	211.63
17	256-QAM	3/4	147.31	163.68	173.31	178.56	171.86	190.96	202.19	208.32	196.42	218.24	231.08	238.08
18	256-QAM	5/6	163.68	181.87	192.56	198.40	190.96	212.18	224.66	231.47	218.24	242.49	256.75	264.53
19	256-QAM	7/8	171.86	190.96	202.19	208.32	200.51	222.79	235.89	243.04	229.15	254.61	269.59	277.76
20	4D-TCM 48QAM	10/11	122.76	136.40	144.42	148.80	143.22	159.13	168.49	173.60	163.68	181.87	192.56	198.40
21	4D-TCM 192QAM	14/15	171.86	190.96	202.19	208.32	200.51	222.79	235.89	243.04	229.15	254.61	269.59	277.76

Table 231l—Data rate for 3 channels and 1 spatial stream

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6 MHz BW				7 MHz BW				8 MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
3	QPSK	1/2	9.21	10.23	10.83	11.16	10.74	11.93	12.64	13.02	12.28	13.64	14.44	14.88
4	QPSK	2/3	12.28	13.64	14.44	14.88	14.32	15.91	16.85	17.36	16.37	18.19	19.26	19.84
5	QPSK	3/4	13.81	15.34	16.25	16.74	16.11	17.90	18.96	19.53	18.41	20.46	21.66	22.32
6	QPSK	5/6	15.34	17.05	18.05	18.60	17.90	19.89	21.06	21.70	20.46	22.73	24.07	24.80
7	16-QAM	1/2	18.41	20.46	21.66	22.32	21.48	23.87	25.27	26.04	24.55	27.28	28.88	29.76
8	16-QAM	2/3	24.55	27.28	28.88	29.76	28.64	31.83	33.70	34.72	32.74	36.37	38.51	39.68
9	16-QAM	3/4	27.62	30.69	32.50	33.48	32.22	35.80	37.91	39.06	36.83	40.92	43.33	44.64
10	16-QAM	5/6	30.69	34.10	36.11	37.20	35.80	39.78	42.12	43.40	40.92	45.47	48.14	49.60
11	64-QAM	1/2	27.62	30.69	32.50	33.48	32.22	35.80	37.91	39.06	36.83	40.92	43.33	44.64
12	64-QAM	2/3	36.83	40.92	43.33	44.64	42.97	47.74	50.55	52.08	49.10	54.56	57.77	59.52
13	64-QAM	3/4	41.43	46.03	48.74	50.22	48.34	53.71	56.87	58.59	55.24	61.38	64.99	66.96
14	64-QAM	5/6	46.03	51.15	54.16	55.80	53.71	59.67	63.19	65.10	61.38	68.20	72.21	74.40
15	256-QAM	1/2	36.83	40.92	43.33	44.64	42.97	47.74	50.55	52.08	49.10	54.56	57.77	59.52
16	256-QAM	2/3	49.10	54.56	57.77	59.52	57.29	63.65	67.40	69.44	65.47	72.75	77.03	79.36
17	256-QAM	3/4	55.24	61.38	64.99	66.96	64.45	71.61	75.82	78.12	73.66	81.84	86.65	89.28
18	256-QAM	5/6	61.38	68.20	72.21	74.40	71.61	79.57	84.25	86.80	81.84	90.93	96.28	99.20
19	256-QAM	7/8	64.45	71.61	75.82	78.12	75.19	83.54	88.46	91.14	85.93	95.48	101.10	104.16
20	4D-TCM 48QAM	10/11	46.03	51.15	54.16	55.80	53.71	59.67	63.19	65.10	61.38	68.20	72.21	74.40
21	4D-TCM 192QAM	14/15	64.45	71.61	75.82	78.12	75.19	83.54	88.46	91.14	85.93	95.48	101.10	104.16

Table 231m—Data rate for 3 channels and 2 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6 MHz BW				7 MHz BW				8 MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
3	QPSK	1/2	18.41	20.46	21.66	22.32	21.48	23.87	25.27	26.04	24.55	27.28	28.88	29.76
4	QPSK	2/3	24.55	27.28	28.88	29.76	28.64	31.83	33.70	34.72	32.74	36.37	38.51	39.68
5	QPSK	3/4	27.62	30.69	32.50	33.48	32.22	35.80	37.91	39.06	36.83	40.92	43.33	44.64
6	QPSK	5/6	30.69	34.10	36.11	37.20	35.80	39.78	42.12	43.40	40.92	45.47	48.14	49.60
7	16-QAM	1/2	36.83	40.92	43.33	44.64	42.97	47.74	50.55	52.08	49.10	54.56	57.77	59.52
8	16-QAM	2/3	49.10	54.56	57.77	59.52	57.29	63.65	67.40	69.44	65.47	72.75	77.03	79.36
9	16-QAM	3/4	55.24	61.38	64.99	66.96	64.45	71.61	75.82	78.12	73.66	81.84	86.65	89.28
10	16-QAM	5/6	61.38	68.20	72.21	74.40	71.61	79.57	84.25	86.80	81.84	90.93	96.28	99.20
11	64-QAM	1/2	55.24	61.38	64.99	66.96	64.45	71.61	75.82	78.12	73.66	81.84	86.65	89.28
12	64-QAM	2/3	73.66	81.84	86.65	89.28	85.93	95.48	101.10	104.16	98.21	109.12	115.54	119.04
13	64-QAM	3/4	82.86	92.07	97.49	100.44	96.67	107.41	113.73	117.18	110.48	122.76	129.98	133.92
14	64-QAM	5/6	92.07	102.30	108.32	111.60	107.41	119.35	126.37	130.20	122.76	136.40	144.42	148.80
15	256-QAM	1/2	73.66	81.84	86.65	89.28	85.93	95.48	101.10	104.16	98.21	109.12	115.54	119.04
16	256-QAM	2/3	98.21	109.12	115.54	119.04	114.58	127.31	134.80	138.88	130.94	145.49	154.05	158.72
17	256-QAM	3/4	110.48	122.76	129.98	133.92	128.90	143.22	151.64	156.24	147.31	163.68	173.31	178.56
18	256-QAM	5/6	122.76	136.40	144.42	148.80	143.22	159.13	168.49	173.60	163.68	181.87	192.56	198.40
19	256-QAM	7/8	128.90	143.22	151.64	156.24	150.38	167.09	176.92	182.28	171.86	190.96	202.19	208.32
20	4D-TCM 48QAM	10/11	92.07	102.30	108.32	111.60	107.41	119.35	126.37	130.20	122.76	136.40	144.42	148.80
21	4D-TCM 192QAM	14/15	128.90	143.22	151.64	156.24	150.38	167.09	176.92	182.28	171.86	190.96	202.19	208.32

Table 231n—Data rate for 3 channels and 4 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6 MHz BW				7 MHz BW				8 MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
3	QPSK	1/2	36.83	40.92	43.33	44.64	42.97	47.74	50.55	52.08	49.10	54.56	57.77	59.52
4	QPSK	2/3	49.10	54.56	57.77	59.52	57.29	63.65	67.40	69.44	65.47	72.75	77.03	79.36
5	QPSK	3/4	55.24	61.38	64.99	66.96	64.45	71.61	75.82	78.12	73.66	81.84	86.65	89.28
6	QPSK	5/6	61.38	68.20	72.21	74.40	71.61	79.57	84.25	86.80	81.84	90.93	96.28	99.20
7	16-QAM	1/2	73.66	81.84	86.65	89.28	85.93	95.48	101.10	104.16	98.21	109.12	115.54	119.04
8	16-QAM	2/3	98.21	109.12	115.54	119.04	114.58	127.31	134.80	138.88	130.94	145.49	154.05	158.72
9	16-QAM	3/4	110.48	122.76	129.98	133.92	128.90	143.22	151.64	156.24	147.31	163.68	173.31	178.56
10	16-QAM	5/6	122.76	136.40	144.42	148.80	143.22	159.13	168.49	173.60	163.68	181.87	192.56	198.40
11	64-QAM	1/2	110.48	122.76	129.98	133.92	128.90	143.22	151.64	156.24	147.31	163.68	173.31	178.56
12	64-QAM	2/3	147.31	163.68	173.31	178.56	171.86	190.96	202.19	208.32	196.42	218.24	231.08	238.08
13	64-QAM	3/4	165.73	184.14	194.97	200.88	193.35	214.83	227.47	234.36	220.97	245.52	259.96	267.84
14	64-QAM	5/6	184.14	204.60	216.63	223.20	214.83	238.70	252.74	260.40	245.52	272.80	288.85	297.60
15	256-QAM	1/2	147.31	163.68	173.31	178.56	171.86	190.96	202.19	208.32	196.42	218.24	231.08	238.08
16	256-QAM	2/3	196.42	218.24	231.08	238.08	229.15	254.61	269.59	277.76	261.89	290.99	308.10	317.44
17	256-QAM	3/4	220.97	245.52	259.96	267.84	257.80	286.44	303.29	312.48	294.62	327.36	346.62	357.12
18	256-QAM	5/6	245.52	272.80	288.85	297.60	286.44	318.27	336.99	347.20	327.36	363.73	385.13	396.80
19	256-QAM	7/8	257.80	286.44	303.29	312.48	300.76	334.18	353.84	364.56	343.73	381.92	404.39	416.64
20	4D-TCM 48QAM	10/11	184.14	204.60	216.63	223.20	214.83	238.70	252.74	260.40	245.52	272.80	288.85	297.60
21	4D-TCM 192QAM	14/15	257.80	286.44	303.29	312.48	300.76	334.18	353.84	364.56	343.73	381.92	404.39	416.64

Table 231o—Data rate for 4 channels and 1 spatial stream

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6 MHz BW				7 MHz BW				8 MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
3	QPSK	1/2	12.28	13.64	14.44	14.88	14.32	15.91	16.85	17.36	16.37	18.19	19.26	19.84
4	QPSK	2/3	16.37	18.19	19.26	19.84	19.10	21.22	22.47	23.15	21.82	24.25	25.68	26.45
5	QPSK	3/4	18.41	20.46	21.66	22.32	21.48	23.87	25.27	26.04	24.55	27.28	28.88	29.76
6	QPSK	5/6	20.46	22.73	24.07	24.80	23.87	26.52	28.08	28.93	27.28	30.31	32.09	33.07
7	16-QAM	1/2	24.55	27.28	28.88	29.76	28.64	31.83	33.70	34.72	32.74	36.37	38.51	39.68
8	16-QAM	2/3	32.74	36.37	38.51	39.68	38.19	42.44	44.93	46.29	43.65	48.50	51.35	52.91
9	16-QAM	3/4	36.83	40.92	43.33	44.64	42.97	47.74	50.55	52.08	49.10	54.56	57.77	59.52
10	16-QAM	5/6	40.92	45.47	48.14	49.60	47.74	53.04	56.16	57.87	54.56	60.62	64.19	66.13
11	64-QAM	1/2	36.83	40.92	43.33	44.64	42.97	47.74	50.55	52.08	49.10	54.56	57.77	59.52
12	64-QAM	2/3	49.10	54.56	57.77	59.52	57.29	63.65	67.40	69.44	65.47	72.75	77.03	79.36
13	64-QAM	3/4	55.24	61.38	64.99	66.96	64.45	71.61	75.82	78.12	73.66	81.84	86.65	89.28
14	64-QAM	5/6	61.38	68.20	72.21	74.40	71.61	79.57	84.25	86.80	81.84	90.93	96.28	99.20
15	256-QAM	1/2	49.10	54.56	57.77	59.52	57.29	63.65	67.40	69.44	65.47	72.75	77.03	79.36
16	256-QAM	2/3	65.47	72.75	77.03	79.36	76.38	84.87	89.86	92.59	87.30	97.00	102.70	105.81
17	256-QAM	3/4	73.66	81.84	86.65	89.28	85.93	95.48	101.10	104.16	98.21	109.12	115.54	119.04
18	256-QAM	5/6	81.84	90.93	96.28	99.20	95.48	106.09	112.33	115.73	109.12	121.24	128.38	132.27
19	256-QAM	7/8	85.93	95.48	101.10	104.16	100.25	111.39	117.95	121.52	114.58	127.31	134.80	138.88
20	4D-TCM 48QAM	10/11	61.38	68.20	72.21	74.40	71.61	79.57	84.25	86.80	81.84	90.93	96.28	99.20
21	4D-TCM 192QAM	14/15	85.93	95.48	101.10	104.16	100.25	111.39	117.95	121.52	114.58	127.31	134.80	138.88

Table 231p—Data rate for 4 channels and 2 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6 MHz BW				7 MHz BW				8 MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
3	QPSK	1/2	24.55	27.28	28.88	29.76	28.64	31.83	33.70	34.72	32.74	36.37	38.51	39.68
4	QPSK	2/3	32.74	36.37	38.51	39.68	38.19	42.44	44.93	46.29	43.65	48.50	51.35	52.91
5	QPSK	3/4	36.83	40.92	43.33	44.64	42.97	47.74	50.55	52.08	49.10	54.56	57.77	59.52
6	QPSK	5/6	40.92	45.47	48.14	49.60	47.74	53.04	56.16	57.87	54.56	60.62	64.19	66.13
7	16-QAM	1/2	49.10	54.56	57.77	59.52	57.29	63.65	67.40	69.44	65.47	72.75	77.03	79.36
8	16-QAM	2/3	65.47	72.75	77.03	79.36	76.38	84.87	89.86	92.59	87.30	97.00	102.70	105.81
9	16-QAM	3/4	73.66	81.84	86.65	89.28	85.93	95.48	101.10	104.16	98.21	109.12	115.54	119.04
10	16-QAM	5/6	81.84	90.93	96.28	99.20	95.48	106.09	112.33	115.73	109.12	121.24	128.38	132.27
11	64-QAM	1/2	73.66	81.84	86.65	89.28	85.93	95.48	101.10	104.16	98.21	109.12	115.54	119.04
12	64-QAM	2/3	98.21	109.12	115.54	119.04	114.58	127.31	134.80	138.88	130.94	145.49	154.05	158.72
13	64-QAM	3/4	110.48	122.76	129.98	133.92	128.90	143.22	151.64	156.24	147.31	163.68	173.31	178.56
14	64-QAM	5/6	122.76	136.40	144.42	148.80	143.22	159.13	168.49	173.60	163.68	181.87	192.56	198.40
15	256-QAM	1/2	98.21	109.12	115.54	119.04	114.58	127.31	134.80	138.88	130.94	145.49	154.05	158.72
16	256-QAM	2/3	130.94	145.49	154.05	158.72	152.77	169.74	179.73	185.17	174.59	193.99	205.40	211.63
17	256-QAM	3/4	147.31	163.68	173.31	178.56	171.86	190.96	202.19	208.32	196.42	218.24	231.08	238.08
18	256-QAM	5/6	163.68	181.87	192.56	198.40	190.96	212.18	224.66	231.47	218.24	242.49	256.75	264.53
19	256-QAM	7/8	171.86	190.96	202.19	208.32	200.51	222.79	235.89	243.04	229.15	254.61	269.59	277.76
20	4D-TCM 48QAM	10/11	122.76	136.40	144.42	148.80	143.22	159.13	168.49	173.60	163.68	181.87	192.56	198.40
21	4D-TCM 192QAM	14/15	171.86	190.96	202.19	208.32	200.51	222.79	235.89	243.04	229.15	254.61	269.59	277.76

Table 231q—Data rate for 4 channels and 4 spatial streams

MODE	Modulation	Coding Rate	Data rate (Mbits/s)											
			6 MHz BW				7 MHz BW				8 MHz BW			
			1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP	1/4 CP	1/8 CP	1/16 CP	1/32 CP
3	QPSK	1/2	49.10	54.56	57.77	59.52	57.29	63.65	67.40	69.44	65.47	72.75	77.03	79.36
4	QPSK	2/3	65.47	72.75	77.03	79.36	76.38	84.87	89.86	92.59	87.30	97.00	102.70	105.81
5	QPSK	3/4	73.66	81.84	86.65	89.28	85.93	95.48	101.10	104.16	98.21	109.12	115.54	119.04
6	QPSK	5/6	81.84	90.93	96.28	99.20	95.48	106.09	112.33	115.73	109.12	121.24	128.38	132.27
7	16-QAM	1/2	98.21	109.12	115.54	119.04	114.58	127.31	134.80	138.88	130.94	145.49	154.05	158.72
8	16-QAM	2/3	130.94	145.49	154.05	158.72	152.77	169.74	179.73	185.17	174.59	193.99	205.40	211.63
9	16-QAM	3/4	147.31	163.68	173.31	178.56	171.86	190.96	202.19	208.32	196.42	218.24	231.08	238.08
10	16-QAM	5/6	163.68	181.87	192.56	198.40	190.96	212.18	224.66	231.47	218.24	242.49	256.75	264.53
11	64-QAM	1/2	147.31	163.68	173.31	178.56	171.86	190.96	202.19	208.32	196.42	218.24	231.08	238.08
12	64-QAM	2/3	196.42	218.24	231.08	238.08	229.15	254.61	269.59	277.76	261.89	290.99	308.10	317.44
13	64-QAM	3/4	220.97	245.52	259.96	267.84	257.80	286.44	303.29	312.48	294.62	327.36	346.62	357.12
14	64-QAM	5/6	245.52	272.80	288.85	297.60	286.44	318.27	336.99	347.20	327.36	363.73	385.13	396.80
15	256-QAM	1/2	196.42	218.24	231.08	238.08	229.15	254.61	269.59	277.76	261.89	290.99	308.10	317.44
16	256-QAM	2/3	261.89	290.99	308.10	317.44	305.54	339.48	359.45	370.35	349.18	387.98	410.80	423.25
17	256-QAM	3/4	294.62	327.36	346.62	357.12	343.73	381.92	404.39	416.64	392.83	436.48	462.15	476.16
18	256-QAM	5/6	327.36	363.73	385.13	396.80	381.92	424.35	449.32	462.93	436.48	484.98	513.50	529.07
19	256-QAM	7/8	343.73	381.92	404.39	416.64	401.02	445.57	471.78	486.08	458.30	509.23	539.18	555.52
20	4D-TCM 48QAM	10/11	245.52	272.80	288.85	297.60	286.44	318.27	336.99	347.20	327.36	363.73	385.13	396.80
21	4D-TCM 192QAM	14/15	343.73	381.92	404.39	416.64	401.02	445.57	471.78	486.08	458.30	509.23	539.18	555.52

9a.3 Functional block diagram applicable to the PHY

The functional block diagram of the transmitter and receiver for the PHY is shown in Figure 160n. This subclause describes the general processing of the A-WRAN baseband signal. The binary data intended for transmission is supplied to the PHY from the MAC layer. This input is sent to a channel coding processor, which includes a data scrambler, encoder, puncturer, and a bit interleaver specified in 9a.6.4. The interleaved data is mapped to data constellations as described in 9a.8 according to the modulation schemes specified as shown in Table 231e. The subcarrier allocator assigns the data constellations to the corresponding subchannels according to the subcarrier allocation methods described in 9a.6.2 and 9a.6.3.

A frame has its first OFDM symbol occupied by the frame preamble in 9a.4.1.1. The pilot subcarriers are transmitted at fixed positions in the frequency domain within each OFDM data symbol as specified in 9a.6.1. Preambles and pilots can support the synchronization, channel estimation, and tracking process. In the frequency domain, an OFDM symbol contains the data, pilot, and null subcarriers, as defined in Table 231d. The resultant stream of constellations is subsequently input to an inverse Discrete Fourier Transform after a serial-to-parallel conversion. The inverse Fast Fourier Transform (IFFT) is the expected means of performing the inverse Discrete Fourier Transform. In order to prevent inter-symbol interference eventually caused by the channel delay spread, the OFDM symbol is extended by a cyclic prefix that contains the same waveform as the corresponding ending part of the symbol. Finally, the OFDM signal is transferred to the RF transmission modules via a digital-to-analog converter.

The OFDM receiver roughly implements the same operations as performed by the transmitter but in reverse order. In addition to the data processing, synchronization and channel estimation must be performed at the receiver.

The CBP packet can also be generated through the same process as that used for the data transmission. The CBP packet subcarrier allocation, preamble, and pilot patterns are described in 9a.5.

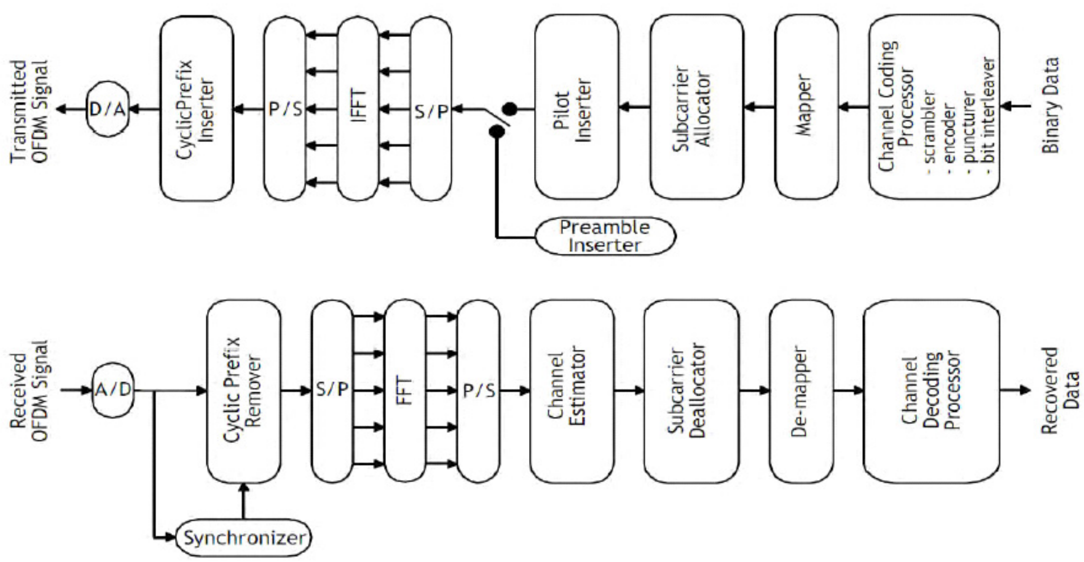


Figure 160n—Transmitter and receiver block diagram for the OFDMA PHY

9a.4 Frame structure

The basic frame structure is shown in Figure 12. See 7.4a for a full description of the frame structure.

Each frame contains a preamble, header, and data bursts.

For both normal and self-coexistence operational modes, the first symbol shall be the frame preamble. The second to fifth symbols shall contain the FCH, and DS-MAP, US-MAP, when needed, DCD and UCD, and data bursts if there is some room left. The FCH specifies the length of the first MAP that will immediately follow the FCH.

In each frame, a TTG shall be inserted between the DS and US bursts to allow the CPE to switch between the receive mode and transmit mode and to absorb the signal propagation time. An RTG shall be inserted at the end of each frame to allow the BS to switch between its receiving mode and transmit mode (see Figure 13b).

The values indicated in Table 231r for the TTG and RTG shall be used for the specified cyclic prefixes and channel bandwidth options.

Table 231r—A-WRAN frame parameters

Cyclic prefix	Number of symbols per frame[1]			Transmit-receive turnaround gap[2] (TTG)			Receive-transmit turnaround gap[3] (RTG)		
BW	6 MHz	7MH	8MHz	6 MHz	7MH	8MHz	6 MHz	7MH	8MHz
1/4	41	48	55	1185 TU	1382 TU	1579 TU	1056 TU	1232 TU	1408 TU
1/8	46	54	61	1185 TU	1382 TU	1579 TU	672 TU	592 TU	1665 TU
1/16	48	57	65	1185 TU	1382 TU	1579 TU	1504 TU	848 TU	1280 TU
1/32	50	59	67	1185 TU	1382 TU	1579 TU	960 TU	592 TU	1280 TU

NOTE 1—Indicates the DS/US payload symbols and symbols for FCH, DS/US MAP, and DCD/UCD. Here, one frame preamble symbol is assumed. Different values may apply when the frame carries more header symbols.
NOTE 2—Example of TTG set to absorb the propagation delay.
NOTE 3—Portion of symbol left over to arrive at the 10 ms frame period.

9a.4.1 Preamble

9a.4.1.1 Frame preamble and local frame preamble

The first symbol of the DS transmission is the preamble. Three different preamble carrier sets are defined, differing in the allocation of subcarriers. Those subcarriers are modulated using a boosted BPSK modulation with a specific pseudo-noise (PN) code.

The preamble carrier sets are defined using Equation (20).

$$PreambleCarrierSet_n = n + 3k \tag{20}$$

where

$PreambleCarrierSet_n$	specifies all subcarriers allocated to the specific preamble
n	is the designating number of the preamble carrier set indexed 0, 1, and 2
k	is a running index. 0...283

Each segment uses a preamble composed of a single carrier set in the following manner:

— Start position of segment 0 uses preamble carrier set 0 (n =0).
— Start position of segment 1 uses preamble carrier set 1 (n =1).
— Start position of segment 2 uses preamble carrier set 2 (n =2).

For the start position of segment 0, the DC carrier will not be modulated at all, and the appropriate PN will be discarded. Therefore, the DC carrier shall always be zeroed.

Each start position of segment eventually modulates each third subcarrier. As an example, Figure 160o depicts the preamble of start position of segment 0. In this figure, subcarrier 0 corresponds to the first subcarrier used in the preamble symbol.

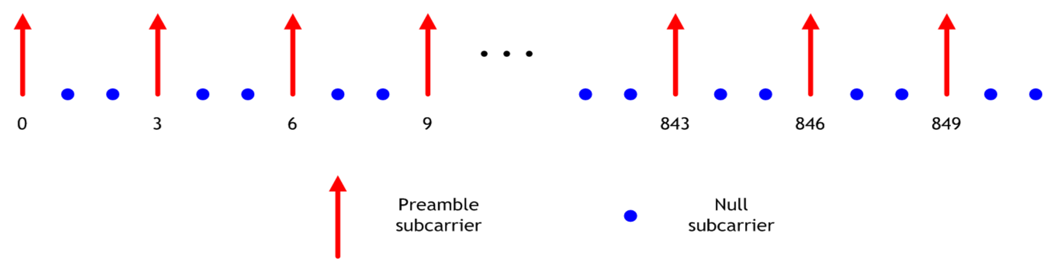


Figure 160o—Example of basic structure of preamble (for the case of n =0)

The PN series modulating the preamble carrier set is defined in Table 231s. The series modulated depends on the start position of segment and segment bandwidth used. The defined series shall be mapped onto the preamble subcarriers in ascending order. Table 231s includes the PN sequence in an hexadecimal format. The value of the PN is obtained by converting the series to a binary series (W_k) and mapping the PN starting from the MSB of each symbol to the LSB (0 mapped to +1 and 1 mapped to –1). For example, for Frame Preamble (the first row of Table 231s), W_k = 101001101111..., and the mapping shall follow: +1 –1 +1 –1 –1 +1 +1 –1 +1 +1 +1 +1....

Table 231s—Frame preamble and local frame preamble modulation series

Preamble type	Start position of segment	Segment bandwidth	Series to modulate (W_k)
Frame Preamble	—	—	0xA6F294537B285E1844677D133E4D53CCB1F182DE 00489E53E6B6E77065C7EE7D0ADBEAF
Local Frame Preamble 0	0	1 segment	0x668321CBBE7F462E6C2A07E8BBDA2C7F7946D5F 69E35AC8ACF7D64AB4A33C467001F3B2
Local Frame Preamble 1	0	2 segments	0x1C75D30B2DF72CEC9117A0BD8EAF8E0502461FC 07456AC906ADE03E9B5AB5E1D3F98C6E
Local Frame Preamble 2	0	3 segments	0x5F9A2E5CA7CC69A5227104FB1CC2262809F3B10D 0542B9BDFDA4A73A7046096DF0E8D3D
Local Frame Preamble 3	1	1 segment	0x82F8A0AB918138D84BB86224F6C342D81BC8BFE7 91CA9EB54096159D672E91C6E13032F
Local Frame Preamble 4	1	2 segments	0xEE27E59B84CCF15BB1565EF90D478CD2C49EE8A 70DE368EED7C9420B0C6FFAF9AF035FC
Local Frame Preamble 5	2	1 segment	0xC1DF5AE28D1CA6A8917BCDAF4E73BD93F931C4 4F93C3F12F0132FB643EFD5885C8B2BC

For the preamble symbol, there will be 86 guard band subcarriers on each side of the spectrum.

The symbols in the DS preamble shall be modulated according to Equation (21).

$$\operatorname{Re}\{PreambleModulated\} = 2 \cdot \sqrt{3} \cdot \left(\frac{1}{2} - W_k\right), \quad \operatorname{Im}\{PreambleModulated\} = 0 \tag{21}$$

9a.4.1.2 CBP preamble

The CBP preamble shall have a duration of 1 OFDM symbol. The PN series modulating the CBP preamble carrier set is defined in Table 231t. The series modulated depends on the start of segment and segment bandwidth used. The defined series shall be mapped onto the CBP preamble subcarriers in ascending order. Table 231t includes the PN sequence in a hexadecimal format. The value of the PN is obtained as described in 9a.4.1.1.

Table 231t—CBP preamble and local CBP preamble modulation series

Preamble type	Start position of segment	Segment bandwidth	Series to modulate (W_k)
CBP Preamble	—	—	0x61AF26BD39A9FFF52826625E04ADA299385A373F A946D837D754E6CFEBB26F5C03B87CF
Local CBP Preamble 0	0	1 segment	0xD77D97CDB93DBEAA65CAFA146F40D72B5E8094 4F750E07325DC164ED60F32434BC7187D
Local CBP Preamble 1	0	2 segments	0x4529D9CA65AF49C1C39BDC18CFAB87E03FE4DA FC0A48FF1457D46B0DF66B414A23ACDDB
Local CBP Preamble 2	0	3 segments	0x33AC0261DAA57C1D611EBA1C730D50AFEE5BE3 E849030A4E891BC8C5F4C78DCDDFEA263
Local CBP Preamble 3	1	1 segment	0xBED48C704F02A84F03BCD299D919DA56F7B71ED F8A0F8A25E8F8496F95A44CE2B9F74C9
Local CBP Preamble 4	1	2 segments	0x0ECCBE0902EBF4B4C29506014A3706622784B7B2 D5153E10AD3112DC5E45277A32E79DE
Local CBP Preamble 5	2	1 segment	0x7CB4937889C7DFD9AA2D37235E06F993D3D4F5D 515B39CA652F62397C08457D66BC5A36

9a.4.2 Control header and MAP definitions

9a.4.2.1 Frame control header (FCH)

The frame control header is transmitted as part of the DS PDU in the DS subframe. The length of the FCH shall be 3 bytes and contain information as specified in Table 2a. The FCH shall be sent in the first subchannel of the symbol immediately following the frame preamble symbol. The FCH shall be encoded using QPSK rate 1/2 with four repetitions using the binary convolutional channel coding (i.e., the FCH information shall be sent on four subchannels with successive logical subchannel numbers). The FCH contains the DS frame prefix as described in 7.5.2a and specifies the length of the DS-MAP message that immediately follows the DS frame prefix and the repetition coding used for the DS-MAP message.

9a.4.2.2 DS-MAP, US-MAP, DCD, and UCD

The length of the DS-MAP PDU is variable and is defined in the FCH (9a.4.2.1). This PDU shall be encoded using the binary convolutional channel coding specified in 9a.7.2.1 and transmitted using the PHY Mode 3 listed in Table 231e in the logical subchannel immediately following the FCH. The length of the US-MAP, DCD, and UCD, when present, shall be specified at the beginning of the DS-MAP in that order. The number of subchannels required to transmit these fields shall be determined by their respective lengths in number of OFDM slots. These fields shall be transmitted using PHY Mode 4. If this number exceeds the number of subchannels, the transmission of these PDUs will continue in the next slot starting with the first logical subchannel. The unused subchannels in the last slot of the frame header shall be used for DS transmissions.

9a.5 CBP packet format

The format of the CBP packet is shown in Figure 160p. The CBP packet consists of a preamble portion and a data portion. The CBP preamble is one OFDM symbol in duration and is generated as described in 9a.4.1.2. The format of the CBP data portion is the same as the data portion of the normal zone.

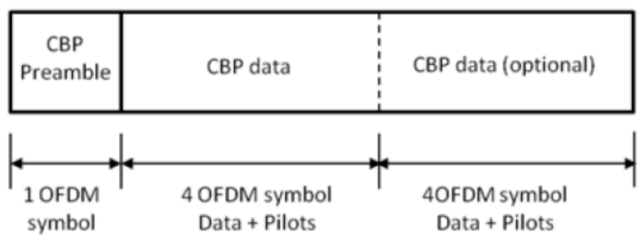


Figure 160p—CBP packet format

9a.6 OFDM subcarrier allocation

Sampling frequencies are F_s =5.6 MHz, 6.53 MHz, and 7.47 MHz for the channel bandwidth of 6 MHz, 7 MHz, and 8 MHz, respectively. Subtracting the guard subcarriers from N_{FFT} (=1024), one obtains the set of used subcarriers which consists of both pilot subcarriers and data subcarriers. In the DS, the pilot subcarriers are allocated first; then data subcarriers are divided into subchannels. In the US, the set of used subcarriers is first partitioned into subchannels, and then the pilot subcarriers are allocated from within each subchannel.

9a.6.1 Pilot pattern

9a.6.1.1 Downstream (DS)

A slot (or a subchannel) in the DS is composed of 4 OFDMA symbols and 16 subcarriers as shown in Figure 160h. Within each slot, there are 48 data subcarriers and 16 fixed-position pilots. The subchannel is constructed from four DS tiles. Each tile has four successive active subcarriers, and its configuration is illustrated in Figure 160q.

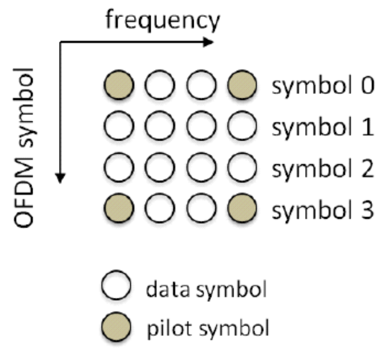


Figure 160q—Pilot pattern for DS

9a.6.1.2 Upstream (US)

A slot (or a subchannel) in the US is composed of 7 OFDMA symbols and 8 subcarriers as shown in Figure 160i. Within each slot, there are 48 data subcarriers and 8 fixed-position pilots. The subchannel is constructed from two US tiles. Each tile has four successive active subcarriers, and its configuration is illustrated in Figure 160r.

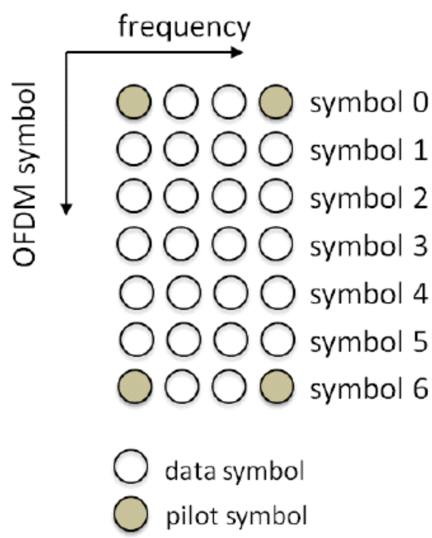


Figure 160r—Pilot pattern for US

9a.6.2 DS subcarrier allocation

9a.6.2.1 Symbol structure for subchannel in the DS

The symbol structure is constructed using pilot, data, and null subcarriers. The symbol is first divided into basic tiles and null carriers are allocated. Pilot and data subcarriers are allocated within each tile. Table 231u summarizes the parameters of the symbol structure in the downstream (DS).

Table 231u—Symbol structure parameters in the downstream (DS)

Parameters	Value	Comments
FFT size	1024	
Number of DC subcarriers	1	Index 512 (counting from 0)
Number of Guard subcarriers, Left	96	—
Number of Guard subcarriers, Right	95	—
Number of used subcarriers (N_{used})	833	Number of total subcarriers including DC, data and pilot
Number of subchannels ($N_{subchannels}$)	52	—
Number of tiles (N_{tiles})	208	—
Number of tiles per subchannel (or slot)	4	—
Number of pilot subcarriers per slot	16	—
Number of data subcarriers per slot	48	—
Number of OFDM symbols per slot	4	—
Number of subcarriers per tile	4	—
Sequence for DS tile permutation (P_t)	6, 48, 37, 21, 31, 40, 42, 32, 47, 30, 33, 18, 10, 15, 50, 51, 46, 23, 45, 16, 39, 35, 7, 25, 11, 22, 38, 28, 19, 17, 3, 27, 12, 29, 26, 5, 41, 49, 44, 9, 8, 1, 13, 36, 14, 43, 2, 20, 24, 4,34, 0	Used to allocate tiles to subchannel

9a.6.2.2 Subcarrier allocation and data mapping onto subcarriers

The carrier allocation to subchannels is performed using the following procedure:

a) Subcarriers shall be divided into the number of tiles (N_{tiles}) containing 4 adjacent subcarriers each (starting from carrier 0). The number of tiles (N_{tiles}) in the DS is 208.

b) Logical tiles are mapped to physical tiles in the FFT using Equation (22).

$$Tiles(s, n) = N_{subchannels} \bullet n + (P_t[(s+n) \bmod N_{subchannels}] + \text{DS\_PermBase}) \bmod N_{subchannels} \quad (22)$$

where

$Tiles(s, n)$ is the physical tile index in the FFT with tiles being ordered consecutively from the most negative to the most positive used subcarrier (0 is the starting tile index)
n is the tile index 0,1,2,3 in a subchannel
$N_{subchannels}$ is the number of subchannels: 52

s	is the index number of a subchannel:0… $N_{subchannels}$–1
P_t	is the sequence for the DS tile permutation shown below DS_PermBase is an integer ranging from 0 to 31, which is set to preamble-Cell ID in the first zone

P_t= {6, 48, 37, 21, 31, 40, 42, 32, 47, 30, 33, 18, 10, 15, 50, 51, 46, 23, 45, 16, 39, 35, 7, 25, 11, 22, 38, 28, 19, 17, 3, 27, 12, 29, 26, 5, 41, 49, 44, 9, 8, 1, 13, 36, 14, 43, 2, 20, 24, 4,34, 0}

DS_PermBase is an integer ranging from 0 to 31, which is set to preamble Cell ID in the first zone.

Example of the logical tile mapping to the physical tile is provided below to clarify the operation of Equation 9.X.6.3.2-1. In this example, tiles used for subchannel s = 2 in DS_PermBase = 1 are computed.

— Apply the permutation due to the selection of the subchannel (s = 2), rotate times: {37, 21, 31, 40, 42, 32, 47, 30, 33, 18, 10, 15, 50, 51, 46, 23, 45, 16, 39, 35, 7, 25, 11, 22, 38, 28, 19, 17, 3, 27, 12, 29, 26, 5, 41, 49, 44, 9, 8, 1, 13, 36, 14, 43, 2, 20, 24, 4,34, 0, 6, 48 }.

— Take the first 4 numbers, and add the DS_PermBase (perform modulo operation if needed): {38, 22, 32, 41}.

— Finally, add the appropriate shift: {38, 74, 136, 197}.

c) After allocating the pilot subcarriers within each tile, indexing of the data subcarriers within each slot is performed starting from the first symbol at the lowest indexed subcarrier of the lowest indexed tile, continuing in an ascending manner through the subcarriers in the same symbol, then going to the next symbol at the lowest indexed data subcarrier, and so on. Data subcarriers shall be indexed from 0 to 47. The indexing of the data subcarriers (48 data subcarriers) in one subchannel in DS is shown in Figure 160s.

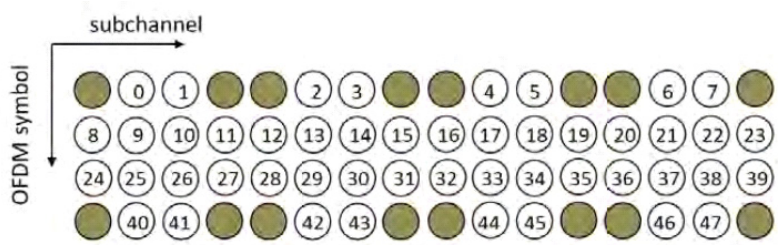


Figure 160s—DS data subcarrier index in one subchannel

d) The mapping of data onto the subcarriers shall follow Equation (23). This equation calculates the subcarrier index to which the data constellation point is to be mapped.

$$Subcarrier(n, s) = (n + 13 \bullet s) \; mod \; N_{subcarriers} \quad (23)$$

where

$Subcarrier(n, s)$	is the permutated subcarrier index corresponding to data subcarrier.
n	is a running index 0…47, indicating the data constellation point
s	is the subchannel number 0…51
$N_{subcarriers}$	is the number of data subcarriers per slot: 48

9a.6.3 Upstream subcarrier allocation

9a.6.3.1 Symbol structure for subchannel in the upstream

The symbol structure is constructed using pilot, data, and null subcarriers. The symbol is first divided into basic tiles and null carriers are allocated. Pilot and data subcarriers are allocated within each tile. Table 231v summarizes the parameters of the symbol structure in the upstream (US).

Table 231v—Symbol structure parameters in the upstream (US)

Parameters	Value	Comments
Number of DC subcarriers	1	Index 512 (counting from 0)
Number of Guard subcarriers, Left	92	—
Number of Guard subcarriers, Right	91	—
Number of used subcarriers (N_{used})	841	Number of all subcarriers including DC, data and pilots used within a symbol
Number of subchannels ($N_{subchannels}$)	105	—
Number of tiles (N_{tiles})	210	—
Number of tiles per subchannel	2	—
Number of pilot subcarriers per slot	8	—
Number of data subcarriers per slot	48	—
Number of OFDM symbols per slot	7	—
Number of subcarriers per tile	4	—
Sequence for US tile permutation (P_t)	33, 52, 35, 67, 94, 13, 80, 6, 34, 45, 43, 68, 84, 66, 7, 37, 71, 89, 55, 101, 27, 60, 51, 14, 21, 17, 93, 72, 95, 73, 81, 24, 103, 86, 39, 29, 56, 62, 70, 64, 23, 22, 54, 15, 90, 76, 100, 33, 36, 18, 9, 91, 19, 26, 12, 92, 48, 25, 87, 74, 5, 31, 85, 40, 104, 2, 102, 69, 57, 50, 1, 44, 0, 20, 88, 79, 16, 28, 46, 42, 41, 59, 96, 97, 99, 82, 30, 49, 65, 77, 63, 11, 8, 75, 98, 38, 32, 83, 4, 47, 58, 61, 78, 10, 53	Used to allocate tiles to subchannel

9a.6.3.2 Subcarrier allocation and data mapping onto subcarriers

The carrier allocation to subchannels is performed using the following procedure:

a) The usable subcarriers in the allocated frequency band shall be divided into N_{tiles} physical tiles with parameters specified by Table 231v. The number of tiles (N_{tiles}) in the US is 210.

b) Logical tiles are mapped to physical tiles in the FFT using Equation (24).

$$Tiles(s, n) = N_{subchannels} \bullet n + (P_t[(s+n) \ mod \ N_{subchannels}] + \text{US\_PermBase}) \ mod \ N_{subchannels} \quad (24)$$

where

$Tiles(s, n)$	is the physical tile index in the FFT with tiles being ordered consecutively from the most negative to the most positive used subcarrier (0 is the starting tile index)
n	is the tile index 0,1 in a subchannel
$N_{subchannels}$	is the number of subchannels: 105
s	is the index number of a subchannel: $0 \ldots N_{subchannels}-1$
P_t	is the sequence for the US tile permutation shown below

P_t= {33, 52, 35, 67, 94, 13, 80, 6, 34, 45, 43, 68, 84, 66, 7, 37, 71, 89, 55, 101, 27, 60, 51, 14, 21, 17, 93, 72, 95, 73, 81, 24, 103, 86, 39, 29, 56, 62, 70, 64, 23, 22, 54, 15, 90, 76, 100, 33, 36, 18, 9, 91, 19, 26, 12, 92, 48, 25, 87, 74, 5, 31, 85, 40, 104, 2, 102, 69, 57, 50, 1, 44, 0, 20, 88, 79, 16, 28, 46, 42, 41, 59, 96, 97, 99, 82, 30, 49, 65, 77, 63, 11, 8, 75, 98, 38, 32, 83, 4, 47, 58, 61, 78, 10, 53}

US_PermBase is an integer value which is assigned by a management entity

Example of the logical tile mapping to the physical tile is provided below to clarify the operation of Equation 9.X.6.3.2-1. In this example, tiles used for subchannel $s = 3$ in US_PermBase = 2 are computed.

— Apply the permutation due to the selection of the subchannel (s = 3), rotate three times: {67, 94, 13, 80, 6, 34, 45, 43, 68, 84, 66, 7, 37, 71, 89, 55, 101, 27, 60, 51, 14, 21, 17, 93, 72, 95, 73, 81, 24, 103, 86, 39, 29, 56, 62, 70, 64, 23, 22, 54, 15, 90, 76, 100, 33, 36, 18, 9, 91, 19, 26, 12, 92, 48, 25, 87, 74, 5, 31, 85, 40, 104, 2, 102, 69, 57, 50, 1, 44, 0, 20, 88, 79, 16, 28, 46, 42, 41, 59, 96, 97, 99, 82, 30, 49, 65, 77, 63, 11, 8, 75, 98, 38, 32, 83, 4, 47, 58, 61, 78,10, 53, 33, 52, 35}.

— Take the first 2 numbers, and add the US_PermBase (perform modulo operation if needed): {69, 96}.

— Finally, add the appropriate shift: {69, 201}.

c) After allocating the pilot subcarriers within each tile, indexing of the data subcarriers within each slot is performed starting from the first symbol at the lowest indexed subcarrier of the lowest indexed tile, continuing in an ascending manner through the subcarriers in the same symbol, then going to the next symbol at the lowest indexed data subcarrier, and so on. Data subcarriers shall be indexed from 0 to 47. The indexing of the data subcarrier (48 data subcarriers) in one subchannel in US is shown in Figure 160t.

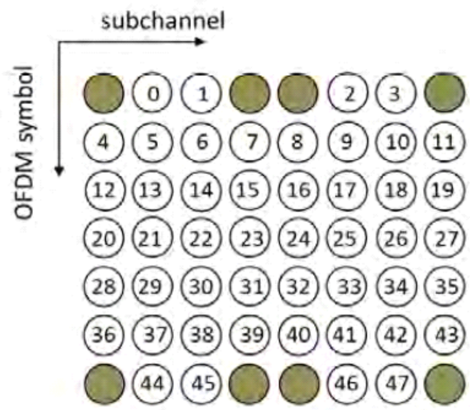


Figure 160t—US data subcarrier index in one subchannel

d) The mapping of data onto the subcarriers shall follow Equation (25). This equation calculates the subcarrier index to which the data constellation point is to be mapped.

$$Subcarrier(n, s) = (n + 13 \cdot s) \bmod N_{subcarriers} \quad (25)$$

where

$Subcarrier(n, s)$	is the permutated subcarrier index corresponding to data subcarrier.
n	is a running index 0…47, indicating the data constellation point
s	is the subchannel number 0…104
$N_{subcarriers}$	is the number of data subcarriers per slot: 48

For example, for subchannel 1 (s = 1), the first data constellation point (n = 0) is mapped onto *Subcarrier* (0,1) = 13 shown in Figure 160u, where 13 is the subcarrier with index 13 according to step a) in this subclause. Considering the US tile structure (4 subcarriers by 7 OFDM symbols), it can be seen that this is the second indexed subcarrier on the third symbol within the slot.

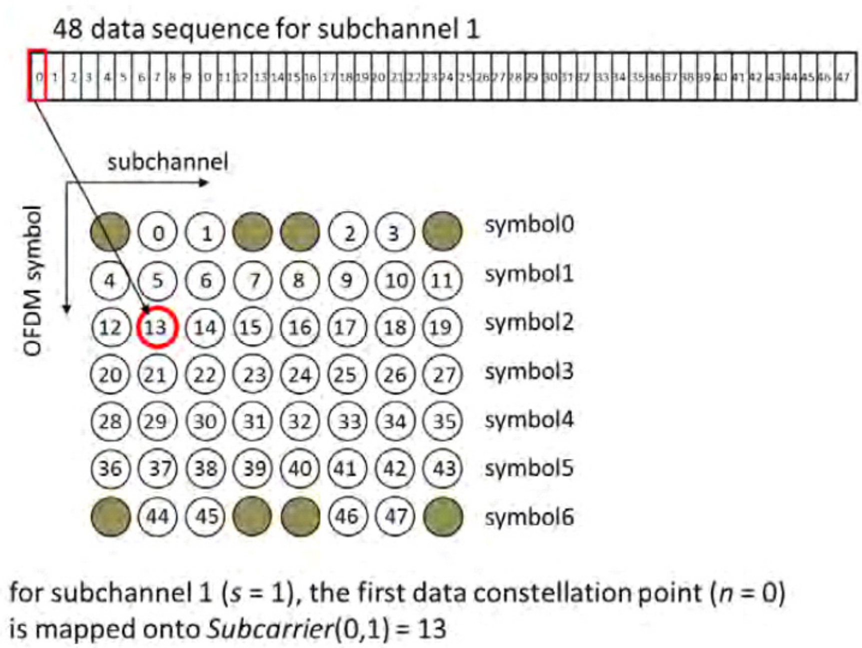


Figure 160u—Example of data mapping onto subcarrier (*s*=1, *n*=0)

Similarly, for subchannel 3, the ninth data constellation point (n = 8) is mapped onto *Subcarrier* (8, 3) =47 shown in Figure 160v. According to step a), this is the last indexed subcarrier of the seventh symbol within the slot.

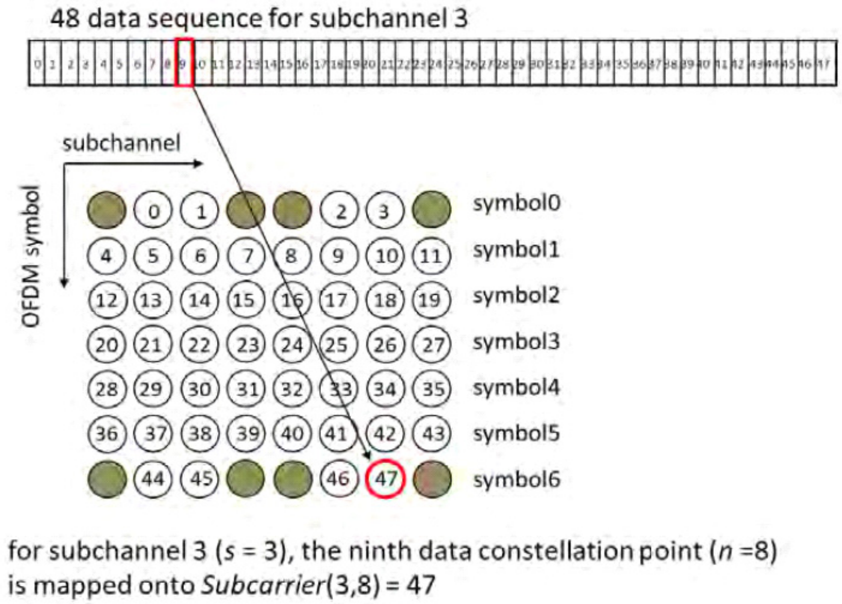


Figure 160v—Example of data mapping onto subcarrier (*s*=3, *n*=8)

9a.6.3.3 Data subchannel rotation scheme

In the US, a rotation scheme shall be applied per OFDMA slot duration. On each slot duration, the rotation scheme shall be applied to all US subchannels that belong to the normal data burst. The rotation scheme is defined by applying the following rules:

a) Per OFDMA slot duration, pick the subchannels that are used for the normal data burst. Renumber these subchannels contiguously so that the lowest numbered physical subchannel is renumbered with 0. The total number of subchannels picked shall be designated N_{subchn}.

b) The mapping function defined by rule a) shall define a function, f, so that temp1_subchannel_number = f (old_subchannel_number).

c) Mark the first US OFDMA slot duration with the slot index S_{idx} = 0. Increase S_{idx} by 1 in every slot duration so that subsequent slots are numbered 1, 2, 3..., etc.

d) Apply the following formula:

$$\text{temp2\_subchannel\_number} = (\text{temp1\_subchannel\_number} + 13 \times \boldsymbol{S}_{\mathbf{idx}}) \bmod \boldsymbol{N}_{\mathbf{subchn}}$$

e) To get the new subchannel number, apply the following formula:

new_subchannel_number = f^{-1}(temp2_subchannel_number), where f^{-1} (.) is the inverse mapping of the mapping defined in rule b).

f) For subchannels that are used for control burst (for the UIUC value less than 14), new_subchannel_number = old_subchannel_number.

g) The new_subchannel_number shall replace the old_subchannel_number in each allocation defined by 9a.1.3.2 data mapping where the new_subchannel_number is the output of the rotation scheme and the old_subchannel_number is the input of the rotation scheme.

9a.6.4 Bit interleaving

All encoded data bits shall be interleaved by a block interleaver with a block size corresponding to the number of coded bits per the encoded block size N_{cbps}. (Possible values of N_{cbps} for each MCS are specified later.) The interleaver is defined by a two-step permutation. The first ensures that adjacent coded bits are mapped onto nonadjacent subcarriers. The second permutation insures that adjacent coded bits are mapped alternately onto less or more significant bits of the constellation, thus avoiding long runs of lowly reliable bits.

Let N_{cpc} be the number of coded bits per subcarrier, i.e., 2, 4, or 6 for QPSK, 16-QAM, or 64-QAM, respectively. Let $s = N_{cpc}/2$. Within a block of N_{cbps} bits at transmission, let k be the index of the coded bit before the first permutation, m_k be the index of that coded bit after the first and before the second permutation and let j_k be the index after the second permutation, just prior to modulation mapping, and d be the modulo used for the permutation.

The first permutation is defined by Equation (26):

$$m_k = (N_{cbps}/d) \bullet k_{mod(d)} + floor(k/d) \quad k = 0, 1, \ldots, N_{cbps} - 1 \quad d = 16 \tag{26}$$

The second permutation is defined by Equation (27).

$$j_k = s \bullet floor(m_k / s) + (m_k + N_{cbps} - floor(d \bullet m_k / N_{cbps}))_{mod(s)} \quad k = 0, 1, \ldots, N_{cbps} - 1 \quad d = 16 \tag{27}$$

The de-interleaver, which performs the inverse operation, is also defined by two permutations. Within a received block of N_{cbps} bits, let j be the index of a received bit before the first permutation; m_j be the index of that bit after the first and before the second permutation; and let k_j be the index of that bit after the second permutation, just prior to delivering the block to the decoder.

The first permutation is defined by Equation (28).

$$m_j = s \bullet floor(j/s) + (j + floor(d \bullet j/ N_{cbps}))_{mod(s)} \quad j = 0, 1, \ldots, N_{cbps} - 1 \quad d = 16 \tag{28}$$

The second permutation is defined by Equation (29).

$$k_j = d \bullet m_j - (N_{cbps} - 1) \bullet floor(d \bullet m_j / N_{cbps}) \quad j = 0, 1, \ldots, N_{cbps} - 1 \quad d = 16 \tag{29}$$

The first permutation in the de-interleaver is the inverse of the second permutation in the interleaver, and conversely.

9a.7 Channel coding

9a.7.1 Data scrambling

The data scrambling of PHY-OM1 (9.7.1) is used for PHY-OM2.

9a.7.2 Forward error correction (FEC)

The BCC mode is mandatory (9a.7.2.1), and there is another optional mode (9a.7.2.2).

9a.7.2.1 BCC mode (mandatory)

9a.7.2.1.1 Binary convolutional coding

The BCC mode of PHY-OM1 (9.7.2.1.1) is used for PHY-OM2.

9a.7.2.1.2 Puncturing

The puncturing procedure of PHY-OM1 (9.7.2.1.2) is used for PHY-OM2.

9a.7.2.1.3 OFDM slot concatenation

The encoding block size shall depend on the number of OFDM slots allocated and the modulation specified for the current transmission. Concatenation of a number of OFDM slots shall be performed in order to allow for transmission of larger blocks of coding where it is possible, with the limitation of not exceeding the largest block size for the corresponding modulation and coding. Table 231w specifies the concatenation index for different modulations and coding.

Table 231w—Concatenation index for different modulations and coding

Modulation and rate	j
QPSK 1/2	6
QPSK 2/3	4
QPSK 3/4	4
QPSK 5/6	2
16-QAM 1/2	3
16-QAM 2/3	2
16-QAM 3/4	2
16-QAM 5/6	1
64-QAM 1/2	2
64-QAM 2/3	1
64-QAM 3/4	1
64-QAM 5/6	1
256-QAM 1/2	1
256-QAM 2/3	1
256-QAM 3/4	1
256-QAM 5/6	1
256-QAM 7/8	1
4D-TCM 48QAM 10/11	1
4D-TCM 192QAM 14/15	1

For any modulation and coding, the following parameters are defined:

— j : index dependent on the modulation level and FEC rate
— n : number of allocated OFDM slots
— k : floor (n / j)
— m : n mod j

Table 231x shows the rules used for OFDM slot concatenation.

Table 231x—OFDM slot concatenation rule

Number of slots	Slots concatenated
$n \leq j$	1 block of n slots

$n > j$	If (n mod j = 0) k blocks of j slots
	else
	(k – 1) blocks of j slots
	1 block of ceil ((m + 1) / 2) slots
	1 block of floor ((m + j) / 2) slots

Table 231y defines the basic sizes of the useful data payloads (in bytes) to be encoded in relation with the selected modulation type, encoding rate (**R** in table), and concatenation rule.

Table 231y—Useful data payload (in bytes) for an FEC block

QPSK				16-QAM				64-QAM				256-QAM					4D-TCM	
R= 1/2	R= 2/3	R= 3/4	R= 5/6	R= 1/2	R= 2/3	R= 3/4	R= 5/6	R= 1/2	R= 2/3	R= 3/4	R= 5/6	R= 1/2	R= 2/3	R= 3/4	R= 5/6	R= 7/8	R= 10/11	R= 14/15
6																		
	8																	
		9																
			10															
12				12														
	16				16													
18		18				18		18										
			20				20											
24	24			24					24			24						
		27								27								
30											30						30	
	32				32								32					

Table 231y—Useful data payload (in bytes) for an FEC block *(continued)*

QPSK				16-QAM				64-QAM				256-QAM					4D-TCM	
R= 1/2	R= 2/3	R= 3/4	R= 5/6	R= 1/2	R= 2/3	R= 3/4	R= 5/6	R= 1/2	R= 2/3	R= 3/4	R= 5/6	R= 1/2	R= 2/3	R= 3/4	R= 5/6	R= 7/8	R= 10/11	R= 14/15
36		36		36		36		36						36				
															40			
																42		42

9a.7.2.2 Multidimensional trellis coded modulation (MD-TCM) mode (optional)

The MD-TCM for PHY-OM1 (9.7.2.5) is used for PHY-OM2.

9a.8 Constellation mapping and modulation

9a.8.1 Data modulation

The data modulation procedures for PHY-OM1 (9.8, except for the information in Table 227) are used for PHY-OM2. See Table 231z for the number of coded bits per slot (NCBPS) and the number of data bits per slot for the different modulation constellation and coding rate combinations for PHY-OM2.

Table 231z—Number of coded bits per OFDM slot (N_{CBPS}) and corresponding number of data bits for different modulation constellation and coding rate combinations

Constellation type	Coding rate	N_{CBPS}	Corresponding number of data bits
QPSK	1/2	96	48
QPSK	2/3	96	64
QPSK	3/4	96	72
QPSK	5/6	96	80
16-QAM	1/2	192	96
16-QAM	2/3	192	128
16-QAM	3/4	192	144
16-QAM	5/6	192	160
64-QAM	1/2	288	144
64-QAM	2/3	288	192
64-QAM	3/4	288	216
64-QAM	5/6	288	240
256-QAM	1/2	384	192
256-QAM	2/3	384	256

Table 231z—Number of coded bits per OFDM slot (N_{CBPS}) and corresponding number of data bits for different modulation constellation and coding rate combinations *(continued)*

Constellation type	Coding rate	N_{CBPS}	Corresponding number of data bits
256-QAM	3/4	384	288
256-QAM	5/6	384	320
256-QAM	7/8	384	336
4D-TCM 48QAM	10/11 for 4D symbol	264	240
4D-TCM 192QAM	14/15 for 4D symbol	360	336

9a.8.2 Pilot modulation

The pilot modulation procedures for PHY-OM1 (9.8.2) are used for PHY-OM2.

9a.9 Control mechanisms

9a.9.1 DS synchronization

The DS synchronization procedures for PHY-OM1 (9.9.1) are used for PHY-OM2. A DS synchronization process shall be performed by each CPE. All the CPEs shall be synchronized with the BS, the A-BS, or a distributed scheduling A-CPE.

9a.9.2 US synchronization

US synchronization shall be achieved through initial ranging and periodic ranging processes. The initial ranging transmission burst is specified 9a.9.3.1.2. The periodic ranging transmission burst is specified in 9a.9.3.1.3. US synchronization shall ensure that all US transmissions are received at the BS with which the CPEs are associated within ± 25% of the shortest cyclic prefix as given in Table 231a, i.e., ± 1.429 ms or ± 8 sampling periods.

9a.9.3 Opportunistic US bursts

A ranging channel is composed of one or more groups of six adjacent subchannels, using the symbol structure defined in 9a.6.3.1, where the groups are defined starting from the first subchannel. Subchannels are considered adjacent if they have successive logical subchannel numbers. The indices of the subchannels that compose the ranging channel are specified in the US-MAP message. BS shall allocate ranging, bandwidth (BW) request or UCS notification allocation as a multiple of subchannels.

9a.9.3.1 CDMA bursts

The number of subchannels for the ranging channel and the number of symbols for each transmission (CDMA initial ranging, CDMA periodic ranging, CDMA BW request, and CDMA UCS notification) are specified in the US-MAP_IE.

CPEs are allowed to collide on the ranging channel. To still provide reliable transmission, each CPE randomly chooses one ranging code from the subgroup of specified binary codes that is defined in 9a.9.3.1.1. These codes are then BPSK modulated onto the subcarriers in the ranging channel. The length of these binary codes is the same as the number of subcarriers in the ranging channel.

9a.9.3.1.1 CDMA codes

The binary codes shall be the pseudo-noise codes produced by the PRBS generator described in Figure 160w, which illustrates the following polynomial generator: $1+ x^1 + x^4 + x^7 + x^{15}$. The PRBS generator shall be initialized by the seed b15...b1 = 0,0,1,0,1,0,1,1,s0,s1,s2,s3,s4,s5,s6 where s6 is the LSB of the PRBS seed, and s6:s0=US_PermBase, where s6 is the MSB of the US_PermBase.

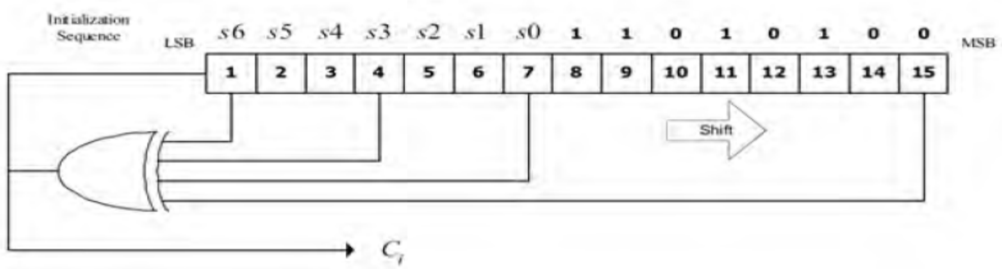


Figure 160w—PRBS generator for ranging code generation

The binary ranging codes shall be subsequences of the pseudo-noise sequence appearing at its output Ci. The length of each ranging code is 144 bits. These bits are used to modulate the subcarriers in a group of six adjacent subchannels. The bits are mapped to the subcarriers in increasing frequency order of the logical subcarriers, such that the lowest indexed bit modulates the subcarrier with the lowest subcarrier index and the highest indexed bit modulates the subcarrier with the highest index. The index of the lowest numbered subchannel in the six shall be an integer multiple of six.

For example, the first 144 bit obtained by clocking the PN generator as specified and by setting US_PermBase = 0, the first code shall be 00110000010001... The next ranging code is produced by taking the output of the 145th to 288th clock of the PRBS generator, etc.

The number of available codes is 256, numbered 0...255. Each BS uses a subset of these codes, where the subgroup is defined by a number S, 0<S<255. The group of codes shall be between S and (S+O+N+M+L) mod 256:

— The first N codes produced are for initial ranging. Clock the PRBS generator 144 × (S mod 256) times to 144 × ((S + N) mod 256) – 1 times.
— The next M codes produced are for periodic ranging. Clock the PRBS generator 144 × ((N + S) mod 256) times to 144 × ((N + M + S) mod 256) – 1 times.
— The next L codes produced are for BW request. Clock the PRBS generator 144 × ((N + M + S) mod 256) times to 144 × ((N + M + L + S) mod 256) – 1 times.
— The next O codes produced are for UCS notification. Clock the PRBS generator 144 × ((N + M + L + S) mod 256) times to 144 × ((N + M + L + O + S) mod 256) – 1 times.

The BS shall separate colliding codes and extract timing (ranging) and power information by using a correlation function. The time (ranging) and power measurements shall be used by the system to compensate for the various BS-CPE-BS propagation distances. In the process of CPE code detection, the BS will also get the Channel Impulse Response (CIR) for the transmission link from the specific CPE. The precise timing offset shall be estimated by terrestrial ranging (see 10.5.2).

9a.9.3.1.2 Initial-ranging transmission

The initial ranging transmission shall be used by all CPEs to synchronize to the system when attempting to associate. The initial ranging transmission will be used for detecting and adjusting the timing offset and adjusting the transmission EIRP level. The initial-ranging transmission is performed using two or four consecutive symbols starting, as indicated in the US-MAP for the CPE, on the first symbol after the TTG.

These symbols shall be generated according to Equation (30), except that $0 \leq t \leq 2T_s$. A time domain illustration used for the initial-ranging transmission is shown in Figure 160x.

$$s(t) = \mathrm{Re}\left\{ e^{j2\pi f_c t} \sum_{k=-\frac{N_{used}-1}{2}, k \neq 0}^{\frac{N_{used}-1}{2}} c_k \cdot e^{j2\pi k \Delta f (t-T_g)} \right\} \tag{30}$$

where

t	is the time, elapsed since the beginning of the subject OFDMA symbol
c_k	is a complex number; the data to be transmitted on the subcarrier whose frequency offset index is k, during the subject OFDMA symbol. It specifies a point in a QAM constellation
T_g	is the guard time
T_s	is the OFDMA symbol duration, including guard time
Δf	is the subcarrier frequency spacing

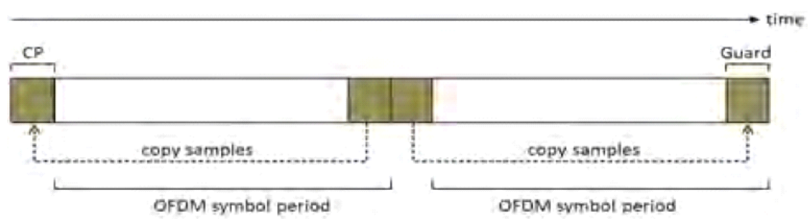


Figure 160x—Initial-ranging transmission

The BS can allocate two consecutive initial ranging slots; onto those slots, the CPE shall transmit the two consecutive initial ranging codes (starting code shall always be a multiple of 2), as illustrated in Figure 160y.

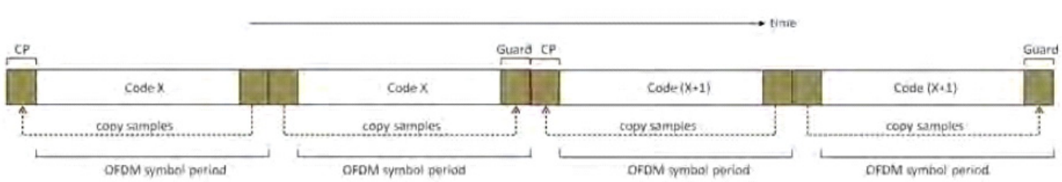


Figure 160y—Initial-ranging transmission, using two consecutive initial ranging codes

9a.9.3.1.3 CDMA periodic-ranging, BW-request, and UCS notification transmission

Periodic-ranging transmissions shall be sent periodically by CPEs identified by the BS for system periodic ranging. Bandwidth-request transmissions shall be for requesting US allocations from the BS. UCS notification transmissions shall be used for reporting detection of an incumbent. These transmissions shall be sent only by CPEs that have already associated with the base station. To perform periodic-ranging, bandwidth-request or UCS notification transmission, the CPE can send a transmission in one of the following manners:

a) Modulate one ranging code on the ranging subchannel for a period of one OFDM symbol. Ranging subchannels shall be dynamically allocated by the MAC layer at the BS and indicated by the number of subchannels in the US-MAP_IE. A time domain illustration of the periodic-ranging, bandwidth-request or UCS notification transmission is shown in Figure 160z.

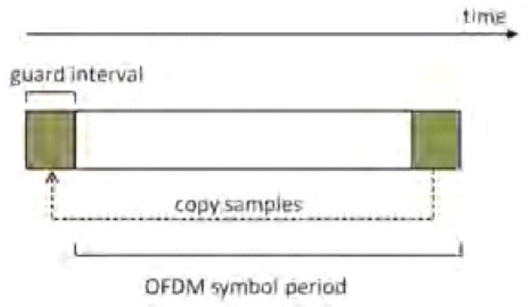


Figure 160z—Periodic-ranging/Bandwidth-request/UCS notification transmission using one code

b) Modulate three consecutive ranging codes (starting code shall always be a multiple of three) on the ranging subchannel for a period of three OFDMA symbols (one code per symbol). Ranging subchannels are dynamically allocated by the MAC and indicated in the US-MAP. A time domain illustration of the periodic ranging, BW request, or UCS notification transmission is shown in Figure 160aa.

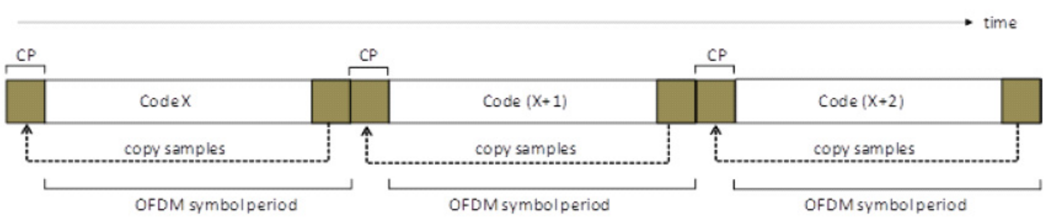


Figure 160aa—Periodic-ranging/Bandwidth-request/UCS notification transmission using three consecutive codes

9a.9.3.1.4 Ranging, BW request, and UCS notification opportunity windows

For CDMA ranging, BW request, and UCS notification transmission, the ranging opportunity size is the number of symbols required to transmit the appropriate ranging/BW-request/UCS notification code (1, 2, 3, or 4 symbols) and is denoted N1. N2 denotes the number of subchannels required to transmit a ranging code. In each allocation of ranging/BW-request/UCS notification, the opportunity size (N1) is fixed and conveyed by the corresponding US-MAP IE that defines the allocation.

The ranging allocation is subdivided into slots of N1 OFDMA symbols by N2 subchannels, in a time first order, i.e., the first opportunity begins on the first symbol of the first subchannel of the ranging allocation, the next opportunities appear in ascending order in the same subchannel, until the end of the ranging/BW-request/UCS notification (or until there are less than N1 symbols in the current subchannel), and then the number of subchannel is incremented by N2. The ranging allocation is not required to be a whole multiple of N1 symbols, so a gap may be formed (that can be used to mitigate interference between ranging and data transmissions). Each CDMA code shall be transmitted at the beginning of the corresponding slot. See Figure 160ab.

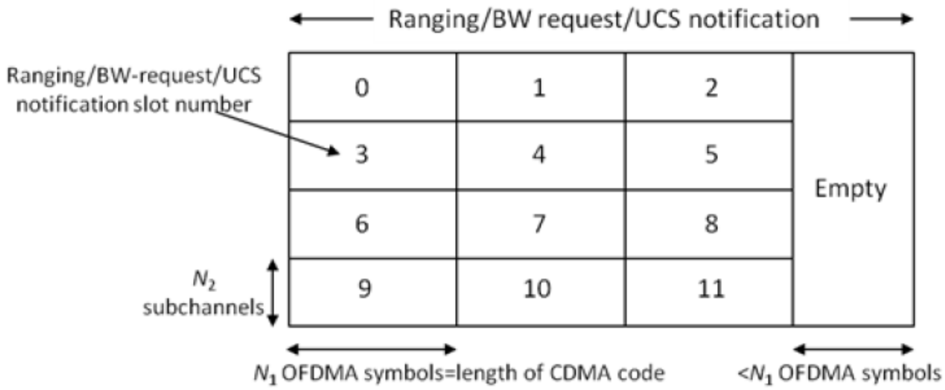


Figure 160ab—Example of Ranging/BW request/UCS notification opportunities windows

9a.9.4 Power control

The power control procedures for PHY-OM1 (9.9.4) are used for PHY-OM2.

9a.9.4.1 Transmit power control boundaries and EIRP limits

The transmit power control boundaries and EIRP limits for PHY-OM1 (9.9.4.1) are used for PHY-OM2.

9a.9.4.2 Transmit power control mechanism

The transmit power control procedures for PHY-OM1 (9.9.4.2, except for the information in Table 228) are used for PHY-OM2. See Table 231aa for the default normalized CNR values per modulation for the BCC for PHY-OM2.

Table 231aa—Normalized CNR per modulation for BER= 2×10^{-4}

Modulation - FEC rate	Normalized CNR (dB)
	AWGN (default)
CDMA code	1.9
QPSK, rate: 1/2	4.7
QPSK, rate: 2/3	6.4
QPSK, rate: 3/4	7.3
QPSK, rate: 5/6	8.4
16-QAM, rate: 1/2	10.5
16-QAM, rate: 2/3	12.6
16-QAM, rate: 3/4	13.8
16-QAM, rate: 5/6	15.1
64-QAM, rate: 1/2	15.4

Table 231aa—Normalized CNR per modulation for BER= 2×10^-4 *(continued)*

Modulation - FEC rate	Normalized CNR (dB)
	AWGN (default)
64-QAM, rate: 2/3	18.3
64-QAM, rate: 3/4	19.7
64-QAM, rate: 5/6	21.2
256-QAM, rate: 1/2	19.6
256-QAM, rate: 2/3	23.3
256-QAM, rate: 3/4	25.1
256-QAM, rate: 5/6	26.9
256-QAM, rate: 7/8	28.2

9a.10 Network synchronization

For multiple A-WRAN cells implementation, it is required that all BSs be time synchronized within a tolerance of ± 8 TU (equivalent to 1.429 µs for 6 MHz, 1.224 µs for 7 MHz BW and 1.071 µs for 8 MHz BW). It should be noted that any filtering at the output of the OFDM modulator to help meeting the rejection required by the RF mask (see 9a.13) will create temporal dispersion that will consume part of the cyclic prefix capability provided for alleviating channel time spreading.

In the event of a loss of synchronization with the common clock or with nearby A-WRAN BSs, the BS shall continue to operate and shall automatically resynchronize through the synchronization process described in 7.23.

For multiple A-WRAN cells implementation, frequency references derived from a common timing reference shall be used to control the frequency accuracy of BSs as specified in 7.23, provided that they meet the frequency accuracy requirements of 9a.11. This applies during normal operation and during loss of timing reference.

9a.11 Frequency control requirements

The frequency control requirements of PHY-OM1 (9.11) are used for PHY-OM2.

9a.12 Antenna

The antenna procedures of PHY-OM1 (9.12) are used for PHY-OM2.

9a.13 RF mask

The RF mask requirements of PHY-OM1 (9.13) are used for PHY-OM2.

9a.14 Receiver requirements

The receiver requirements of PHY-OM1 (9.14) are used for PHY-OM2.

9a.15 MIMO pilot allocation

9a.15.1 Overview

When using MIMO scheme for PHY-OM2, the data allocation to tile is changed to accommodate multiple antennas transmission for the channel estimation. MIMO pilot allocations for the cases of two TX antennas and four TX antennas are described in 9a.15.2 and 9a.15.3, respectively. Each subclause includes both DS and US pilot allocations for multiple transmit antennas.

9a.15.2 Pilot allocation for two antennas

For two transmit BS antennas, the DS data allocation to tile is changed (Figure 160ac) to accommodate two antennas transmission for channel estimation. Figure 160ac replaces Figure 160q in 9a.6.1.1 when MIMO is enabled.

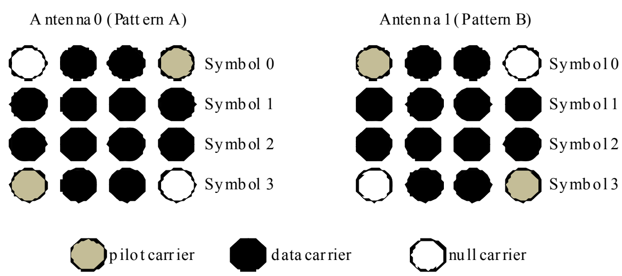


Figure 160ac—DS tile structure for two TX antennas

For two transmit CPE antennas, the US data allocation to tile is changed (Figure 160ad) to accommodate two antennas transmission for channel estimation. Figure 160ad replaces Figure 160r in 9a.6.1.2 when MIMO is enabled.

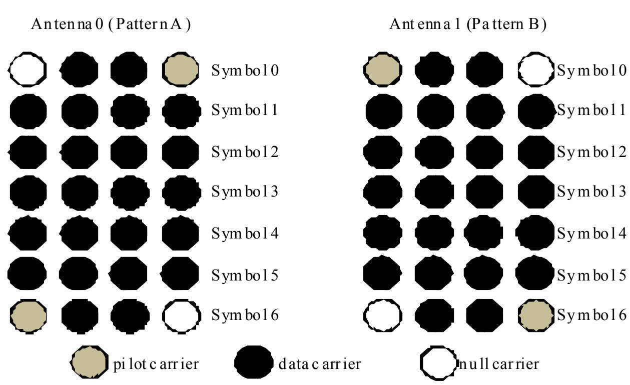


Figure 160ad—US tile structure for two TX antennas

9a.15.3 Pilot allocation for four antennas

For four transmit BS antennas, the DS data allocation to tile is changed (Figure 160ae) to accommodate four antennas transmission for channel estimation. Figure 160ae replaces Figure 160q in 9a.6.1.1 when MIMO is enabled.

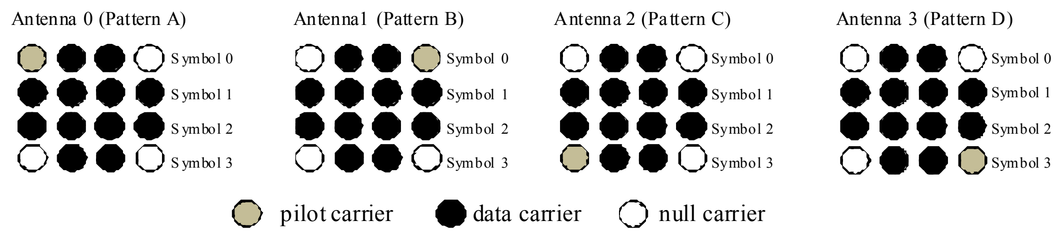


Figure 160ae—DS Tile structure for four TX antennas

For four transmit CPE antennas, the US data allocation to tile is changed (Figure 160af) to accommodate four antennas transmission for channel estimation. Figure 160af replaces Figure 160r in 9a.6.1.2 when MIMO is enabled.

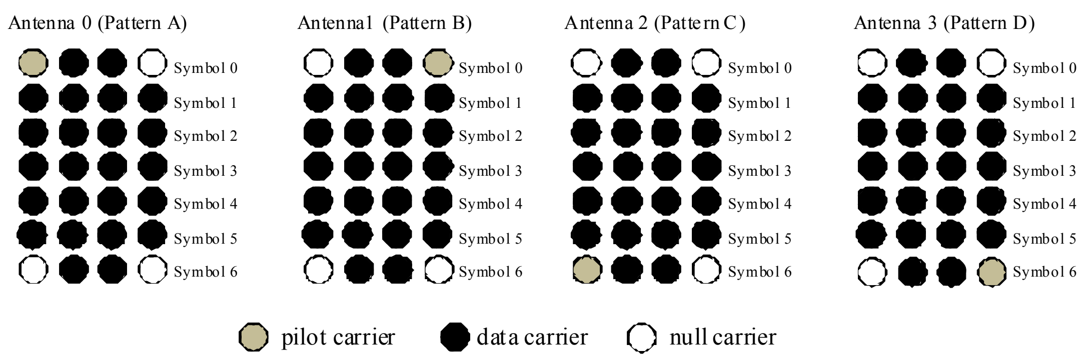


Figure 160af—US tile structure for four TX antennas

9a.15.4 Space time coding (STC)

The MIMO technique is common to PHY-OM1 and PHY-OM2. The procedures for PHY-OM1 (9.15.3) are used for PHY-OM2.

10. Cognitive radio capability

10.1 General

Insert the following paragraph at the end of 10.1:

A-WRAN devices shall employ the cognitive radio capability required by regulatory.

12. Parameters and connection management

12.1 Parameters, timers, message IEs

12.1.1 MAC (dynamic service flow, multicast, ARQ, capability, and bandwidth management)

Change all instances of "BS" to "BS/A-BS/Distributed Scheduling A-CPE" in Table 272.

Insert the following subclause (12.1.1.1 and its table) after 12.1.1:

12.1.1.1 MAC (Relay, Multi-channel)

Table 272a—MAC parameters, timers, message IEs

Entity	Name	Reference	Min value	Default value	Max value
CPE	T61	Wait for container ACK	10 ms	—	≤ T9
CPE	T62	Wait for local cell update acknowledgment	—	—	≤ T9
CPE	T63	Wait for DTT-RSP timeout	10 ms	—	≤ T9
A-BS	T64	Wait for DTT-RPT timeout	10 ms	—	≤ T9
CPE	T65	Wait for DTT-CFM timeout	20 ms	—	≤ T9
A-BS	T66	Wait for CAM-STP timeout	20 ms	—	160 ms
A-BS	T67	Wait for CAM-SWH timeout	10 ms	—	160 ms

12.1.2 PHY (initialization, operation, and DS/US synchronization)

Change Table 273 as follows:

Table 273—PHY parameters, timers, message IEs

Entity/ Scope	Name	Reference	Min value	Default value	Max value
BS/A-BS/ Distributed Scheduling A-CPE	DCD Interval	Time between transmission of DCD messages.			10 s
BS/A-BS/ Distributed Scheduling A-CPE	UCD Interval	Time between transmission of UCD messages.			10 s

Table 273—PHY parameters, timers, message IEs *(continued)*

Entity/ Scope	Name	Reference	Min value	Default value	Max value
BS/A-BS/ Distributed Scheduling A-CPE	UCD Transition	The time the BS/A-BS/Distributed Scheduling A-CPE shall wait after repeating a UCD message with an incremented Configuration Change Count before issuing a US-MAP message referring to Upstream_Burst_Profiles defined in that UCD message.	2 MAC frames		
BS/A-BS/ Distributed Scheduling A-CPE	DCD Transition	The time the BS/A-BS/Distributed Scheduling A-CPE shall wait after repeating a DCD message with an incremented Configuration Change Count before issuing a DS-MAP message referring to Downstream_Burst_Profiles defined in that DCD message.	2 MAC frames		
BS/A-BS/ Distributed Scheduling A-CPE	Initial Ranging Interval	Time between Initial Ranging opportunities assigned by the BS/A-BS/ Distributed Scheduling A-CPE.			2 s
BS/A-BS/ Distributed Scheduling A-CPE	CLK-CMP Interval	Time between the clock compare measurements used for the generation of CLK-CMP messages.	50 ms	50 ms	50 ms
CPE	Lost DSMAP Interval (T56)	Time since last received DS-MAP message before DS synchronization is considered lost.			600 ms
CPE	Lost USMAP Interval (T57)	Time since last received US-MAP message before upstream synchronization is considered lost.			600 ms
CPE	Lost SCH (T58)	Number of SCH on PHY-OM 1 that can be lost until synchronization is considered lost.			15
CPE	CDMA Ranging Retries	Number of retries on CDMA Ranging Requests.	1		4
CPE, BS/ A-BS/ Distributed Scheduling A-CPE	Invited Ranging Retries	Number of retries on inviting Ranging Requests.	16		
BS/A-BS/ Distributed Scheduling A-CPE	US-MAP Process Time	Time provided between arrival of the last bit of a US-MAP at a CPE and effectiveness of that map.	5 symbols		
BS/A-BS/ Distributed Scheduling A-CPE	CPE Ranging Response Processing Time	Time allowed for a CPE following receipt of a ranging response before it is expected to reply to an invited ranging request.	10 ms		

Table 273—PHY parameters, timers, message IEs *(continued)*

Entity/ Scope	Name	Reference	Min value	Default value	Max value
CPE	T1	Wait for DCD timeout.			5 × DCD interval maximum value
CPE	T2	Wait for broadcast ranging timeout.			5 × ranging interval
CPE	T3	Ranging Response reception timeout following the transmission of a Ranging Request.		200 ms	200 ms
CPE	T4	Wait for unicast ranging opportunity. If the pending-until-complete field was used earlier by this CPE, then the value of that field shall be added to this interval.	1 s	30 min (fixed) 10 min (portable)	30 min
BS/A-BS/ Distributed Scheduling A-CPE	T5	Wait for Upstream Channel Change response.			2 s
CPE	T12	Wait for UCD descriptor.			5 × UCD Interval maximum value
CPE	T20	Time the CPE searches for preambles on a given channel.	2 MAC frames		
CPE	T21	Time the CPE searches for DS-MAP on a given channel.			10 s
BS/A-BS/ Distributed Scheduling A-CPE	$EIRP_{BS}$	EIRP of BS/A-BS/Distributed Scheduling A-CPE (DS).	–64 dBm		63.5 dBm
BS/A-BS/ Distributed Scheduling A-CPE	TTG	Transmit/Receive Transition Gap.	105 µs	210 µs	333 µs
BS/A-BS/ Distributed Scheduling A-CPE	DIUC Mandatory Exit Threshold	CINR at or below which this DIUC can no longer be used and where change to a more robust DIUC is required.	–64 dB		+63.5 dB
BS/A-BS/ Distributed Scheduling A-CPE	DIUC Mandatory Entry Threshold	The minimum CINR required to start using this DIUC when changing from a more robust DIUC is required.	–64 dB		+63.5 dB
BS/A-BS/ Distributed Scheduling A-CPE	Boosting	Boosting applied to a DS allocation.	–12 dB	0 dB	+9 dB

Table 273—PHY parameters, timers, message IEs *(continued)*

Entity/ Scope	Name	Reference	Min value	Default value	Max value
BS/A-BS/ Distributed Scheduling A-CPE, CPE	BW Request Backoff Start	Initial size of BW Request opportunity used by CPEs to contend to send BW requests to BS/A-BS/Distributed Scheduling A-CPE.	0		15
BS/A-BS/ Distributed Scheduling A-CPE, CPE	BW Request Backoff End	Final size of BW Request opportunity used by CPEs to contend to send BW requests to BS/A-BS/Distributed Scheduling A-CPE.	1		15
BS/A-BS/ Distributed Scheduling A-CPE, CPE	UCS notification Backoff Start	Initial backoff window size in units of UCS notification opportunity used by CPEs to contend to send UCS notifications to BS/A-BS/Distributed Scheduling A-CPE.	0		15
BS/A-BS/ Distributed Scheduling A-CPE, CPE	UCS notification Backoff End	Final size of UCS notification opportunity used by CPEs to contend to send UCS notification to BS/A-BS/ Distributed Scheduling A-CPE.	1		15
BS/A-BS/ Distributed Scheduling A-CPE, CPE	Contention based reservation Timeout	Number of US-MAPs to receive before contention-based reservation is attempted again for the same connection.	1		255
BS/A-BS/ Distributed Scheduling A-CPE, CPE	BW Request opportunity size and CRZ BW Request opportunity size	Size (in OFDM slots) of PHY bursts, that a CPE may use to format and transmit a bandwidth request message in a contention request opportunity.	1		255
BS/A-BS/ Distributed Scheduling A-CPE, CPE	UCS notification request opportunity size and CRZ UCS notification request opportunity size	Size (in OFDM slots) of PHY bursts that a CPE may use to transmit a UCS notification.	1		255
BS/A-BS/ Distributed Scheduling A-CPE, CPE	# of initial and CRZ initial ranging codes	Number of initial ranging CDMA codes (N).	1		255
BS/A-BS/ Distributed Scheduling A-CPE, CPE	# of periodic and CRZ periodic ranging codes	Number of periodic ranging CDMA codes (M).	1		255

Table 273—PHY parameters, timers, message IEs *(continued)*

Entity/ Scope	Name	Reference	Min value	Default value	Max value
BS/A-BS/ Distributed Scheduling A-CPE, CPE	# of bandwidth and CRZ bandwidth request codes	Number of bandwidth request CDMA codes (L).	1		255
BS/A-BS/ Distributed Scheduling A-CPE, CPE	# of UCS notification and CRZ UCS notification codes	Number of UCS notification CDMA codes (I).	1		255
BS/A-BS/ Distributed Scheduling A-CPE, CPE	Start of CDMA codes group	Indicates the starting number, S, of the group of codes used for the US.	0	See 6.10.3	255
BS/A-BS/ Distributed Scheduling A-CPE, CPE	EIRP Density Level	EIRP Transmitted per subcarrier.	–104 dBm		+23.5 dBm
BS/A-BS/ Distributed Scheduling A-CPE, CPE	EIRP Control	EIRP per subcarrier that the CPE should apply to correct its current transmission EIRP.	–104 dBm		+23.5 dBm
BS/A-BS/ Distributed Scheduling A-CPE	EIRP Per subcarrier	EIRP transmitted per subcarrier.	–104 dBm		+23.5 dBm
CPE	Lost FCH (T68)	Number of FCH on PHY-OM2 that can be lost until synchronization is considered lost.			Lost SCH × 16
CPE	Lost DRZ-FCH (T69)	Number of DRZ-FCH that can be lost until synchronization in DRZ is considered lost.			Lost SCH × 16

14. Management plane interfaces and procedures

14.2 Primitive definitions

14.2.1 Management SAP (M-SAP)

14.2.1.4 BS configuration and monitoring primitives

Change the text of 14.2.1.4 as follows:

The BS SM occasionally sends the available channel list to its higher layers for additional channel classification. The available channel list can be presented to its higher layers to have channels classified as disallowed. The classification of an operating channel by the BS is also performed by its higher layers. The M-SAP is an interface that provides a means of exchanging information between the SM and the higher layers in the BS. Table 299 summarizes the primitives supported by the SM to pass the available channel list and to receive disallowed channel classifications and the selected operating channel/channels through the M-SAP interface. The primitives are discussed in the subclauses referenced in the table.

Change Table 299 as follows:

Table 299— BS configuration and monitoring primitives supported by the M-SAP

Name	Request	Indication	Confirm
M-AVAIL-TV-CH-REPORT	14.2.1.4.1	14.2.1.4.2	
M-DISALLOWED-TV-CHS			14.2.1.4.3
M-OPERATING-TV-CH			14.2.1.4.4
M-OPERATING-TV-CHS			14.2.1.5.4

14.2.1.4.1 M-AVAIL-TV-CH-REPORT.REQUEST

14.2.1.4.1.5 Data

Change Table 300 as follows:

Table 300—M-AVAIL-TV-CH-REPORT.REQUEST parameters

Name	Type	Length	Description
Number of Available Channels	Integer	1 byte	Number of channels provided.
For ($i = 0$; $i <$ Number of Available Channels; i++) {			
Channel Start Frequency	Integer	8 bytes	Channel Start Frequency in Hz.

Table 300—M-AVAIL-TV-CH-REPORT.REQUEST parameters *(continued)*

Name	Type	Length	Description
Channel End Frequency	Integer	8 bytes	Channel End Frequency in Hz.
Maximum Allowed EIRP	Integer	1 byte	Maximum allowed EIRP on channel “TV Channel Number”, defined on the range –64 dBm to +63.5 dBm in 0.5 dB steps.
}			
Mode	Integer	1 byte	The expected response from the higher layers: 0x00 = Test 0x01 = Request for disallowed channel classification 0x02 = Request for selection of operating channel 0x03 = Request for selection of operating channels in multi-channel operation mode 0x04–0xFF = *Reserved*
Timestamp	Character String	20 characters	Timestamp of the present request at time of transmission. Time format defined in 14.1.5.

14.2.1.4.1.6 When generated

Change 14.2.1.4.1.6 as follows:

The M-AVAIL-TV-CH-REPORT.REQUEST primitive is generated by the BS SM and issued to the higher layers (depending on the mode) to request disallowed channel classification or selection of an operating channel or selection of operating channels in multi-channel operation mode during BS initialization as described in 7.14.1.

14.2.1.4.2 M-AVAIL-TV-CH-REPORT-INDICATION

14.2.1.4.2.7 Effect of receipt

Change 14.2.1.4.2.7 as follows:

When the SM of a CPE/BS receives the M-AVAIL-TV-CH-REPORT-INDICATION primitive, it expects, depending on the mode, the higher layers to return nothing, or an M-DISALLOWED-TV-CHS-CONFIRMATION primitive with classified disallowed channels, or an M-OPERATING-TV-CH-CONFIRMATION with the selected channel, or an M-OPERATING-TV-CHS-CONFIRMATION with the selected channels if operating in multi-channel mode.

Insert the following subclause (14.2.1.4.5 and it subclauses and table) after 14.2.1.4.4.7:

14.2.1.4.5 M-OPERATING-TV-CHS-CONFIRMATION

14.2.1.4.5.1 Purpose

The M-OPERATING-TV-CHS-CONFIRMATION primitive is used by the higher layers to return the selected operating channels in multi-channel operation mode on the available channel list to the SM per its request. Table 303a specifies the parameters for the M-OPERATING-TV-CHS-CONFIRMATION primitive.

14.2.1.4.5.2 SAP Type

M-SAP

14.2.1.4.5.3 Operation Type

Information Confirmation

14.2.1.4.5.4 Destination

BS SM

14.2.1.4.5.5 Data

Table 303a—M-OPERATING-TV-CHS-CONFIRMATION parameters

Name	Type	Length	Description
Number of channels in multi-channel operation	Integer	1 byte	Number of channels selected for multi-channel operation
For (i=1; i≤ Number of ChannelsinMulti-channel Operation; i++) {			
Channel Start Frequency	Integer	8 bytes	Channel start frequency in Hz
Channel End Frequency	Integer	8 bytes	Channel end frequency in Hz
}			
Timestamp	Character String	20 characters	Copied from the timestamp in the M-AVAIL-TVCH-REPORT-REQUEST. Time format defined in 14.1.5.

14.2.1.4.5.6 When generated

The M-OPERATING-TV-CHS-CONFIRMATION primitive is generated by the higher layers and issued to the BS SM to indicate the selected operating channels in multi-channel operation mode from the available channel list.

14.2.1.4.5.7 Effect of receipt

When the SM receives the M-OPERATING-TV-CHS-CONFIRMATION primitive, it will identify whether the response to its request for the higher layers to select the operating channels in multi-channel operation mode from the available channel list was successfully received by the higher layers. If the response was successful, the SM will obtain the selected operating channels, and the BS will continue to commence multi-channel operation on the selected channels. If the response is not successful, the SM may decide to issue another request.

14.2.1.5 CPE reports the resulting available WRAN services list

Change the preliminary text of 14.2.1.5 and Table 304 as follows:

The selection of WRAN service or WRAN services by the CPE is performed by its higher layers. The M-SAP is an interface that provides a means of exchanging information between the SA and the higher layers. Table 304 summarizes the primitives supported by the SM to pass the available WRAN services list and the selected WRAN service or WRAN services through the M-SAP interface. The primitives are discussed in the subclauses referenced in the table.

Table 304— Available WRAN services list primitives supported by the M-SAP

Name	Request	Indication	Confirm
M-WRAN-SERVICE-REPORT	14.2.1.5.1		14.2.1.5.3
M-WRAN-SERVICE-INDICATION		14.2.1.5.2	
M-WRAN-SERVICES-INDICATION		14.2.1.5.4	

Insert the following subclause (14.2.1.5.4 and its subclauses and table) after 14.2.1.5.3.7:

14.2.1.5.4 M-WRAN-SERVICES-INDICATION

14.2.1.5.4.1 Purpose

The M-WRAN-SERVICES-INDICATION primitive is used by the higher layers to return selected WRAN channels from the available WRAN services list to the SA per its request, when engaged in multi-channel operation mode. Table 307a specifies the parameters for the M-WRAN-SERVICES-INDICATION primitive.

14.2.1.5.4.2 SAP Type

M-SAP

14.2.1.5.4.3 Operation Type

Event Indication

14.2.1.5.4.4 Destination

CPESA

14.2.1.5.4.5 Data

Table 307a—M-WRAN-SERVICES-INDICATION parameters

Name	Type	Length	Description
Number of channels in multi-channel operation	Integer	1 byte	Number of channels selected for multi-channel operation
For (i=1; i≤ Number of ChannelsinMulti-channel Operation; i++) {			
Channel Start Frequency	Integer	8 bytes	Channel start frequency in Hz
Channel End Frequency	Integer	8 bytes	Channel end frequency in Hz
}			
Timestamp	Character String	20 characters	Copied from the timestamp in the M-AVAIL-TVCH-REPORT-REQUEST. Time format defined in 14.1.5.

14.2.1.5.4.6 When generated

The M-WRAN-SERVICES-INDICATION primitive is generated by the higher layers and issued to the CPE SA to indicate the selected channels from the available WRAN services list.

14.2.1.5.4.7 Effect of receipt

When the SA receives the M-WRAN-SERVICES-INDICATION primitive, it will identify whether the response to its request for the higher layers to select channels from the available WRAN services list was successfully received by the higher layers. If the response was successful, the SA will obtain the selected channels, and CPE will continue to the subsequent steps of initialization. If the response is not successful, the SA may decide to issue another query.

Annex G

(informative)

Bibliography

Insert the following reference into the bibliography in numeric order in Annex G:

[B7a] IEEE 802.22 Working Group on Wireless Regional Area Networks, "WRAN Channel Modeling," doc.: IEEE 802.22-05/0055.

Insert the new Annex H after Annex G:

Annex H

(informative)

Multiple-input, multiple-output (MIMO)—Receiver side implementation

H.1 Overview

The MIMO receiver side techniques described in this annex is common to both PHY-OM1 and PHY-OM2 of the PHY considered in this standard.

H.1.1 Receiver side implementation of scheme in 9.15.3.2

The transmit scheme of 9.15.3.2 yields the received signals r_1 and r_2 given in Equation (16) (see 9.15.3.2). After performing the following signal combination at the receiver,

$$\hat{s}_2 = h_2^* r_1 - h_1 r_2^*, \qquad \text{(H.1)}$$

$$\hat{s}_1 = h_1^* r_1 + h_2 r_2^*$$

the estimated symbols are given by

$$\hat{s}_1 = s_1 (|h_1|^2+|h_2|^2) + h1^* n_1 + h_2 n_2^*, \qquad \text{(H.2)}$$

$$\hat{s}_2 = s_2 (|h_1|^2+|h_2|^2) - h_1 n_2^* + h_2^* n_1.$$

The diversity order provided by the Alamouti scheme is the same as the one provided by the maximum ratio combining (MRC) receiver with a single transmit antenna and two receive antennas. However, Alamouti scheme benefits from having the complexity transferred to the transmitter premises where device size is not a major constraint.

H.1.2 Receiver side implementation of scheme in 9.15.3.3

H.1.2.1 General

The transmit scheme of 9.15.3.3 has to be processed at the receiver side in the manner described in this subclause in order to obtain transmit diversity with array interference gain.

The receiver is composed of the “channel estimator,” “combiner,” “array gain maximization,” and “maximum likelihood (ML) detector” blocks in order to recover the transmitted symbols, however, with array-interference gain. The aforementioned blocks are described in the following subclauses.

H.1.2.2 Two TX antenna systems

H.1.2.2.1 Overview

In two TX antenna systems, a total of two unique transmit vectors G_m, for $m \in \{0,1\}$ exists. The aligned array interference I_{Am}, where $m \in \{0,1\}$, are functions of the fading channel **H**, and both TX and RX can estimate **H** due to the reciprocity of uplink/downlink. Consequently, I_{Am} can be calculated beforehand and stored in RX device memory. See Figure H.1.

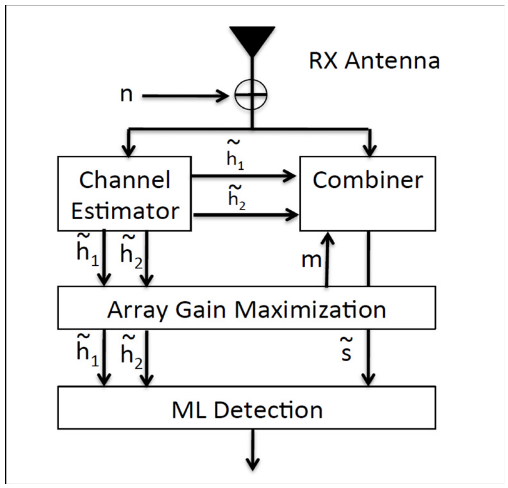


Figure H.1—Transmit diversity with array-interference gain for two TX antennas (RX side)

The channel estimator block performs channel estimation based on pilots. The estimation is then provided to the combiner block and the array gain maximization block.

The array gain maximization block in RX performs

$$\arg\max_m (I_{Am}), \forall m \in \{0,1\}$$

in order to compare all the I_{Am} and selects the one that has the maximum value.

Then, the array gain maximization block at the receiver sends the index *m*, in binary, to the combiner block, which is collocated in the same RX device. For instance, if *m* = '1', the combiner block will utilize the weight w_1, when it receives the signal from TX.

The combiner block provides symbol estimate to the ML detector block.

H.1.2.2.2 Array gain maximization block

In the array gain maximization block, the array interference I_{Am} is stored as a function of **H** (see 9.15.3.3.2.2).

In order to select the most aligned interference, the array gain maximization block performs

$$\arg\max_m (I_{Am}), \forall m \in \{0,1\}$$

The array gain maximization block at the receiver sends *m* to the collocated combiner block. For the following implementation examples, consider that *m* is represented by 3 bits.

H.1.2.2.3 Combiner block

Let $H = [\mathrm{h}_1\ \mathrm{h}_2]$, ^{T} denote transpose operation, and *n* denote the zero-mean additive white Gaussian noise (AWGN).

— If the combiner block receives $m = 000$ from the array gain maximization block, the received signal is

$$y = G_0 \cdot H^T + n\,.$$

The combiner block, then, utilizes

$$w_0 = [\ 1\ \ 1]$$

for the combination. However, for the specific case of m = 000, multiplying vector w_m is not necessary and left here for illustration purposes only. The combiner block performs the following combination:

$$\tilde{S} = yH^* \cdot w_0^T$$

which is then passed to the ML detector block to perform the symbol estimation.

— If the combiner block receives m = 001, then

$$y = G_1 \cdot H^T + n$$

The combiner block then utilizes

$$w_1 = [\ 1\ \text{-}1]$$

yielding

$$\tilde{S} = yH^* \cdot w_1^T$$

This is then passed to the ML detector block to perform the symbol estimation.

H.1.2.3 Four TX antenna systems

H.1.2.3.1 Overview

In a four TX antenna system, the receiver has to perform the following steps:

H.1.2.3.2 Array gain maximization block

For four TX antennas, there are eight I_{Am} (see 9.15.3.3.3.1) as well as w_m, m ∈ $\{0,1,2,3,4,5,6,7\}$.

In order to select the most aligned interference, the array gain maximization block performs

$$\arg\max_{m}(I_{Am}), \forall m \in \{0,1,2,3,4,5,6,7\}$$

The array gain maximization block at the receiver sends *m* to the combiner block collocated at the receiver.

H.1.2.3.3 Combiner block

Let $\underset{\sim}{H} = [\mathrm{h}_1\ \mathrm{h}_2\ \mathrm{h}_3\ \mathrm{h}_4]$ and for the sake of simplicity in the example, the channel estimation be perfect, i.e., $H = H$.

— If the combiner block receives m = 000 from the array gain maximization block, it utilizes

$$w_0 = [\ 1\ 1\ 1\ 1]$$

to perform the combination

$$\tilde{S} = yH^{*} \cdot w_0^T$$

which is then passed to the ML detector block to perform the symbol estimation.

— If the combiner block receives m = 001 from the array gain maximization block, it utilizes

$$w_1 = [\ 1\ \text{-1}\ \ 1\ \text{-1}]$$

and performs the following combination:

$$\tilde{S} = yH^{*} \cdot w_1^T$$

which is then passed to the ML detector block to perform the symbol estimation.

— If the combiner block receives m = 010 from the array gain maximization block, it utilizes

$$w_2 = [\ 1\ \ 1\ \text{-1}\ \text{-1}]$$

and performs the following combination:

$$\tilde{S} = yH^{*} \cdot w_2^T$$

which is then passed to the ML detector block to perform the symbol estimation.

— If the combiner block receives m = 011 from the array gain maximization block, it utilizes

$$w_3 = [\ 1\ \text{-1}\ \text{-1}\ \ 1]$$

and performs the following combination:

$$\tilde{S} = yH^* \cdot w_3^T$$

which is then passed to the ML detector block to perform the symbol estimation.

— If the combiner block receives m = 100 from the array gain maximization block, it utilizes

$$w_4 = [\ 1\ \ 1\ \ 1\ \text{-}1]$$

and performs the following combination:

$$\tilde{S} = yH^* \cdot w_4^T$$

which is then passed to the ML detector block to perform the symbol estimation.

— If the combiner block receives m = 101 from the array gain maximization block, it utilizes

$$w_5 = [\ 1\ \ 1\ \text{-}1\ \ 1]$$

and performs the following combination:

$$\tilde{S} = yH^* \cdot w_5^T$$

which is then passed to the ML detector block to perform the symbol estimation.

— If the combiner block receives m = 110 from the array gain maximization block, it utilizes

$$w_6 = [\ 1\ \text{-}1\ \ 1\ \ 1]$$

and performs the following combination:

$$\tilde{S} = yH^* \cdot w_6^T$$

which is then passed to the ML detector block to perform the symbol estimation.

— If the combiner block receives m = 111 from the array gain maximization block, it utilizes

$$w_7 = [\text{-}1\ \ 1\ \ 1\ \ 1]$$

and performs the following combination:

$$\tilde{S} = yH^* \cdot w_7^T$$

which is then passed to the ML detector block to perform the symbol estimation.

The above procedure must follow the steps described in 9.15.3.3.2 and 9.15.3.3.3 in order to obtain diversity added with array gain for systems with multiple antennas at the transmitter, however, with single antenna at the receiver. Below, extension to system configuration consisting of multiple receiving antennas is presented.

If more than one antenna is available in the receiver terminal, maximum ratio combining (MRC) can be utilized to significantly enhance link reliability. For simplicity, in the following example consider that the number of antennas available at the receiver is two. The technique, however, can be utilized for any number of receive antennas.

In order to use MRC, little modification is necessary to what has been presented. The array gain maximization block, now, performs

$$\arg\max_{m}(I_{Am} + I'_{Am}), \forall m \in \{0,1\}$$

for two TX antennas and

$$\arg\max_{m}(I_{Am} + I'_{Am}), \forall m \in \{0,1,2,3,4,5,6,7\}$$

for four TX antennas. Here, I_{Am} and I'_{Am} can be found in 9.15.3.3.3.

The array gain maximization block at the receiver sends *m* to the collocated combiner block. The combiner block will combine the received signal, just as described in the previous subclauses, in order to deliver $S + S`$ to the ML detector block. Note that $S$ is given in the previous subclauses and $S`$ is given by $S' = y' H^{*} \cdot w_m^T$ with y' being the signal received by the second RX antenna and **H** = [h_3 h_4], for 2TX, or **H** = [h_5 h_6 h_7 h_8], for 4 TX.

The technique described above is full rate and yields full spatial diversity added to antenna array gain thus yielding better link reliability.

H.1.3 Receiver side implementation of scheme in 9.15.4

H.1.3.1 Overview

In this subclause we provide examples on how to process the signals received by transmissions following the scheme described in 9.15.4 in order to obtain throughput enhancements.

H.1.3.2 Spatial multiplexing signal detection for a system with two TX antennas

Several receiver techniques exist to obtain the estimate of the transmitted symbols $\tilde{s}_1$ and $\tilde{s}_2$. In this subclause the linear zero-forcing (ZF) method is described along with its ordered successive interference cancellation (OSIC) variant. Employing the following weight matrix,

$$\boldsymbol{Z} = (\boldsymbol{H}^{\mathrm{H}}\mathrm{H})^{-1}\boldsymbol{H}^{\mathrm{H}}, \tag{H.3}$$

the ZF method intends to cancel the interference between symbols s_1 and s_2 by

$$\tilde{\boldsymbol{s}} = \boldsymbol{Z}\,\boldsymbol{y}. \tag{H.4}$$

Substituting Equation (H.2) and Equation (H.3) into Equation (H.4) yields

$$\tilde{\boldsymbol{s}} = \boldsymbol{s} + (\boldsymbol{H}^{\mathrm{H}}\mathrm{H})^{-1}\boldsymbol{H}^{\mathrm{H}}\boldsymbol{n}. \tag{H.5}$$

or

$$\begin{bmatrix}\tilde{s}_1\\ \tilde{s}_2\end{bmatrix} = \begin{bmatrix}s_1\\ s_2\end{bmatrix} + (\boldsymbol{H}^{\boldsymbol{H}}\boldsymbol{H})^{-1}\boldsymbol{H}^{\boldsymbol{H}}\begin{bmatrix}n_1\\ n_2\end{bmatrix} \tag{H.6}$$

Obviously, perfect recovery, i.e., nulling of interference, is not achieved due to the presence of an enhanced noise component $(\boldsymbol{H}^{\mathrm{H}}\mathrm{H})^{-1}\boldsymbol{H}^{\mathrm{H}}\boldsymbol{n}$ in Equation (H.5) and Equation (H.6).

For an improved bit-error-rate (BER) and packet-error-rate (PER) performance, OSIC technique successively cancels components from the received signal until one of the data streams is detected. Although this method leads to increase in complexity, it is not significant in the face of BER and PER improvements.

From Figure H.2, the principle of OSIC detection can be easily understood. The symbol from a parallel stream, which is estimated first, is then subtracted from the originally received signal yielding a reduced interference signal. This reduced interference signal is used in the following stage of the OSIC detection where the other symbol will be estimated. Here, *i* refers to the estimation order, which does not necessarily follow the same symbol order, i.e., s_i could be s_2 while $s_{i+1,}$ $s_{1.}$ Several criteria are used to select the symbol estimation order, e.g., SNIR-based order, SNR-based order, column norm-based order. The third option has been adopted through this subclause.

To determine the estimation order, we rewrite Equation (H.1) as

$$\begin{bmatrix}y_1\\ y_2\end{bmatrix} = \begin{bmatrix}h_{1,1}\\ h_{2,1}\end{bmatrix} s_1 + \begin{bmatrix}h_{1,2}\\ h_{2,2}\end{bmatrix} s_2 + \begin{bmatrix}n_1\\ n_2\end{bmatrix}. \tag{H.7}$$

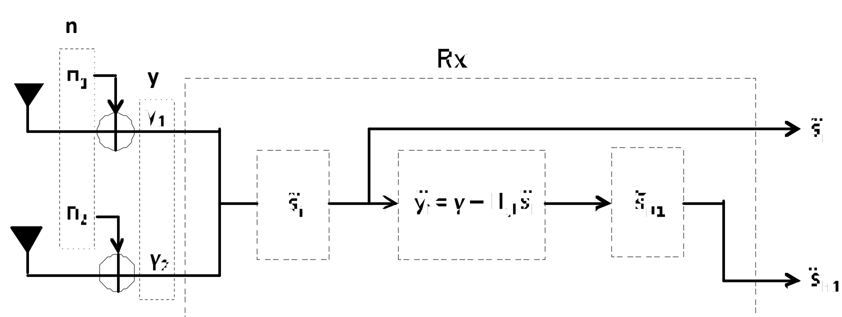


Figure H.2—Schematic diagram of SM detection based on OSIC technique

From Equation (H.7) it is clear that symbols s_1 and s_2 have their magnitude affected by the norm of $\|\boldsymbol{H}_{:,1}\|$ and $\|\boldsymbol{H}_{:,2}\|$, denoting first and second columns of $\boldsymbol{H}$, respectively. It is, therefore, obvious to estimate the symbols according to the order of the norms of $\boldsymbol{H}$.

The first symbol s_i is estimated by the ith row of $\boldsymbol{Z}$,

$$\tilde{s}_i = \boldsymbol{Z}_{i,:}\,\mathrm{y}, \tag{H.8}$$

yielding

$$\tilde{s}_i = s_i + \boldsymbol{Z}_{i,:}\, \boldsymbol{n}, \tag{H.9}$$

which is then mapped to the possible transmitted symbol from the constellation C with the closest Euclidian distance to it.

Once the first estimation occurs, the mapped $\tilde{s}_i$ is then used in the next stage to estimate $\tilde{s}_{i+1}$,

$$\tilde{\boldsymbol{y}}_i = \boldsymbol{y} - \boldsymbol{H}_{:,i}\, \tilde{s}_i. \tag{H.10}$$

If $\tilde{s}_i$ is correctly estimated, mapping Equation (H.10) to the symbol with closest Euclidian distance from C yields $\tilde{s}_{i+1}$. For instance, consider that $\tilde{s}_i = s_1$ and it was correctly estimated. It can be easily seen that Equation (H.10) becomes

$$\tilde{\boldsymbol{y}}_1 = \begin{bmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{bmatrix} \cdot \begin{bmatrix} s_1 \\ s_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} - \begin{bmatrix} h_{1,1} \\ h_{2,1} \end{bmatrix} s_1, \tag{H.11}$$

yielding

$$\tilde{\boldsymbol{y}}_1 = \begin{bmatrix} h_{1,2} \\ h_{2,2} \end{bmatrix} s_2 + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix}. \tag{H.12}$$

If $\tilde{s}_i$ is not correctly estimated, error propagation occurs and compromises BER and PER performances.

H.1.3.3 Spatial multiplexing signal detection for a system with four TX antennas

Linear zero-forcing (ZF) method yields the estimated symbols $\tilde{\boldsymbol{s}} = \boldsymbol{s} + (\boldsymbol{H}^{\mathrm{H}}\mathrm{H})^{-1}\boldsymbol{H}^{\mathrm{H}}\boldsymbol{n}$ due to $\tilde{\boldsymbol{s}} = \boldsymbol{Z}\,\boldsymbol{y}$, where $\boldsymbol{Z} = (\boldsymbol{H}^{\mathrm{H}}\mathrm{H})^{-1}\boldsymbol{H}^{\mathrm{H}}$, where $^{\mathbf{H}}$ represents Hermitian operator.

Similarly to the 2x2 case, improved BER and PER performance can be obtained through OSIC technique. Here we detail the OSIC technique applied to a 4x4 SM-MIMO system. The symbol from a parallel stream, which is estimated first, is then subtracted from the originally received signal yielding a reduced interference signal. This reduced interference signal is used in the following stage of the OSIC detection where another symbol will be estimated and then subtracted from the signal in order to further reduce interference. This procedure is repeated until all symbols are estimated.

Again considering column norm-based order, $\|\boldsymbol{H}_{:,1}\|$, $\|\boldsymbol{H}_{:,2}\|$, $\|\boldsymbol{H}_{:,3}\|$ and $\|\boldsymbol{H}_{:,4}\|$, and for illustrations purposes, considering that $\|\boldsymbol{H}_{:,1}\| > \|\boldsymbol{H}_{:,2}\| > \|\boldsymbol{H}_{:,3}\| > \|\boldsymbol{H}_{:,4}\|$, the symbols are estimated in the following order: s_1, s_2, s_3, s_4.

The first symbol s_1 is estimated by the 1st row of $\boldsymbol{Z}$,

$$\tilde{s}_1 = \boldsymbol{Z}_{1,:}\, \mathrm{y}, \tag{H.13}$$

yielding

$$\tilde{s}_1 = s_1 + \boldsymbol{Z}_{1,:}\, \boldsymbol{n}, \tag{H.14}$$

which is then mapped to the possible transmitted symbol from the constellation C with the closest Euclidian distance to it.

Generating the reduced interference (provided that $\tilde{s}_1 = s_1$) signal,

$$\tilde{\boldsymbol{y}}_1 = \boldsymbol{y} - \boldsymbol{H}_{:,1}\,\tilde{s}_1. \tag{H.15}$$

A new MIMO matrix is constructed by deleting the first column:

$$\breve{\boldsymbol{H}} = \begin{bmatrix} h_{1,2} & h_{1,3} & h_{1,4} \\ h_{2,2} & h_{2,3} & h_{2,4} \\ h_{3,2} & h_{3,3} & h_{3,4} \\ h_{4,2} & h_{4,3} & h_{4,4} \end{bmatrix},$$

with $\breve{\boldsymbol{Z}} = (\breve{\boldsymbol{H}}^{\mathrm{H}}\breve{\boldsymbol{H}})^{-1}\breve{\boldsymbol{H}}^{\mathrm{H}}$.

Then, $\tilde{s}_2$ is estimated by

$$\tilde{s}_2 = \breve{\boldsymbol{Z}}_{1,:}\,\tilde{\boldsymbol{y}}_1. \tag{H.16}$$

Again, a further reduced interference signal (provided that $\tilde{s}_2 = s_2$) is generated by

$$\tilde{\boldsymbol{y}}_2 = \tilde{\boldsymbol{y}}_1 - \breve{\boldsymbol{H}}_{:,1}\,\tilde{s}_2, \tag{H.17}$$

along with

$$\hat{\boldsymbol{H}} = \begin{bmatrix} h_{1,3} & h_{1,4} \\ h_{2,3} & h_{2,4} \\ h_{3,3} & h_{3,4} \\ h_{4,3} & h_{4,4} \end{bmatrix} \text{ and } \hat{\boldsymbol{Z}} = (\hat{\boldsymbol{H}}^{\mathrm{H}}\hat{\boldsymbol{H}})^{-1}\hat{\boldsymbol{H}}^{\mathrm{H}}.$$

Estimation of $\tilde{s}_3$ follows:

$$\tilde{s}_3 = \hat{\boldsymbol{Z}}_{1,:}\,\tilde{\boldsymbol{y}}_2. \tag{H.18}$$

Finally, the last reduced interference signal (provided that $\tilde{s}_3 = s_3$) is generated by

$$\tilde{\boldsymbol{y}}_3 = \tilde{\boldsymbol{y}}_2 - \hat{\boldsymbol{H}}_{:,1}\,\tilde{s}_3, \tag{H.19}$$

along with

$$\dddot{\boldsymbol{H}} = \begin{bmatrix} h_{1,4} \\ h_{2,4} \\ h_{3,4} \\ h_{4,4} \end{bmatrix} \text{ and } \dddot{\boldsymbol{Z}} = (\dddot{\boldsymbol{H}}^{\mathrm{H}}\dddot{\boldsymbol{H}})^{-1}\dddot{\boldsymbol{H}}^{\mathrm{H}}$$

The last estimation follows:

$$\tilde{s}_4 = \dddot{\boldsymbol{Z}}_{1,:}\,\tilde{\boldsymbol{y}}_3 \tag{H.20}$$

Note that precoder-based spatial multiplexing could be employed by exploiting the channel reciprocity inherent to TDD systems. This is due to the fact that both the DL and the UL of TDD systems operate in the same frequency, however in different time-slots and thus are highly correlated. The channel state information (CSI) can be obtained by the Tx side during (UL) transmissions.

Once CSI is known, the Tx transmits the ***Ws***, where ***W*** is the $N_t x N_s$ precoding matrix with N_t referring to the number of transmit antennas and N_s to the number of streams. For instance, for the 4x4 SM-MIMO with zero-forcing considered above, $\mathbf{W} = \alpha \mathbf{H}^{-1}$,

$$\alpha = \left(\frac{N_t}{Tr(H^{-1}(H^{-1})^H)}\right)^{1/2}, \tag{H.21}$$

due to Tx power constraints and where *Tr* represents the trace of $(H^{-1}(H^{-1})^H)$.

After dividing the received signal α**,** it then becomes

$$y = \frac{1}{\alpha}(HWs + n) \tag{H.22}$$

or

$$y = s + \frac{1}{\alpha}n \tag{H.23}$$

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