~~DRAFT Amendment to IEEE Standard for~~
   ~~Local and metropolitan area networks~~

Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems

Advanced Air Interface (working document)

~~Sponsor~~

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

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4. Abbreviations and acronyms

[Insert the following abbreviations:]

AAI	advanced air interface
A-MAP	advanced MAP
A-Preamble	advanced preamble
CAS	CRU allocation size
CL	closed-loop
CMI	codebook matrix index
CRU	contiguous resource unit
CoRe	constellation re-arrangement
CSM	collaborative spatial multiplexing
DL	downlink
DRU	distributed resource unit
FP	frequency partition
FMT	UL feedback mini-tile
FPC	frequency partition configuration
FPCT	frequency partition count
FPS	frequency partition size
FPSC	frequency partition subband count
GRA	group resource allocation
HARQ	hybrid ARQ
HE	horizontal encoding
HMT	UL HARQ mini-tiles
IE	information element
IR	incremental redundancy
LRU	logical resource unit
MCS	modulation and coding scheme

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MLRU	A-MAP logical resource unit
MU	multi-user
OL	open-loop
PA	persistent allocation
PA-Preamble	primary advanced preamble
PFBCH	UL primary fast feedback channel
PMI	preferred matrix index
PRU	physical resource unit
P-SFH	primary superframe header
RCP	ranging cyclic prefix
RFMT	Reordered UL feedback mini-tile
RHMT	Reordered UL HARQ mini-tile
RP	ranging preamble
RU	resource unit
SAC	subband allocation count
SA-Preamble	secondary advanced preamble
SFBC	space-frequency block code
SFBCH	UL secondary fast feedback channel
SFH	superframe header
SPID	subpacket ID
S-SFH	secondary superframe header
STC	space-time coding
SU	single-user
UCAS	uplink CRU allocation size
UFPC	uplink frequency partition configuration
UL	uplink
USAC	uplink subband allocation count

VE   vertical encoding

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3. Definitions

[Insert the following definitions:]

3.95 superframe: A structured data sequence of predefined duration used by the Advanced Air Interface specification.

3.96 subframe: A structured data sequence of fixed duration used by the Advanced Air Interface specifications. A superframe is comprised of four frames.

3.97 multi-carrier transmission: Use of more than 1 carrier is used to exchange data between BS and MSs.

3.98 primary carrier: An OFDMA carrier on which BS and the MS exchange traffic and full PHY/MAC control information defined in the Advanced Air Interface specification. Further, the primary carrier is used for control functions for proper MS operation, such as network entry. Each MS shall have only one carrier it considers to be its primary carrier in a cell.

3.99 secondary carrier: An OFDMA carrier that MS may use for traffic, only per BS's specific allocation commands and rules,typically received from the primary carrier. The secondary carrier may also include control signaling to support multi-carrier operation.

3.100 fully configured carrier: A carrier for which all control channels including synchronization, broadcast, multicast and unicast control signaling are configured. Further, information and parameters regarding multi-carrier operation and the other carriers can also be included in the control channels.

3.101 partially configured carrier: A carrier with essential control channel configuration to support traffic exchanges during multi-carrier operations.

3.102 physical resource unit (PRU): The basic resource allocation unit that consists of 18 adjacent carriers in consecutive symbols in same subframe.

3.103 distributed resource unit (DRU): The resource allocation unit of the same size as the PRU that has undergone the subband partitioning and miniband permutation, assigned to distributed allocation and will be submitted to the subcarrier permutation in DL and tile permutation in UL.

3.104 contiguous resource unit (CRU): The resource allocation unit of the same size as the PRU that has undergone the subband partitioning and miniband permutation, assigned to contiguous allocation and will bypass subcarrier permutation in DL and tile permutation in UL. Also known as a localized resource unit.

3.105 logical resource unit (LRU): the generic name of logical units for distributed and localized resource allocations. LRU is of same size as PRU.

3.106 transmission time interval (TTI): The duration of the transmission of the physical layer encoded packet over the radio air interface and is equal to an integer number of subframes. The default TTI is 1 subframe.

3.107 layer: An information path fed to the MIMO encoder as an input

3.108 stream: Each information path encoded by the MIMO encoder that is passed to the precoder

3.109 rank: For the spatial multiplexing modes in SU-MIMO, the number of streams to be used for the user allocated to the Resource Unit (RU)

3.110 rate: The number of QAM symbols signaled per array channel use.

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3.111 horizontal encoding: Indicates transmitting multiple separately FEC-encoded layers over multiple antennas. The number of encoded layers may be more than 1

3.112 vertical encoding: Indicates transmitting a single FEC-encoded layer over multiple antennas. The number of encoded layers is always 1.

3.113 resource unit: A granular unit in frequency and time, described by the number of OFDMA subcarriers and OFDMA symbols

3.114 single user MIMO: A MIMO transmission scheme in which a single MS is scheduled in one RU

3.115 multi-user MIMO: A MIMO transmission scheme in which multiple MSs are scheduled in one RU, by virtue of spatial separation of the transmitted signals

[Insert the following clause:]

15. Advanced Air Interface

15.1 Introduction

15.2 Medium access control

15.2.1 Addressing

The AMS has a global address and logical addresses that identify the AMS and connections during operation.

15.2.1.1 MS MAC Address

The AMS, ARS and ABS are identified by the globally unique 48-bit IEEE Extended Unique Identifier (EUI-48™) based on the 24-bit Organizationally Unique Identifier (OUI) value administered by the IEEE Registration Authority.

15.2.1.2 Logical Identifiers

The following logical identifiers are defined in the following subsections.

15.2.1.2.1 Station Identifier (STID)

The ABS assigns a 12 bits long STID to the AMS during network entry, and, in some cases, network re-entry, that uniquely identifies the AMS within the domain of the ABS. Each AMS registered in the network has an assigned STID. Some specific "STIDs" are reserved, for example, for broadcast, multicast, and ranging.

15.2.1.2.2 Flow Identifier (FID)

Each AMS connection is assigned a 4bits long FID that uniquely identifies the connection within the AMS. FIDs identify management connections and transport connections. Some specific FIDs may be pre-assigned.

15.2.1.2.3 Temporary Identifier

The network may assign a temporary Identifier to uniquely identify an AMS in the idle mode in aparticular paging group. The temporary identifier is assigned during idle mode entry or location update due to paging group change. Such identifier remains valid as long as the AMS stays in the same paging group. The temporary identifier is used in paging messages to identify the AMS. It is also used by the AMS to identify itself during its network re-entry procedure as response to paging or location update when paging group is not changed.

15.2.2 Bandwidth request procedure

The random access based bandwidth request procedure for MZone or LZone with AMC is described in <<Figure 1>>. In these cases, a 5-step regular procedure or an optional 3-step quick access procedure (steps 1,4 and 5) may be supported concurrently. Steps 2 and 3 are used only in 5-step regular procedure. In step 1, the AMS sends a bandwidth request indicator and a message for quick access that may indicate information such as AMS addressing and/or request size (FFS) and/or uplink transmit power report (FFS), and/or QoS

identifiers (FFS), and the ABS may allocate uplink grant based on certain policy. The 5-step regular proce-
dure is used independently or as a fallback mode for the 3-step bandwidth request quick access procedure.
The AMS may piggyback additional BW REQ information along with user data during uplink transmission
(step 5). Following step 1 and step 3, ABS may acknowledge the reception of bandwidth request. If AMS
does not receive any acknowledgement or UL grant, it waits until the expiration of a pre-defined period and
restarts the bandwidth request. The pre-defined period may be differentiated by factors such as QoS parame-
ters (e.g. scheduling type, priority, etc). In case BW is granted immediately, there is no need for ABS to send
explicit ACK.
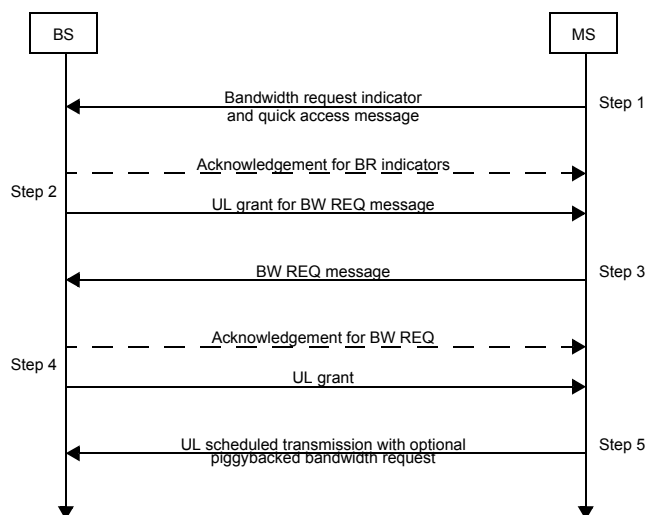
Figure 387—Bandwidth request procedure in the MZone or the LZone with AMC

The bandwidth request procedure for LZone with PUSC is described in Figure 388. In LZone with PUSC,
only a 5-step regular procedure is supported. In step 1, AMS sends a bandwidth request indicator only. The
rest of LZone with PUSC bandwidth request procedure shall be the same as the 5-step procedure in
Figure 387.
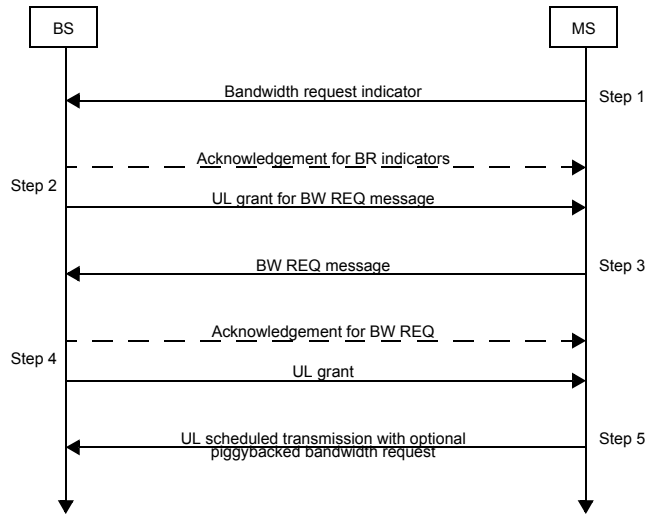
Figure 388—Bandwidth request procedure in the LZone with PUSC

15.2.3 Security

15.2.4 Persistent scheduling in advanced air interface

15.2.4.1 Allocation mechanism

15.2.4.2 Deallocation mechanism

15.2.4.3 HARQ retransmissions

15.2.4.4 Error handling procedure

15.2.5 Group Resource Allocation

Group Resource Allocation mechanism allocates resources to multiple users as a group in order to save control overhead. The mechanism takes advantage of common traffic characteristics and grouping is done based on some common parameters such as MCS (modulation and coding scheme) and resource size, which further saves overhead.

15.2.5.1 Grouping Mechanism

Users are assigned to groups based on the combination of MCS used and the resource allocation size (number of LRUs) required. A set of n-bit codes can be used to represent the different combinations of MCSs and resource sizes that are used by a group. These codes are included in a bitmap as part of the group's resource allocation information.

15.2.5.2 Group Configuration

15.2.5.3 Group Management

15.2.5.3.1 Addition of AMS to a Group

15.2.5.3.2 Deletion of AMS from a Group

15.2.5.3.3 Bitmaps in Group Resource Allocation

GRA makes use of bitmaps to signal resource allocation information for users within a group. These bitmaps are sent in the Group Resource Allocation IE. The first bitmap is the User Bitmap which uses 1 bit per user to signal which users are scheduled in the frame.

The second bitmap is the Resource Allocation bitmap which uses *n* bits per user to signal the MCS and Resource Size for users that are scheduled in the frame. An example of bitmaps is shown in Figure 389.
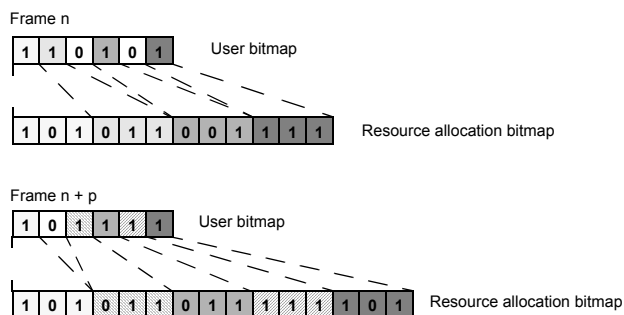
Figure 389—User bitmap and resource allocation bitmap

15.2.5.4 HARQ Operation for Group Resource Allocation

15.2.5.5 Error Handling Procedure

15.3 Physical layer

15.3.1 Introduction

The Advanced Air Interface is designed for NLOS operation in the licensed frequency bands below 6 GHz.

The Advanced Air Interface supports TDD and FDD duplex modes, including H-FDD MS operation. Unless otherwise specified, the frame structure attributes and baseband processing are common for all duplex modes.

The Advanced Air Interface uses OFDMA as the multiple access scheme in the downlink and uplink.

15.3.2 OFDMA symbol description, symbol parameters and transmitted signal

15.3.2.1 Time domain description

Inverse-Fourier-transforming creates the OFDMA waveform; this time duration is referred to as the useful symbol time T_b. A copy of the last T_g of the useful symbol period, termed CP, is used to collect multipath, while maintaining the orthogonality of the tones. Figure 390 illustrates this structure.
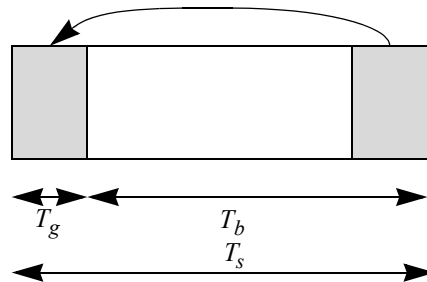
Figure 390—OFDMA symbol time structure

15.3.2.2 Frequency domain description

The frequency domain description includes the basic structure of an OFDMA symbol.

An OFDMA symbol is made up of subcarriers, the number of which determines the FFT size used. There are several subcarrier types:

— Data subcarriers: for data transmission

— Pilot subcarriers: for various estimation purposes

— Null carrier: no transmission at all, for guard bands and DC carrier

The purpose of the guard bands is to enable the signal to naturally decay and create the FFT "brick wall" shaping.

15.3.2.3 Primitive parameters

The following four primitive parameters characterize the OFDMA symbol:

— *BW*: The nominal channel bandwidth.

— N_{used}: Number of used subcarriers (which include the DC subcarrier).

— *n*: Sampling factor. This parameter, in conjunction with BW and Nused determines the subcarrier spacing and the useful symbol time. This value is given in Table 647 for each nominal bandwidth.

— *G*: This is the ratio of CP time to "useful" time. The following values shall be supported: 1⁄8 and 1⁄16.

15.3.2.4 Derived parameters

The following parameters are defined in terms of the primitive parameters of 15.3.2.3:

— N_{FFT}: Smallest power of two greater than N_{used}

— Sampling frequency: $F_s = \text{floor}(n \cdot BW / 8000) \times 8000$

— Subcarrier spacing: $\Delta f = F_s / N_{FFT}$

— Useful symbol time: $T_b = 1/\Delta f$

— CP time: $T_g = G \cdot T_b$

— OFDMA symbol time: $T_s = T_b + T_g$

— Sampling time: T_b / N_{FFT}

Values of the derived parameters and the primitive parameters above are specified in Table 647.

Table 647—OFDMA parameters

The nominal channel bandwidth, BW (MHz)			5	7	8.75	10	20
Sampling factor, n			28/25	8/7	8/7	28/25	28/25
Sampling frequency, F_s (MHz)			5.6	8	10	11.2	22.4
FFT size, N_{FFT}			512	1024	1024	1024	2048
Subcarrier spacing, Δf (kHz)			10.94	7.81	9.77	10.94	10.94
Useful symbol time, T_b (µs)			91.4	128	102.4	91.4	91.4
CP ratio, $G = 1/8$	OFDMA symbol time, T_s (µs)		102.857	144	115.2	102.857	102.857
	FDD	Number of OFDMA symbols per 5ms frame	48	34	43	48	48
		Idle time (µs)	62.857	104	46.40	62.857	62.857
	TDD	Number of OFDMA symbols per 5ms frame	47	33	42	47	47
		TTG + RTG (µs)	165.714	248	161.6	165.714	165.714
CP ratio, $G = 1/16$	OFDMA symbol time, T_s (µs)		97.143	136	108.8	97.143	97.143
	FDD	Number of OFDMA symbols per 5ms frame	51	36	45	51	51
		Idle time (µs)	45.71	104	104	45.71	45.71
	TDD	Number of OFDMA symbols per 5ms frame	50	35	44	50	50
		TTG + RTG (µs)	142.853	240	212.8	142.853	142.853

Table 647—OFDMA parameters

CP ratio, *G* = 1/4		OFDMA symbol time, T_s (µs)	114.286			114.286	114.286
	FDD	Number of OFDMA symbols per 5ms frame	42			42	42
		Idle time (µs)	199.98			199.98	199.98
	TDD	Number of OFDMA symbols per 5ms frame	42			42	42
		TTG + RTG (µs)	199.98			199.98	199.98
Number of Guard Sub-Carriers		Left	40	80	80	80	160
		Right	39	79	79	79	159
Number of Used Sub-Carriers			433	865	865	865	1729
Number of Physical Resource Blocks (18x6)			24	48	48	48	96

15.3.2.5 Transmitted signal

Equation (173) specifies the transmitted signal voltage to the antenna, as a function of time, during any OFDMA symbol.

$$s(t) = \text{Re}\left\{ e^{j2\pi f_c t} \sum_{\substack{k = -(N_{used}-1)/2 \\ k \neq 0}}^{(N_{used}-1)/2} c_k \cdot e^{j2\pi k \Delta f(t - T_g)} \right\} \tag{173}$$

Where,

t is the time, elapsed since the beginning of the subject OFDMA symbol, with

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

Δf is the subcarrier frequency spacing

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15.3.2.6 Definition of basic terms on the transmission chain

The basic terms related with the transmission chain are defined as illustrated in Figure 391.
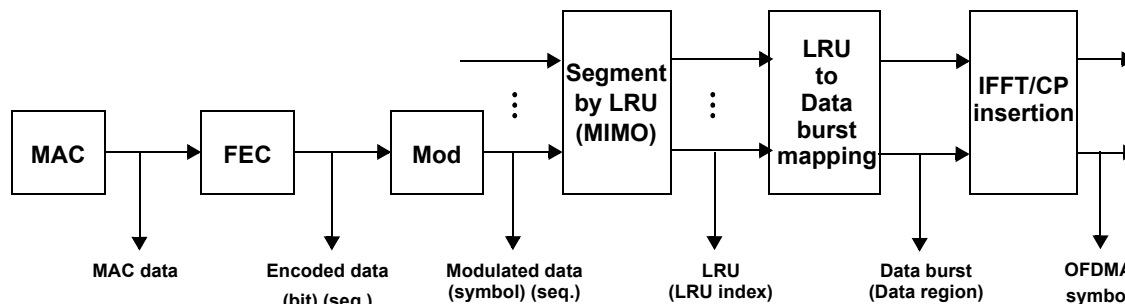
Figure 391—Definition of basic terms on the transmission chain

15.3.3 Frame structure

15.3.3.1 Basic frame structure

The advanced air interface basic frame structure is illustrated in Figure 392. Each 20 ms superframe is divided into four equally-sized 5 ms radio frames. When using the same OFDMA parameters as in Table 647 with the channel bandwidth of 5 MHz, 10 MHz, or 20 MHz, each 5 ms radio frame further consists of eight subframes. A subframe shall be assigned for either DL or UL transmission. There are three types of subframes:

1) the type-1 subframe consists of six OFDMA symbols,

2) the type-2 subframe consists of seven OFDMA symbols,

3) the type-3 subframe which consists of five OFDMA symbols, and

4) the type-4 subframe which consists of nine OFDMA symbols. This type shall be applied only to UL subframe for the 8.75MHz channel bandwidth when supporting the WirelessMAN-OFDMA frames.

The basic frame structure is applied to FDD and TDD duplexing schemes, including H-FDD MS operation. The number of switching points in each radio frame in TDD systems shall be two, where a switching point is defined as a change of directionality, i.e., from DL to UL or from UL to DL.

When H-FDD MSs are included in an FDD system, the frame structure from the point of view of the H-FDD MS is similar to the TDD frame structure; however, the DL and UL transmissions occur in two separate frequency bands. The transmission gaps between DL and UL (and vice versa) are required to allow switching the TX and RX circuitry.

A data burst shall occupy either one subframe (i.e. the default TTI transmission) or contiguous multiple subframes (i.e. the long TTI transmission). The long TTI in FDD shall be 4 subframes for both DL and UL. The long TTI in TDD shall be the whole DL (UL) subframes for DL (UL) in a frame.

Every superframe shall contain a superframe header (SFH). The SFH shall be located in the first DL subframe of the superframe, and shall include broadcast channels.
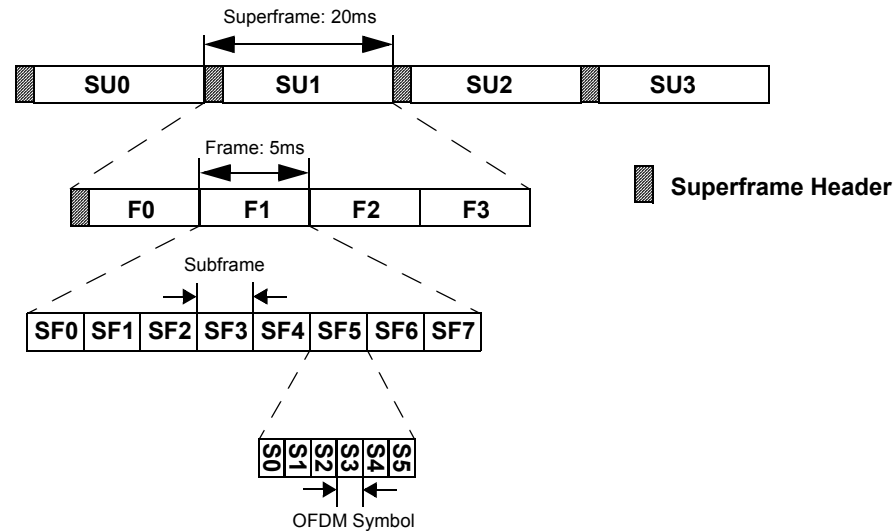
Figure 392—Basic frame structure for 5, 10 and 20 MHz channel bandwidths

15.3.3.2 Frame structure for CP = 1/8 T_b

15.3.3.2.1 FDD frame structure

A BS supporting FDD mode shall be able to simultaneously support half duplex and full duplex MSs operating on the same RF carrier. The MS supporting FDD mode shall use either H-FDD or FDD.

The FDD frame shall be constructed on the basis of the basic frame structure defined in 15.3.3.1. In each frame, all subframes are available for both DL and UL transmissions. The DL and UL transmissions are separated in the frequency domain.

FDD MS is able to receive data burst in any DL subframe while accessing UL subframe at the same time. For H-FDD MS, either transmission or reception, but not both, is allowed in each subframe.

The idle time specified in Table 647 shall be placed at the end of each FDD frame as shown in Figure 393.

Figure 393 illustrates an example FDD frame structure, which is applicable to the nominal channel bandwidth of 5, 10, and 20 MHz with $G = 1/8$.

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Frame structure with Type-1 subframe in FDD for 5, 10, and 20 MHz channel bandwidths (CP=1/8 T_b)
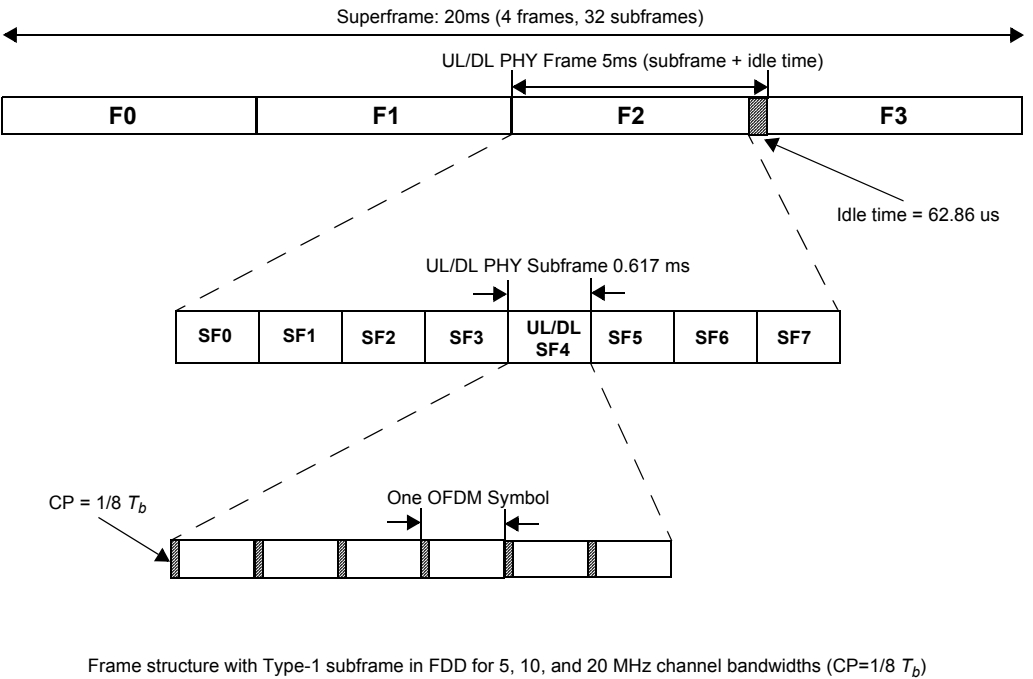
Figure 393—Frame structure with Type-1 FDD subframe

Figure 394 illustrates an example FDD frame structure, which is applicable to the nominal channel bandwidth of 7 MHz with G = 1/8. Four subframes among six subframes are the type-1 subframes, and the other two subframes are the type-3 subframe. The [third] and [forth] subframes are the type-3 subframe.

Frame structure with Type-1 and Type-3 subframe in FDD for 5, 10, and 20 MHz channel bandwidths (CP=1/8 T_b)
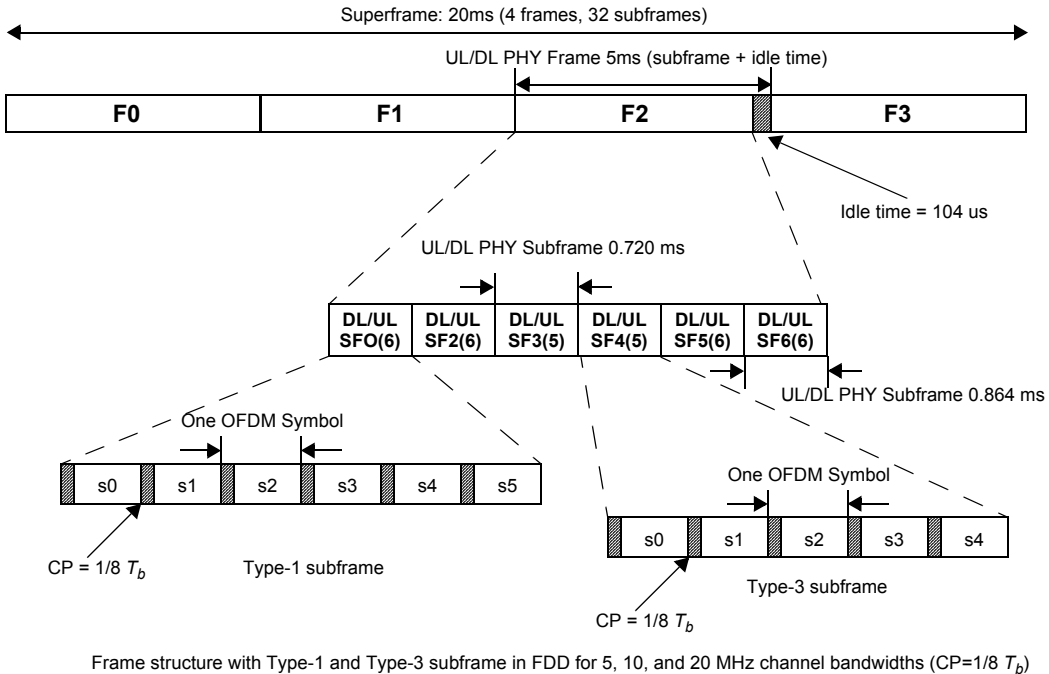
Figure 394—Frame structure with Type 1 and Type 3 subframe

Figure 395 illustrates an example FDD frame structure, which is applicable to the nominal channel bandwidth of 8.75 MHz with G = 1/8. In Figure 395 the fourth subframe is a type-2 subframe and the other subframes are type-1 subframes.

Frame structure with Type-1 and Type-2 subframes in FDD for 8.75 MHz channel bandwidths (CP=1/8 T_b)
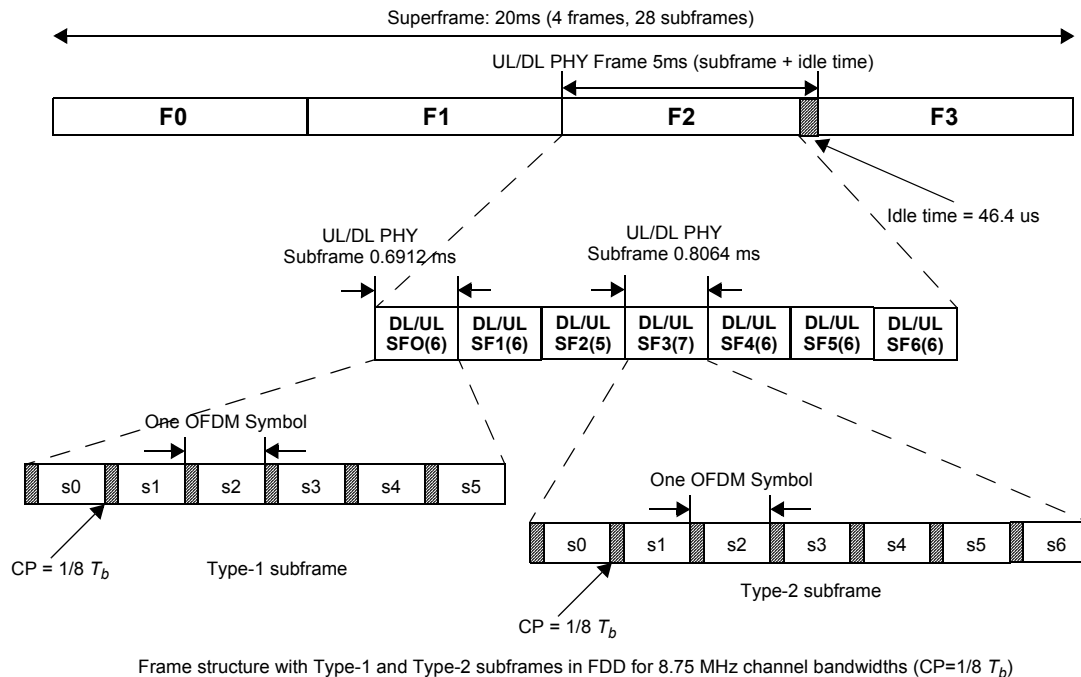
Figure 395—Frame structure for 8.75 MHz FDD

15.3.3.2.1.1 H-FDD frame structure

15.3.3.2.2 TDD frame structure

The TDD frame shall be constructed on the basis of the basic frame structure defined in 15.3.3.1.

In a TDD frame with DL to UL ratio of D:U, the 1st contiguous D subframes and the remaining U subframes are assigned for DL and UL, respectively, where D + U = 8 for 5, 10 and 20 MHz channel bandwidths, D + U = 7 for 8.75 MHz channel bandwidth, and D + U = 6 for 7 MHz channel bandwidth. The ratio of D:U shall be selected from one of the following values: 8:0, 6:2, 5:3, 4:4, or 3:5 for 5, 10 and 20 MHz channel bandwidths, and [TBD] for 7 and 8.75 MHz channel bandwidths.

In each frame, the TTG and RTG shall be inserted between the DL and UL switching points.

Figure 396 illustrates an example TDD frame structure with D:U = 5:3, which is applicable to the nominal channel bandwidths of 5, 10, and 20 MHz with G = 1/8. In Figure 396 the last DL subframe, i.e. DL SF4, is a type-3 subframe and the other subframes are type-1 subframes. TTG and RTG are 105.714 µs and 60µs, respectively.

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Frame structure with type-1 and type-3 subframes in TDD mode
for 5, 10, and 20 MHz channel bandwidths (CP=1/8 T_b)
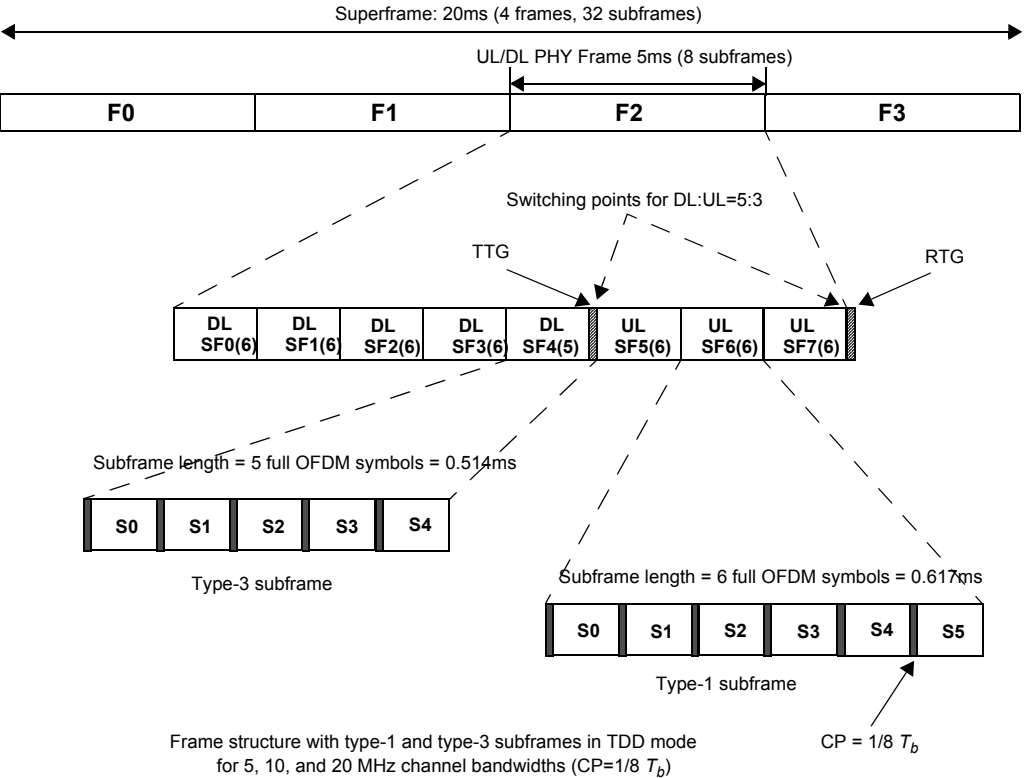
Figure 396—Frame structure with Type-1 TDD subframe

Figure 397 illustrates an example TDD frame structure with D:U = 4:2, which is applicable to the nominal channel bandwidths of 7 MHz with G = 1/8. Three subframes among six subframes are the type-1 subframes, and the other three subframes are the type-3. The [second], [third] and [forth] DL subframes are the type-3 subframe. TTG and RTG are 188μs and 60μs, respectively.

Frame structure 7 MHz TDD (CP=1/8 T_b)
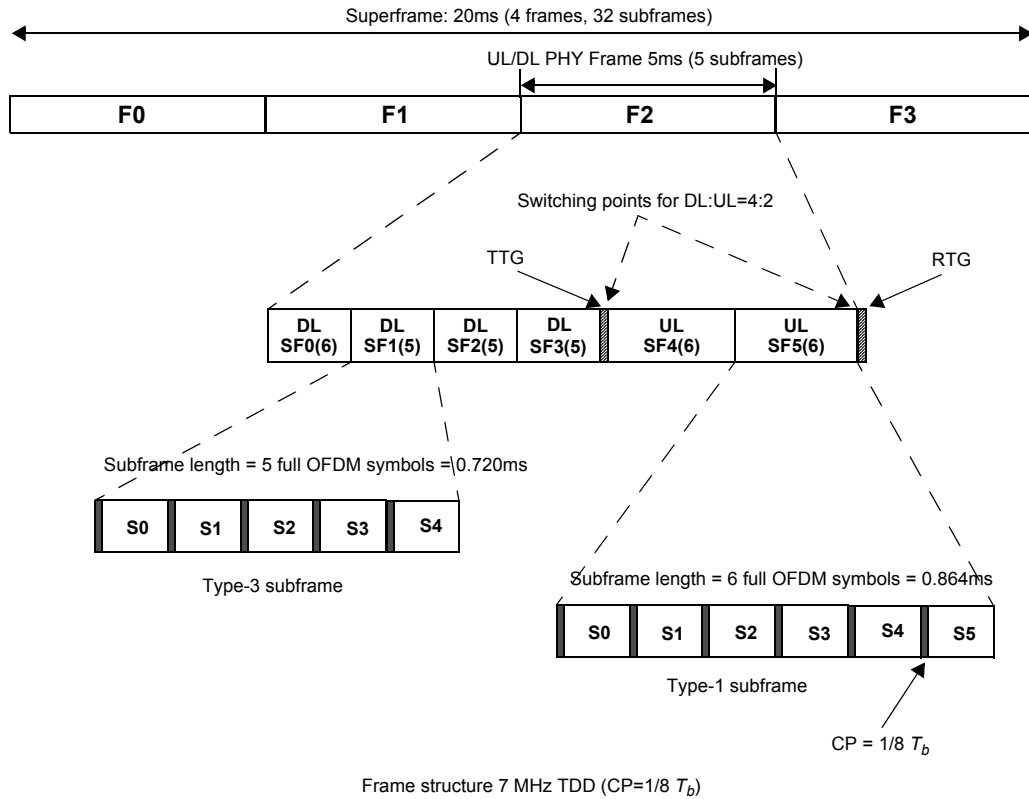
Figure 397—Frame structure for 7MHz TDD mode

Figure 398 illustrates an example TDD frame structure with D:U =5:2, which is applicable to the nominal channel bandwidths of 8.75 MHz with G = 1/8. In Figure 398 all seven subframes in a frame are type-1 subframes. TTG and RTG are 87.2 µs and 74.4µs, respectively.
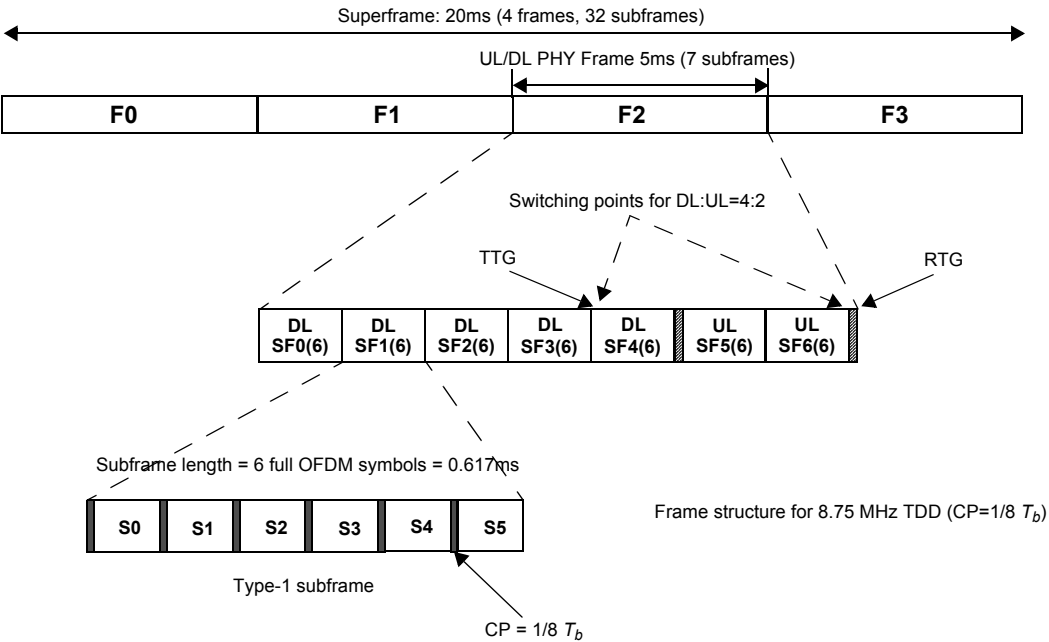
Figure 398—Frame structure for 8.75MHz TDD mode

15.3.3.3 Frame structure for CP = 1/16 T_b

The frame structure for a CP length of 1/16 T_b shall consist of type-1 and type-2 subframes.

For channel bandwidths of 5, 10, and 20 MHz, an FDD frame shall have five type-1 subframes and three type-2 subframes , and a TDD frame shall have six type-1 subframes and two type-2 subframes. The subframe preceding a DL to UL switching point shall be a type-1 subframe.

In the TDD frame, the first and last subframes within each frame shall be type-2 subframes.

In the FDD frame, the first, fifth, and last subframes within each frame shall be type-2 subframes.

Figure 399 illustrates an example of TDD and FDD frame structure for 5, 10, and 20 MHz channel bandwidths with a CP of 1/16 T_b. Assuming OFDMA symbol duration of 97.143 µs and a CP length of 1/16 T_b, the length of type-1 and type-2 subframes are 0.583 ms and 0.680 ms, respectively. TTG and RTG are 82.853 µs and 60 µs, respectively.
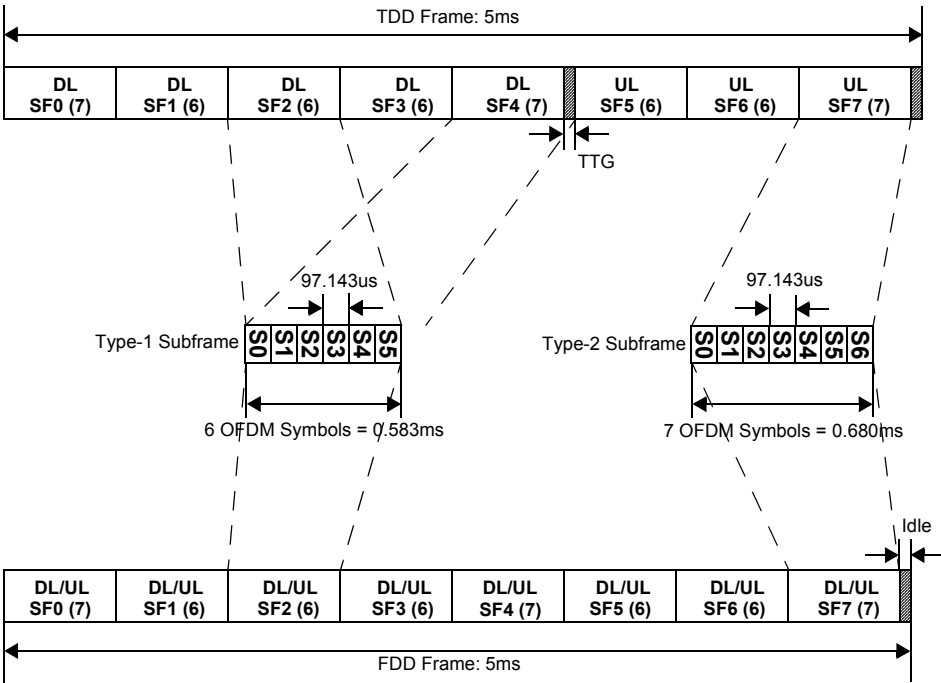
TDD and FDD frame structure with a CP of 1/16 T_b (DL to UL ratio of 5:3).

Figure 399—TDD and FDD frame structure

For a channel bandwidth of 7 MHz, a frame shall have seven type-1 subframes for FDD, and six type-1 sub-frames and one type-3 subframes for TDD. In the TDD frame, the subframe preceding a DL to UL switching point is a type-3 subframe.

Figure 400 illustrates an example of TDD and FDD frame structure for the 7 MHz channel bandwidth with a CP of 1/16 Tb. Assuming OFDMA symbol duration of 136 µs and a CP length of 1/16 Tb, the length of type-1 and type-3 subframes are 0.816 ms and 0.680 ms, respectively. TTG and RTG are 180µs and 60µs, respectively.
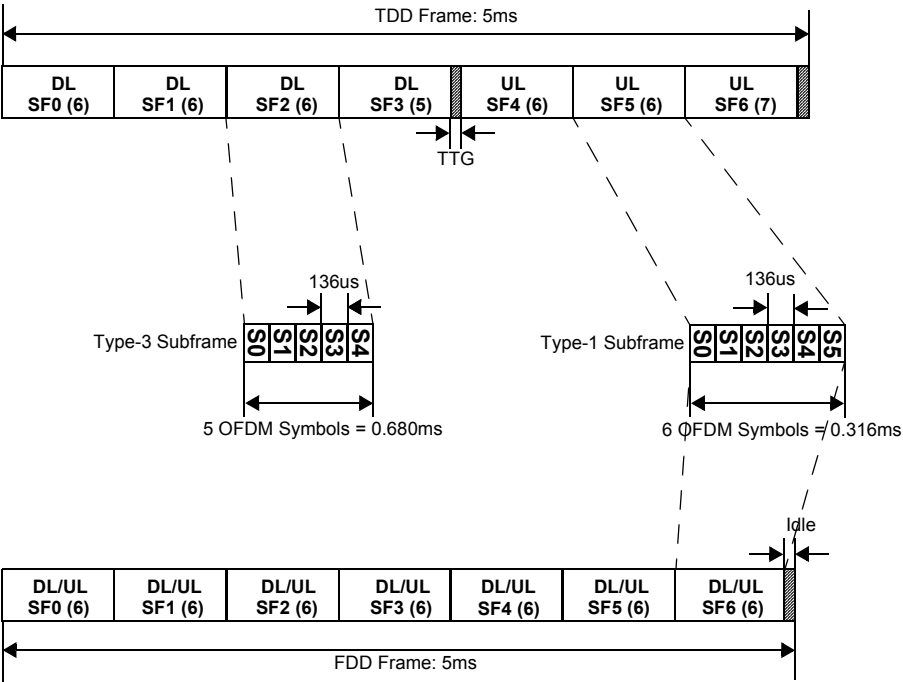
TDD and FDD frame structure for 7MHz channel with a CP of $1/16$ T_b (DL to UL ratio of 4:3).

Figure 400—7 MHz TDD and FDD frame structure

For a channel bandwidth of 8.75 MHz, a frame shall have four type-1 subframes and three type-2 subframes for FDD, and five type-1 subframes and two type-2 subframes for TDD.

In the TDD frame, the first and last subframes within each frame shall be type-2 subframes. In the FDD frame, the first, forth, and last subframe within each frame shall be type-2 subframes.

<<Figure xyy>> illustrates an example of TDD and FDD frame structure for the 8.75 MHz channel bandwidth with a CP of 1/16 Tb. Assuming OFDMA symbol duration of 108.8 μs and a CP length of 1/16 Tb, the length of type-1 and type-2 subframes are 0.6528 ms and 0.7616 ms, respectively. TTG and RTG are 138.4 μs and 74.4μs, respectively.
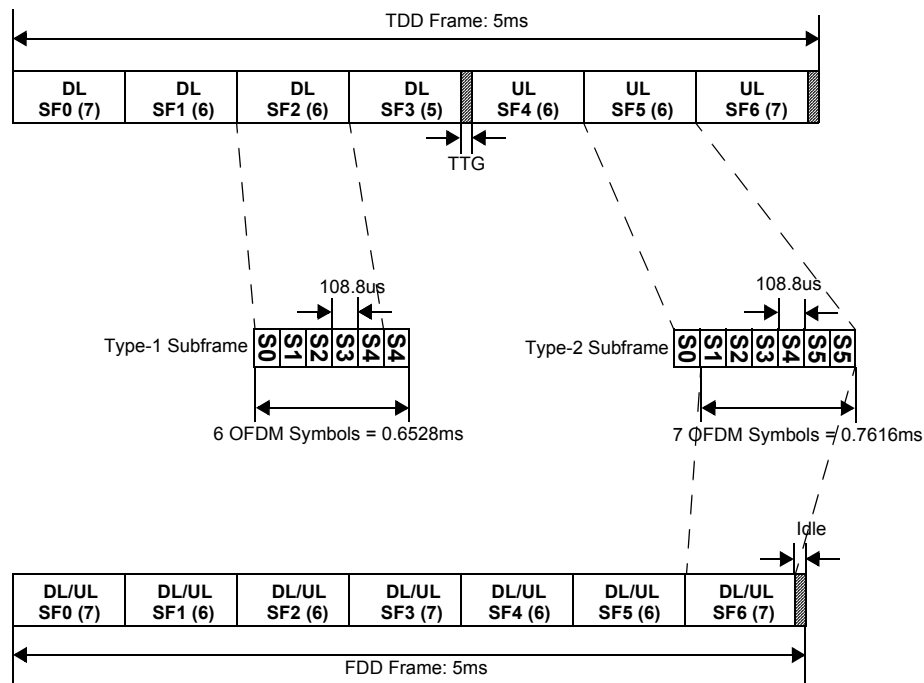
TDD and FDD frame structure for 8.75MHz channel with a CP of 1/16 T_b (DL to UL ratio of 4:3).

Figure 401—8.75 MHz TDD and FDD frame structure

15.3.3.4 Frame structure supporting the WirelessMAN-OFDMA frames

15.3.3.4.1 TDD frame structure

The WirelessMAN-OFDMA and the Advanced Air Interface frames shall be offset by a fixed number of subframes, FRAME_OFFSET = 1,2, … , K as shown in Figure 402 and Figure 403. When the Advanced Air Interface frames support the WirelessMAN-OFDMA for 5, 10, 20MHz channel bandwidths, all subframes in the Advanced Air Interface DL Zone are type-1 subframes. The number of symbols in the WirelessMAN-OFDMA DL Zone is 5+6·(FRAME_OFFSET-1). The maximum value of parameter K is equal to the number of DL subframes minus two. In the case where Advanced Air Interface BSs coexist with WirelessMAN-OFDMA BSs, two switching points shall be selected in each TDD radio frame.

In the DL, a subset of DL subframes is dedicated to the WirelessMAN-OFDMA operation to enable one or more WirelessMAN-OFDMA DL time zones. The subset includes the 1st WirelessMAN-OFDMA DL time zone to support the transmission of the preamble, FCH and MAP, which are defined in 8.4.

Data bursts for the WirelessMAN-OFDMA MSs shall not be transmitted in the DL subframes for operation of the Advanced Air Interface. Those DL subframes shall be indicated as a DL time zone by transmitting an STC_DL_ZONE_IE() with the Dedicated Pilots field set to 1, as defined in Table 328, in the DL-MAP messages.

In the UL, the two configurations are applicable:

1) FDM mode: A group of subcarriers (subchannels), spanning the entire UL transmission, is dedicated to the WirelessMAN-OFDMA operation. The remaining subcarriers, denoted the Advanced Air Interface UL subchannels group and forming the Advanced Air Interface UL subframes, are dedi-

cated to the Advanced Air Interface operation. Figure 402 illustrates an example frame configuration for supporting the WirelessMAN-OFDMA operation when FDM mode is used. In the case of 5, 10, and 20 MHz, all UL subframes are type-1 subframes. In the case of 8.75 MHz with 15 UL OFDM symbols, the [first] UL subframe is type-4 subframe and the [second] UL subframe is type-1 subframe.

Data bursts from the WirelessMAN-OFDMA MSs shall not be transmitted in the UL subchannels group for operation of the Advanced Air Interface. The UL subchannels group for operation of the WirelessMAN-OFDMA shall be indicated by the UL allocated subchannels bitmap TLV or the UL AMC Allocated physical bands bitmap TLV, defined in Table TBD, in the UCD message.
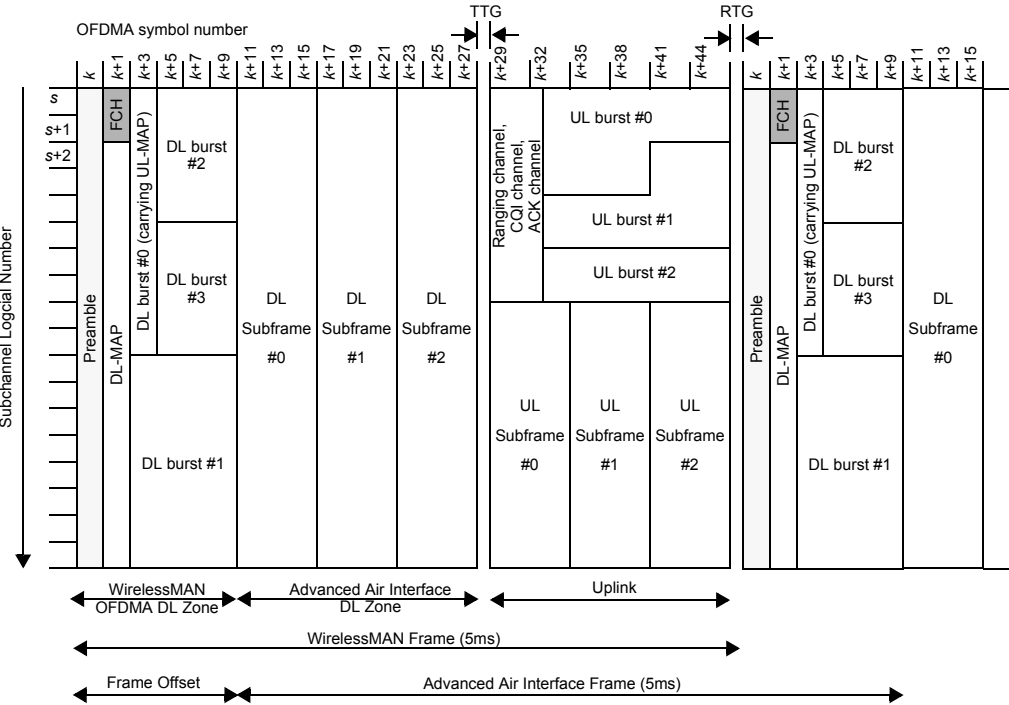
Figure 402—TDD frame configuration for supporting the WirelessMAN-OFDMA operation with UL FDM

2) TDM mode: A subset of UL subframes is dedicated to the WirelessMAN-OFDMA operation to enable one or more WirelessMAN-OFDMA UL time zones. The subset includes the 1st WirelessMAN-OFDMA UL time zone to support the transmission of the ranging channel, CQI channel and ACK channel, which are defined in 8.4. Figure 403 illustrates an example frame configuration for supporting the WirelessMAN-OFDMA operation when TDM mode is used. In the case of 5, 10, 20, and 8.75 MHz, all subframes in the Advanced Air Interface UL Zone are type-1 subframes.

Data bursts from the WirelessMAN-OFDMA MSs shall not be transmitted in the UL subframes for operation of the Advanced Air Interface. Those UL subframes shall be indicated as a UL time zone by transmitting an UL_ZONE_IE(), defined in Table TBD, in the UL-MAP message.
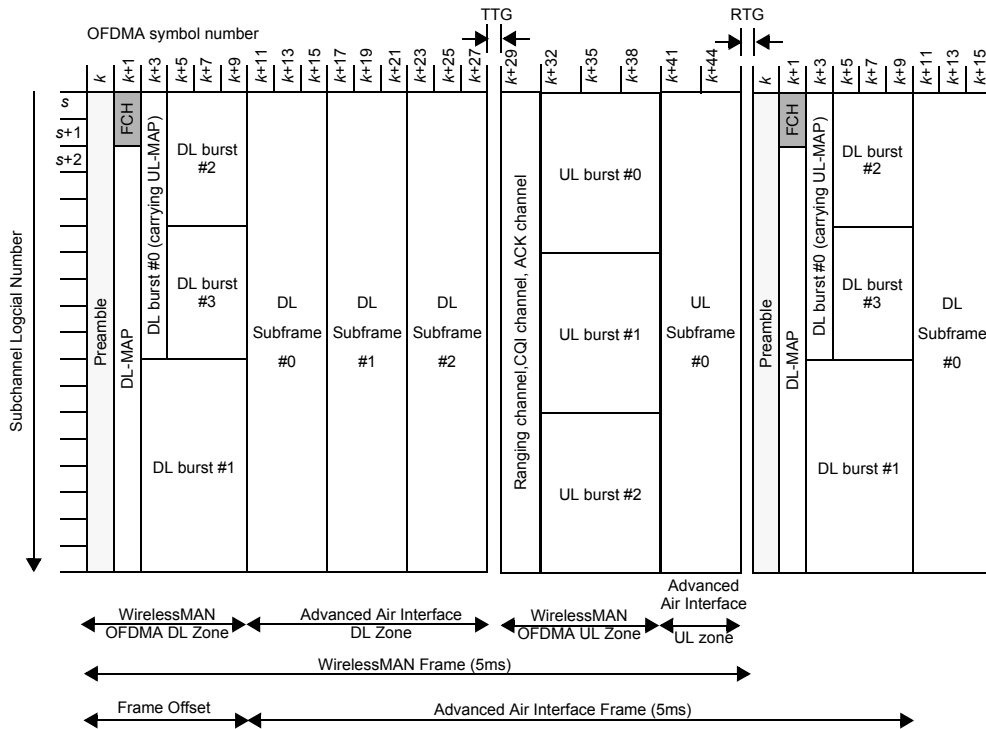
Figure 403—TDD frame configuration for supporting the WirelessMAN-OFDMA operation with UL TDM

15.3.3.4.2 FDD frame structure

15.3.3.5 Frame structure supporting wider bandwidth

The same frame structure (15.3.3.1, 15.3.3.2, 15.3.3.3) is used for each carrier in multi-carrier mode operation. Each carrier shall have its own superframe header. Some carriers may have only part of superframe header. Figure 404 illustrates the example of the frame structure to support multi-carrier operation. For FDD UL, the preamble and superframe headers are replaced with traffic OFDMA symbols.

The multiple carriers involved in multi-carrier operation may be in a contiguous or non-contiguous spectrum. When carriers are in the same spectrum and adjacent and when the separation of center frequency between two adjacent carriers is multiples of subcarrier spacing, no guard subcarriers are necessary between adjacent carriers.

Each MS is controlled through an RF carrier which is the primary carrier. When multi-carrier feature is supported, the system may define and utilize additional RF carriers to improve the user experience and QoS or provide services through additional RF carriers configured or optimized for specific services. These additional RF carriers are the secondary carriers. The detailed description of the multi-carrier operation can be found in (ref TBD).
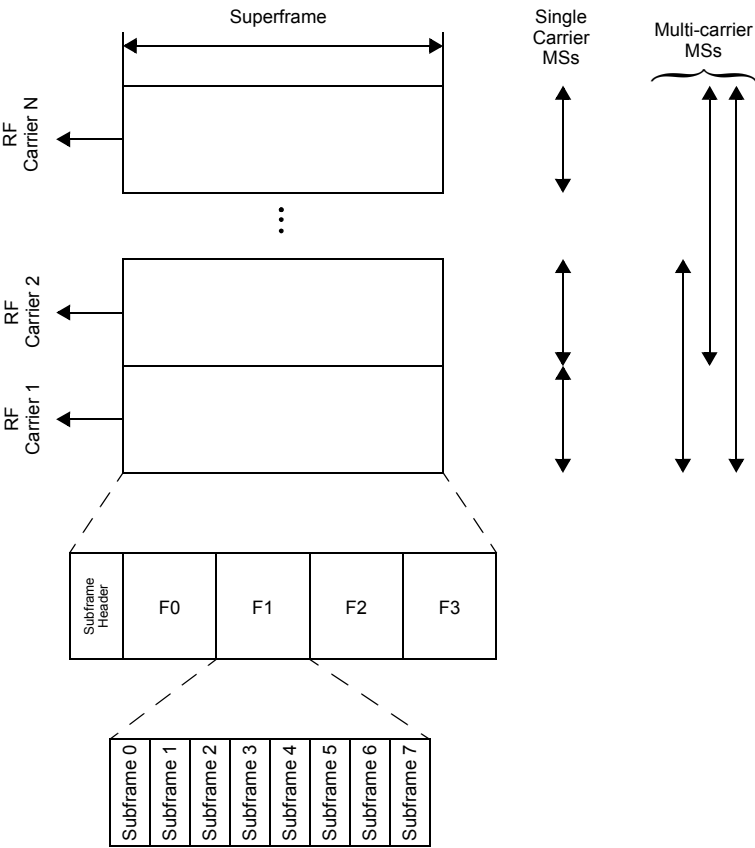
Figure 404—Example of the frame structure to support multi-carrier operation

15.3.3.5.1 Frame structure supporting multi-carrier operation in WirelessMAN-OFDMA support mode

In the multi-carrier mode supporting WirelessMAN-OFDMA, each carrier can have either a basic frame structure (15.3.3.1) or a basic frame structure configured to support the WirelessMAN-OFDMA (15.3.3.3). Figure 405 illustrates an example of the frame structure in the multi-carrier mode supporting WirelessMAN-OFDMA. In the multi-carrier mode, to support WirelessMAN-OFDMA, the uplink can be also configured as TDM as defined 15.3.3.3.

The multi-carrier operation (ref. TBD) is only performed between subframes where the Advanced Air Interface frame is defined. No multi-carrier operation is defined between the Advanced Air Interface frames and WirelessMAN-OFDMA frames.
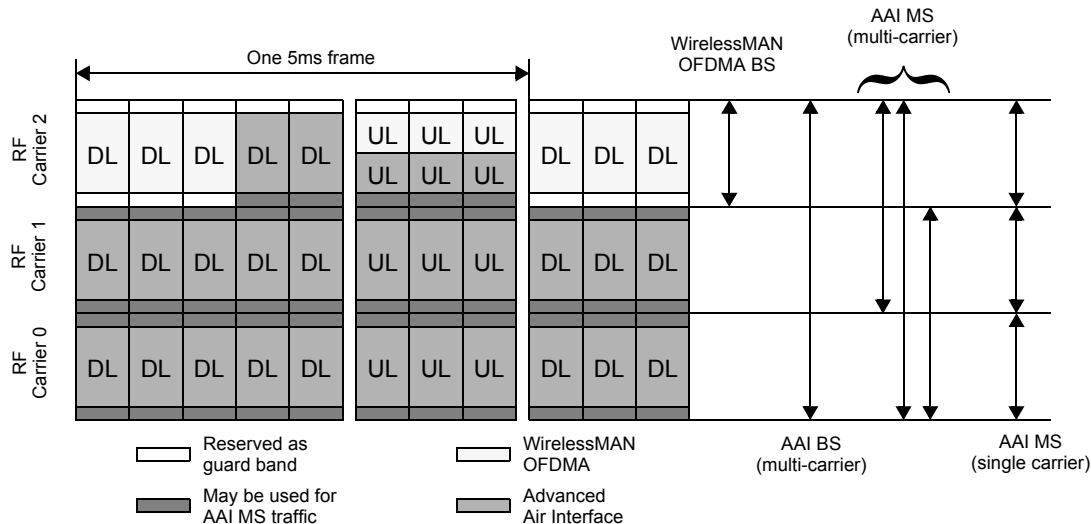
Figure 405—Example of the frame structure to support multi-carrier operation in Wireless-MAN-OFDMA support mode

15.3.3.5.2 Subcarrier alignment for multi-carrier operation

When contiguous carriers are involved in multi-carrier operation, the overlapped guard sub-carriers shall be aligned in frequency domain. In order to align the overlapped sub-carriers of the OFDMA signals transmitted over adjacent carriers, a permanent frequency offset (Δf) will be applied over the original center frequency. The basic principle is shown by the example in Figure 406.
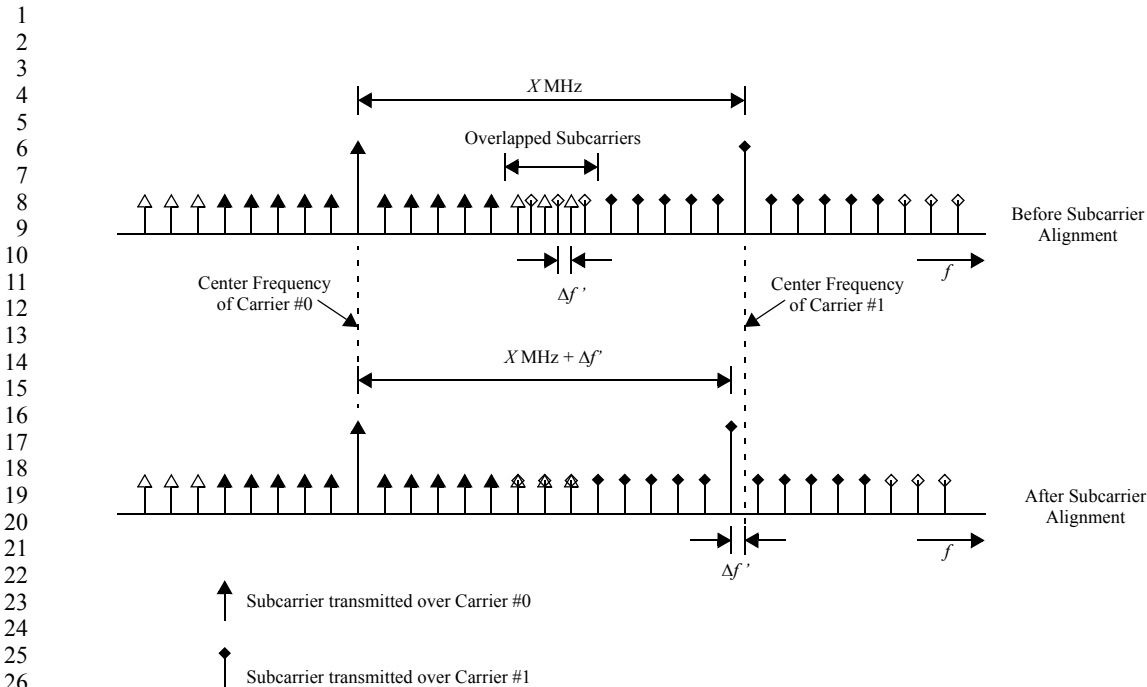
Figure 406—Example of subcarrier alignment of adjacent carriers

During the network entry procedure defined in [TBD], the ABS will notify the AMS of the frequency offset to be applied over each carrier for sub-carrier alignment. According to the multi-carrier configuration index and the reference carrier index broadcasted by ABS, AMS can derive the center frequency of the adjacent carriers and the associated frequency offset $\Delta f'$ using Table 648.

Based on the center frequency of the carrier that AMS is currently receiving this information and the bandwidth of each carrier, the center frequency of each carrier before sub-carrier alignment can be derived. Then the AMS can obtain the frequency offset $\Delta f'$ to be applied over each carrier based on the multi-carrier configuration index, the reference carrier index and Table 648. So that AMS can obtain the correct center frequency of each carrier including the sub-carrier alignment effect.

Table 648—Center frequency of adjacent carriers with subcarrier alignment

#	Multi-Carrier Configuration (MHz)	Reference Carrier Index	Frequency Offset ?f' (kHz)	Contiguous Channel Bandwidth (MHz)
(TBD)				

15.3.3.5.3 Data Transmission over guard subcarriers in multi-carrier operation

When contiguous carriers are involved in multi-carrier operation, the guard sub-carriers between contiguous frequency channels may be utilized for data transmission. During the network entry procedure defined in [TBD], the ABS will notify the information on available guard sub-carriers eligible for data transmission to the AMS.

15.3.3.6 Relay support in frame structure

15.3.4 Reserved

15.3.5 Downlink physical structure

Each downlink subframe is divided into 4 (TBD) or fewer frequency partitions; each partition consists of a set of physical resource units across the total number of OFDMA symbols available in the subframe. Each frequency partition can include contiguous (localized) and/or non-contiguous (distributed) physical resource units. Each frequency partition can be used for different purposes such as fractional frequency reuse (FFR) or multicast and broadcast services (MBS). Figure 407 illustrates the downlink physical structure in the example of two frequency partitions with frequency partition 2 including both contiguous and distributed resource allocations.
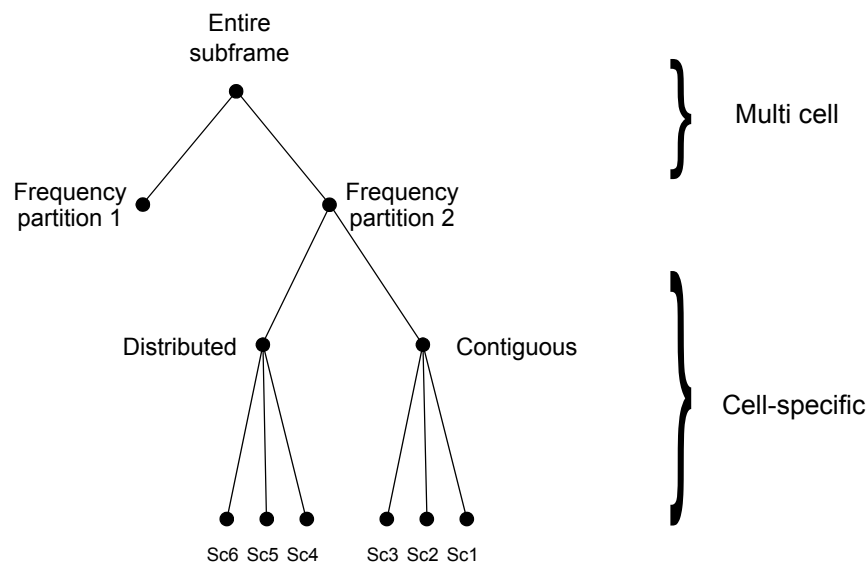
Figure 407—Example of downlink physical structure

15.3.5.1 Physical and logical resource unit

A physical resource unit (PRU) is the basic physical unit for resource allocation that comprises P_{sc} consecutive subcarriers by N_{sym} consecutive OFDMA symbols. P_{sc} is 18 subcarriers and N_{sym} is 6 OFDMA symbols for type-1 subframes, N_{sym} is 7 OFDM symbols for type-2 sub frames, and N_{sym} is 5 OFDMA symbols for type-3 subframes. A logical resource unit (LRU) is the basic logical unit for distributed and localized resource allocations. An LRU is $P_{sc} \cdot N_{sym}$ subcarriers for type-1 subframes, type-2 subframes, and type-3 subframes. The LRU includes the pilots (ref. TBD) that are used in a PRU. The effective number of subcarriers in an LRU depends on the number of allocated pilots.

15.3.5.1.1 Distributed resource unit

The distributed resource unit (DRU) contains a group of subcarriers which are spread across the distributed resource allocations within a frequency partition. The size of the DRU equals the size of PRU, i.e., P_{sc} subcarriers by N_{sym} OFDMA symbols. The minimum unit for forming the DRU is equal to a pair of subcarriers, called tone-pair, as defined in (ref. TBD).

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15.3.5.1.2 Contiguous resource unit

The localized resource unit, also known as contiguous resource unit (CRU) contains a group of subcarriers which are contiguous across the localized resource allocations. The size of the CRU equals the size of the PRU, i.e., P_{sc} subcarriers by N_{sym} OFDMA symbols.

15.3.5.2 Multi-cell resource mapping

15.3.5.2.1 Subband partitioning

The PRUs are first subdivided into subbands and minibands where a subband comprises N_1 adjacent PRUs and a miniband comprises N_2 adjacent PRUs, where N_1=4 and N_2=1. Subbands are suitable for frequency selective allocations as they provide a contiguous allocation of PRUs in frequency. Minibands are suitable for frequency diverse allocation and are permuted in frequency.

The number of subbands reserved is denoted by K_{SB}. The number of PRUs allocated to subbands is denoted by L_{SB}, where $L_{SB} = N_1 \cdot K_{SB}$, depending on system bandwidth. A 4 or 3-bit (TBD) field called Subband Allocation Count (SAC) field determines the value of K_{SB}. The SAC is transmitted in the SFH. The remainder of the PRUs are allocated to minibands. The number of minibands in an allocation is denoted by K_{MB}. The number of PRUs allocated to minibands is denoted by L_{MB}, where $L_{MB} = N_2 \cdot K_{MB}$. The total number of PRUs is denoted as N_{PRU} where $N_{PRU} = L_{SB} + L_{MB}$. The maximum number of subbands that can be formed is denoted as N_{sub} where $N_{sub} = N_{PRU}/N_1$.

Table 649 and Table 650 show the mapping between SAC and KSB for the 10 and 20MHz bands and the 5MHz band, respectively.

Table 649—Mapping between SAC and KSB for 10MHz or 20MHz

SAC	# of subbands allocated (KSB)	SAC	# of subbands allocated (KSB)
0	0	8	10
1	1	9	12
2	2	10	14
3	3	11	16
4	4	12	18
5	5	13	20
6	6	14	22
7	8	15	24

Table 650—Mapping between SAC and KSB for 5MHz

SAC	# of subbands allocated (KSB)	SAC	# of subbands allocated (KSB)
0	0	4	4
1	1	5	5
2	2	6	6
3	3	7	N.A

PRUs are partitioned and reordered into two groups subband PRUs and miniband PRUs, denoted PRU_{SB} and PRU_{MB}, respectively. The set of PRU_{SB} is numbered from 0 to ($L_{SB} - 1$). The set of PRU_{MB} are numbered from 0 to ($L_{MB} - 1$). Equation (174) defines the mapping of PRUs to PRU_{SB}s. Equation (176) defines the mapping of PRUs to PRU_{MB}s. Figure 408 illustrates the PRU to PRU_{SB} and PRU_{MB} mapping for a 5 MHz bandwidth with K_{SB} equal to 3.

$$PRU_{SB}[j] = PRU[i]; j = 0, 1, …, L_{SB} - 1 \tag{174}$$

where:

$$i = N_1 \cdot \left\{ \left\lceil \frac{N_{sub}}{K_{SB}} \right\rceil \cdot \left\lfloor \frac{j}{N_1} \right\rfloor + \left\lfloor \left\lfloor \frac{j}{N_1} \right\rfloor \cdot \frac{GCD(N_{sub}, \lceil N_{sub}/K_{SB} \rceil)}{N_{sub}} \right\rfloor \right\} \mod(N_{sub}) + j \cdot \mod(N_1) \tag{175}$$

where x mod y is modulus when dividing x by y, and $GCD(x,y)$ is the greatest common divisor of x and y.

$$PRU_{MB}[k] = PRU[i]; k = 0, 1, …, L_{MB} - 1 \tag{176}$$

where:

$$i = N_1 \cdot \left\{ \left\lceil \frac{N_{sub}}{K_{SB}} \right\rceil \cdot \left\lfloor \frac{k + L_{SB}}{N_1} \right\rfloor + \left\lfloor \left\lfloor \frac{k + L_{SB}}{N_1} \right\rfloor \cdot \frac{GCD(N_{sub}, \lceil N_{sub}/K_{SB} \rceil)}{N_{sub}} \right\rfloor \right\} \mod(N_{sub}) + (k + L_{SB}) \cdot \mod(N_1)$$

$$\tag{177}$$

where $GCD(x,y)$ is the greatest common divisor of x and y.

(a) PRU to PRU$_{MB}$ mapping   **(b) PRU to PRU$_{SB}$ mapping**
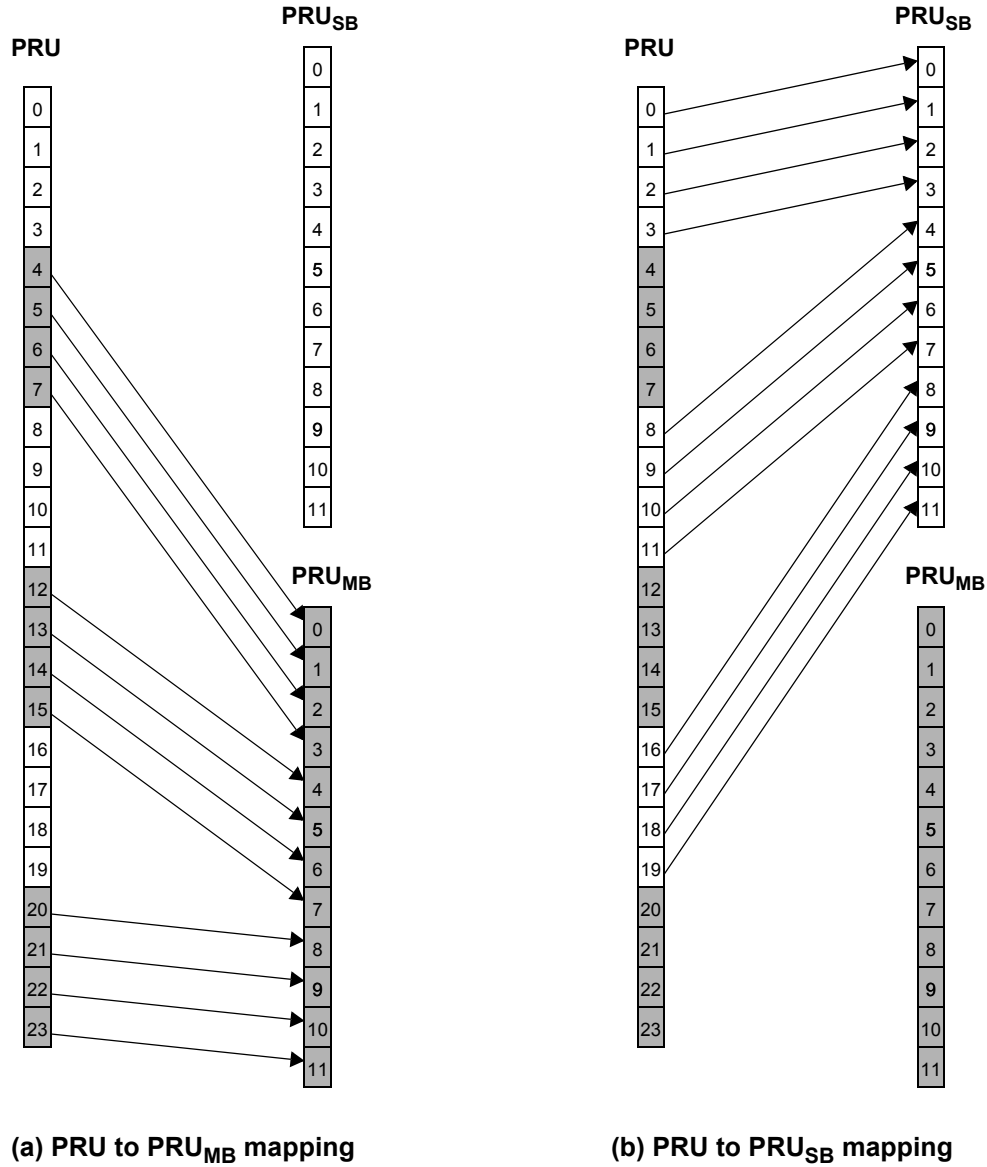
Figure 408—PRU to PRU$_{SB}$ and PRU$_{MB}$ mapping for BW=5 MHz, K$_{SB}$=3

15.3.5.2.2 Miniband permutation

The miniband permutation maps the PRU$_{MB}$s to Permuted PRU$_{MB}$s (PPRU$_{MB}$s) to insure frequency diverse PRUs are allocated to each frequency partition. Equation (178) provides a mapping from PRU$_{MB}$ to PPRU$_{MB}$s:

$$PPRU_{MB}[j] = PRU_{MB}[i]; j = 0, 1, \ldots, L_{MB} - 1 \tag{178}$$

$$i = (q(j) \bmod(D)) \cdot P + \left\lfloor \frac{q(j)}{D} \right\rfloor, j = 0, 1, 2, \ldots, K_{MB} - 1 \tag{179}$$

where:

$$P = min(K_{MB}, N_1/N_2)$$

$$r(j) = max(j - (K_{MB} \bmod(P \cdot D)), 0)$$

$$q(j) = j + \left\lfloor \frac{r(j)}{D-1} \right\rfloor, D = \left\lfloor \frac{K_{MB}}{P} + 1 \right\rfloor$$

Figure 409 depicts the mapping from PRUs to PRU$_{SB}$ and PPRU$_{MB}$.
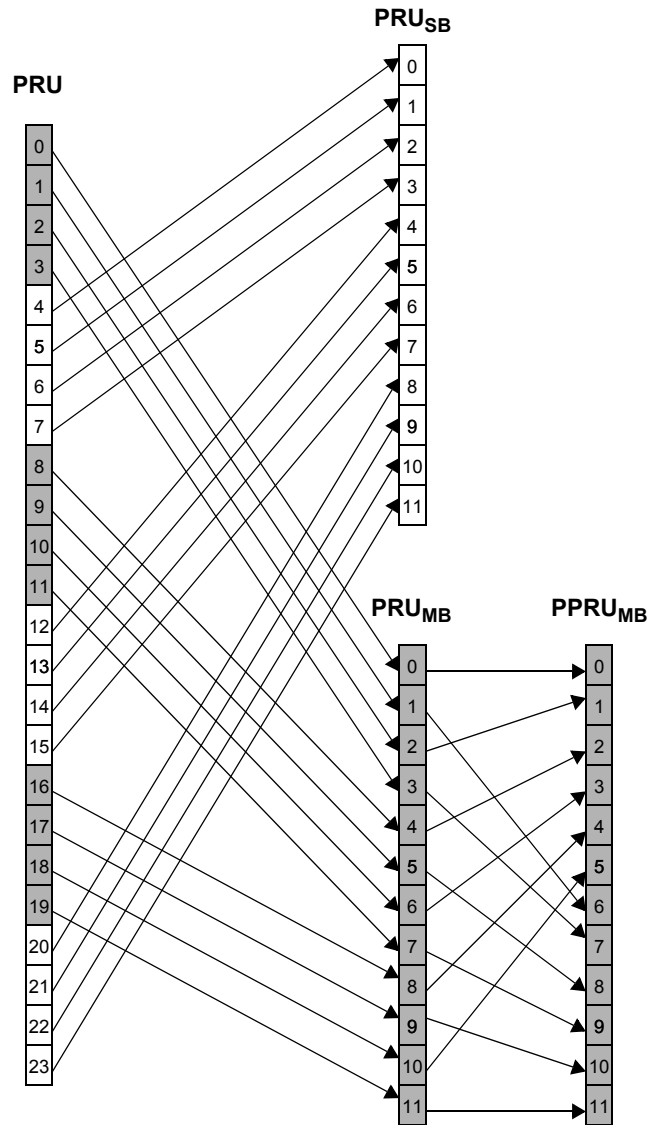
Figure 409—Mapping from PRUs to PRU$_{SB}$ and PPRU$_{MB}$ for BW=5 MHz, K$_{SB}$=3

15.3.5.2.3 Frequency partitioning

The PRU_{SB} and $PPRU_{MB}$ are allocated to one or more frequency partitions. By default, only one partition is present. The maximum number of frequency partitions is 4 (TBD). The frequency partition configuration is transmitted in the SFH in a 4 (or 3-bit) called the Frequency Partition Configuration (FPC) depending on system bandwidth. Frequency Partition Count (FPCT) defines the number of frequency partitions. Frequency Partition Size (FPS_i) defines the number of PRUs allocated to FP_i. FPCT and FPS_i are determined from FPC as shown in Table 651 and Table 652. The 3 bits carry the Frequency Parition Subband Count (FPSC) which defines the number of subbands allocated to FP_i, i>0.

Table 651—Mapping between FPC and frequency partitioning for 10MHz or 20MHz

FPC	Freq. Partitioning (FP0:FP1:FP2:FP3)	FPCT	FPS_0	FPS_i (i>0)
0	1 : 0 : 0 : 0	1	N_{PRU}	0
1	0 : 1 : 1 : 1	3	0	$N_{PRU} * 1/3$
2	1 : 1 : 1 : 1	4	$N_{PRU} * 1/4$	$N_{PRU} * 1/4$
3	3 : 1 : 1 : 1	4	$N_{PRU} * 3/6$	$N_{PRU} * 1/6$
4	5 : 1 : 1 : 1	4	$N_{PRU} * 5/8$	$N_{PRU} * 1/8$
5	9 : 1 : 1 : 1	4	$N_{PRU} * 9/12$	$N_{PRU} * 1/12$
6-15	*Reserved*			

Table 652—Mapping between FPC and frequency partitioning for 5Mhz

FPC	Freq. Partitioning (FP0:FP1:FP2:FP3)	FPCT	FPS_0	FPS_i (i>0)
0	1 : 0 : 0 : 0	1	N_{PRU}	0
1	0 : 1 : 1 : 1	3	0	$N_{PRU} * 1/3$
2	1 : 1 : 1 : 1	4	$N_{PRU} * 1/4$	$N_{PRU} * 1/4$
3	3 : 1 : 1 : 1	4	$N_{PRU} * 3/6$	$N_{PRU} * 1/6$
4	5 : 1 : 1 : 1	4	$N_{PRU} * 5/8$	$N_{PRU} * 1/8$
5-7	*Reserved*			

A 4 or 3-bit (TBD) field called Uplink Subband Allocation Count (USAC) determines the value of KSB depending on system bandwidth.

The number of subbands in i^{th} frequency partition is denoted by $K_{SB,FPi}$. The number of minibands is denoted by $K_{MB,FPi}$, which is determined by FPS and FPSC fields. The number of subband PRUs in each frequency partition is denoted by $L_{SB,FPi}$, which is given by $L_{SB,FPi} = N_I \cdot K_{SB,FPi}$. The number of miniband PRUs in each frequency partition is denoted by $L_{MB,FPi}$, which is given by $L_{MB,FPi} = N_2 \cdot K_{MB,FPi}$.

$$K_{SB,FP_i} = \begin{cases} K_{SB} - (FPCT - 1) \cdot FPSC & i = 0 \\ FPSC & i > 0 \end{cases} \tag{180}$$

$$K_{MB,FP_i} = \begin{cases} K_{MB} - (FPCT - 1) \cdot \left(FPS - \dfrac{FPSC \cdot N_1}{N_2} \right) & i = 0 \\ FPS - \dfrac{FPSC \cdot N_1}{N_2} & i > 0 \end{cases} \tag{181}$$

The mapping of subband PRUs and miniband PRUs to the frequency partition is given by Equation (182):

$$PRU_{FP_i}(j) = \begin{cases} PRU_{SB}(k_1) & \text{for } 0 \le j < L_{SB,FP_i} \\ PPRU_{MB}(k_2) & \text{for } L_{SB,FP_i} \le j < (L_{SB,FP_i} + L_{MB,FP_i}) \end{cases} \tag{182}$$

where

$$k_1 = \sum_{m=0}^{i-1} L_{SB,FP_m} + j$$

and

$$k_2 = \sum_{m=0}^{i-1} L_{MB,FP_m} + j - L_{SB,FP_i}.$$

Figure 410 depicts the frequency partitioning BW=5 MHz, K_{SB}=3, FPCT=2, FPS=12, and FPSC=1.
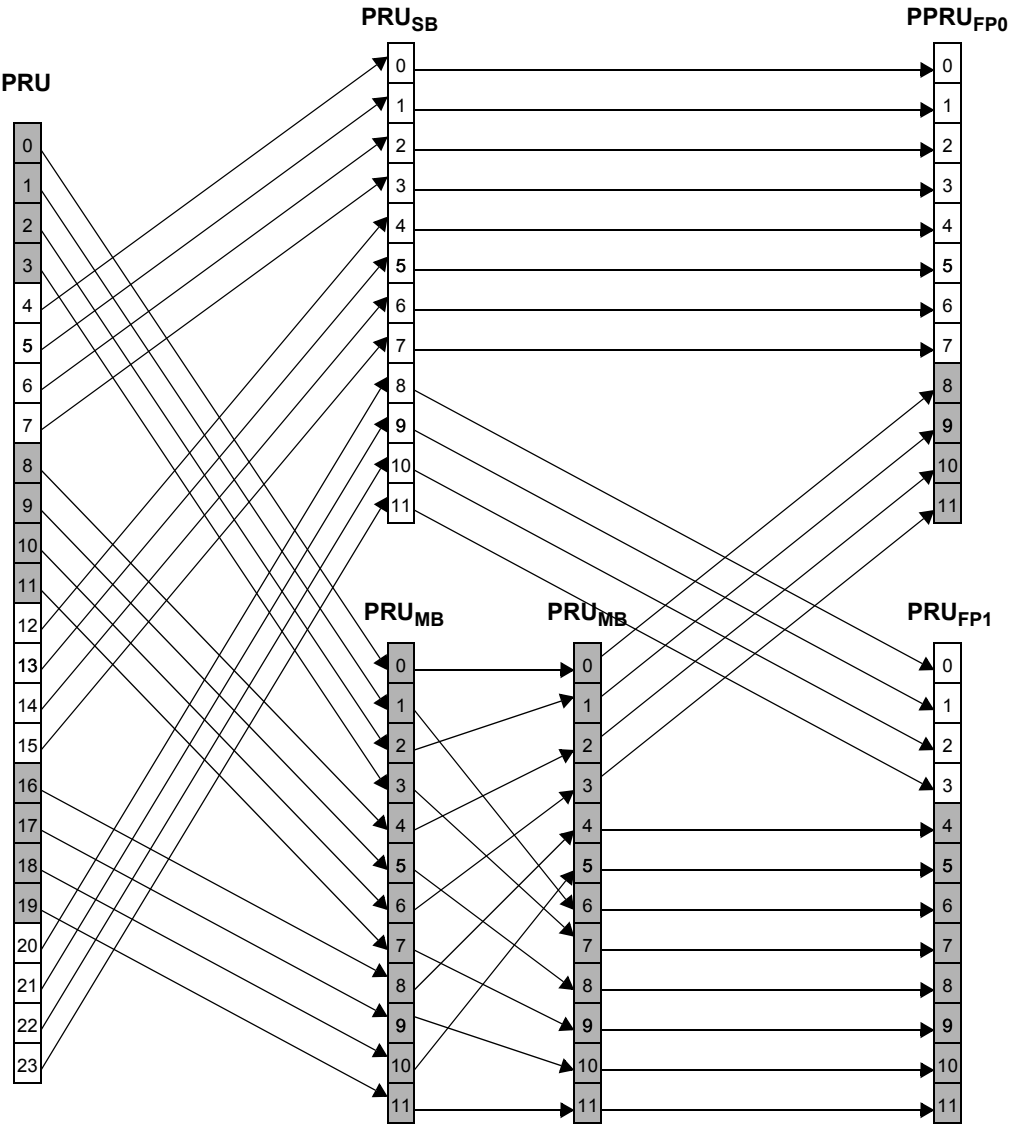
Figure 410—Frequency partitioning: BW=5MHz, SAC=3, FPCT=2, FPS=12, FPSC=1

15.3.5.3 Cell-specific resource mapping

PRU_{FPi}s are mapped to LRUs.   All further PRU and subcarrier permutation are constrained to the PRUs of a frequency partition.

15.3.5.3.1 CRU/DRU allocation

The partition between CRUs and DRUs is done on a sector specific basis. 4-bit subband-based CRU allocation size (CAS_{SBi}) field is sent in the SFH for each allocated frequency partition. CAS_{SBi} indicates the num-

ber of allocated CRUs for partition FPi in a unit of subband size. A [6]-bit miniband-based CRU allocation size (CAS_{MB}) is sent in the SFH only for partition FP0, which indicates the number of allocated miniband-based CRUs for partition FP0.

The number of CRUs in each frequency partition is denoted by $L_{CRU,FPi}$, where

$$L_{CRU, FP_i} = \begin{cases} CAS_{SB,i} \cdot N_1 + CAS_{MB} \cdot N_2 & i=0 \\ CAS_{SB,i} \cdot N_1 & 0 < i < FPCT \end{cases} \tag{183}$$

The number of DRUs in each frequency partition is denoted by $L_{DRU,FPi}$, where $L_{DRU,FP_i} = FPS_i \cdot N_2 - L_{CRU,FPi}$ for $0 \le i < FPCT$ and FPS_i is the number of PRUs allocated to *FPi* in the number of minibands.

The mapping of PRU_{FPi} to CRU_{FPi} is given by:

$$CRU_{FPi}[j] = \begin{cases} PRU_{FPi}[j], & 0 \le j < CAS_{SB,i} \cdot N_1 \\ PRU_{FPi}[k + CAS_{SB,i} \cdot N_1], & CAS_{SB,i} \cdot N_1 \le j < L_{CRU,FPi} \end{cases} \quad 0 \le i < FPCT \tag{184}$$

where $k = s[j - CAS_{SB,i} \cdot N_1] \cdot s[]$ is the CRU/DRU allocation sequence defined in Equation (185) and $0 <= s[j] < FPS_i \cdot N_2 - CAS_{SB,i} \cdot N_1$.

$$s[j] = \{PermSeq(j) + DL\_PermBase\} mod(FPS_i \cdot N_2 - CAS_{SB} \cdot N_1), \tag{185}$$

where *PermSeq*() is the permutation sequence of length ($FPS_i \cdot N_2 - CAS_{SB,i} \cdot N_1$) and is determined by SEED = {*IDcell**1367} mod 210. The permutation sequence is generated by the random sequence generation algorithm specified in Section <<15.3.5.3.4>>. *DL_PermBase* is an interger ranging from 0 to 31(TBD), which is set to preamble *IDcell*.

The mapping of PRU_{FPi} to DRU_{FPi} is given by:

$$DRU_{FP_i}[j] = PRU_{FP_i}[k + CAS_{SB,i} \cdot N_1], \; 0 \le j < L_{DRU,FP_i} \tag{186}$$

where $k = s^c[j] \cdot s^c[]$ is the sequence which is obtained by renumbering the remainders of the PRUs which are not allocated for CRU from 0 to $L_{DRU,FPi} - 1$.

15.3.5.3.2 Subcarrier permutation

The subcarrier permutation defined for the DL distributed resource allocations within a frequency partition spreads the subcarriers of the DRU across the whole distributed resource allocations. The granularity of the subcarrier permutation is equal to a pair of subcarriers.

After mapping all pilots, the remainders of the used subcarriers are used to define the distributed LRUs. To allocate the LRUs, the remaining subcarriers are paired into contiguous tone-pairs. Each LRU consists of a group of tone-pairs.

Let $L_{SC,l}$ denote the number of data subcarriers in *l-th* OFDMA symbol within a PRU, i.e., $L_{SC,l} = P_{sc} - n_l$, where n_l denotes the number of pilot subcarriers in the *l*-th OFDMA symbol within a PRU. Let $L_{SP,l}$ denote the number of data subcarrier-pairs in the lth OFDMA symbol within a PRU and is equal to $L_{SC,l}/2$. A permutation sequence *PermSeq*() is defined by (TBD) to perform the DL subcarrier permutation as follows:

For each *l*-th OFDMA symbol in the subframe:

1) Allocate the n_l pilots within each DRU as described in section (TBD). Denote the data subcarriers of $DRU_{FPi}[j]$ in the lth OFDMA symbol as $SC_{DRUi,l,LFPi}$, $0 \le j < L_{DRU,FPi}$, which are numbered from 0 to $L_{SC,l}$-1.

2) Renumber the $L_{DRU,FPi} \cdot L_{SC,l}$ data subcarriers of the DRUs in order, from 0 to $L_{DRU,FPi} \cdot L_{SC,l}$ - 1. Group these contiguous and logically renumbered subcarriers into $L_{DRU,FPi} \cdot L_{SP,l}$ pairs and renumber them from 0 to $L_{DRU,FPi} \cdot L_{SP,l}$ - 1. The renumbered subcarrier pairs in the *l*-th OFDMA symbol are denoted by $RSP_{l,FPi}$.

$$RSP_{l,FPi}[u] = \{SC_{DRUj,l,FPi}[2v], SC_{DRUj,l,FPi}[2v+1]\}, \qquad 0 \le u < L_{DRU,FPi} \cdot L_{SP}$$

where $j = \lfloor u/L_{SP,l} \rfloor$ and $v = \{u\}mod(L_{SP,L})$.

3) Apply the subcarrier permutation formula Equation (187) to the $RSP_{l,FPi}$ to form the permuted subcarrier pairs (PSP) from 0 to $L_{DRU,FPi} \cdot L_{pair,1}$ - 1. Map PSP $[s \cdot L_{SP,l}, (s+1) \cdot L_{SP,l}$ - 1] into the sth distributed LRUs $s = 0,1,..., L_{DRU,FPi}$ - 1. The subcarrier permutation formula is given by

$$SC_{LRUs,l,FPi}[m] = RSP_{l,FPi}[k] \qquad 0 \le m \le L_{SP,l} \tag{187}$$

where

$$k = L_{DRU,FPi} \cdot f(m,s) + g(PermSeq(),s,m,l,t)$$

$SC_{LRUs,l,FPi}[m]$ is the mth subcarrier pair ($0 \le m < L_{SP,l}$) in the lth OFDMA symbol ($0 \le l < N_{sym}$) in the sth distributed LRU of the tth subframe; *t* is the subframe index with respect to the frame, *s* is the distributed LRU index ($0 \le s < L_{DRU,FPi}$). *PermSeq*() is the permutation sequence of length $L_{DRU,FPi}$ and is determined by SEED=(*IDcell* * 1367) mod 2^{10}. The permutation sequence is generated by the random sequence generation algorithm specified in Section <<15.3.5.3.4>>. *g*(*PermSeq*(),*s,m,l,t*) is a function with value from the set [0, $L_{DRU,FPi}$ - 1], which is defined according to Equation (188).

$$g(PermSeq(),s,m,l,t) = (PermSeq(f(m,s)+s+l)mod(L_{DRU,FPi}) + DL\_PermBase)mod(L_{DRU,FPi}) \tag{188}$$

where *DL_PermBase* is an integer ranging from 0 to 31(TBD), which is set to preamble *IDcell*, and $f(m,s) = (m+13*s) \bmod L_{SP}$.

15.3.5.3.3 Random sequence generation

The permutation sequence generation algorithm with 10-bit SEED (Sn-10, Sn-9,…,Sn-1) shall generate a permutation sequence of size *M* by the following process:

1) Initialization

a) Initialize the variables of the first order polynomial equation with the 10-bit seed, SEED.

   Set d_1 = floor(SEED/2^5) + 1 and d^2 = SEED mod 2^5.

b) Initialize the maximum iteration number, *N*=4.

c) Initialize an array A with size *M* with the numbers 0, 1, … , *M*-1 (i.e. A[0]=0, A[1]=1, … , A[*M*-1]=*M*-1).

d) Initialize the counter *i* to *M*-1.

e) Initialize *x* to -1.

2) Repeat the following steps if *i* > 0

a) Initialize the counter *j* to 0.

b) Repetition loop as follows,

c) Increment *x* and *j* by 1.

d) Calculate the output variable of *y* = {(d_1*x + d_2) mod 1031} mod *M*.

e)   Repeat the above step a. and b., if $y>i$ and $j<N$.

f)   If $y > i$, set $y = y$ mod i.

g)   Swap the ith and the yth elements in the array (i.e. perform the steps Temp= A[i], A[i]=A[y], A[y]=Temp).

h)   Decrement i by 1.

3)   *PermSeq*[i] = A[i], where $0<=i<M$.

15.3.5.3.4 Formation of MLRU

To form MLRUs for the assignment A-MAP,

1)   Renumber all tone pairs in the distributed LRUs in the A-MAP region in a time first manner. Since each LRU has 8 tone-pairs per symbol, the renumbered A-MAP tone-pairs are denoted by $RMP[u]$, where u ranges from 0 to $L_{AMAP} \cdot N_{sym} \cdot 8 - 1$.

2)   A distributed tone-pair, $SC_{LRUs,l,FPi}[m]$, is mapped to $RMP[u]$, where $u = s \cdot N_{sym} \cdot 8 + m \cdot N_{sym} + l$. $SC_{LRUs,l,FPi}[m]$ is the tone-pair index of the mth tone-pair in the lth OFDMA symbol in the sth distributed LRU of frequency partition i as defined in Section <<15.3.5.3.3>>.

3)   Suppose $RMP[v]$ is the first tone-pair for allocation A-MAP. The kth MLRU is formed by tone-pairs from $RMP[v + k \cdot N_{MLRU} / 2]$ to $RMP[v + (k+1) \cdot N_{MLRU} / 2 - 1]$, where N_{MLRU} is the size of MLRU.

15.3.5.3.5 Logical Resource Unit Mapping

Both contiguous and distributed LRUs are supported in the downlink. The CRUs are directly mapped into contiguous LRUs. The DRUs are permuted as described in <<15.3.5.3.3>> to form distributed LRUs.

15.3.5.4 Pilot structure

The transmission of pilot subcarriers in the downlink is necessary for enabling channel estimation, measurements of channel quality indicators such as the SINR, frequency offset estimation, etc. To optimize the system performance in different propagation environments and applications, IEEE 802.16m supports both common and dedicated pilot structures. The categorization in common and dedicated pilots is done with respect to their usage. The common pilots can be used by all MSs. Dedicated pilots can be used with both localized and distributed allocations. The dedicated pilots are associated with a specific resource allocation, can be only used by the MSs allocated to said specific resource allocation, and therefore can be precoded or beamformed in the same way as the data subcarriers of the resource allocation. The pilot structure is defined for up to eight transmission (Tx) streams and there is a unified pilot pattern design for common and dedicated pilots. There is equal pilot density per Tx stream, while there is not necessarily equal pilot density per OFDMA symbol of the downlink subframe. Further, within the same subframe there is equal number of pilots for each PRU of a data burst assigned to one MS.

15.3.5.4.1 Pilot patterns

Pilot patterns are specified within a PRU.

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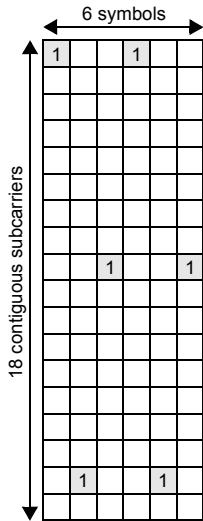
Figure 411—Pilot patterns used for 1 DL data stream

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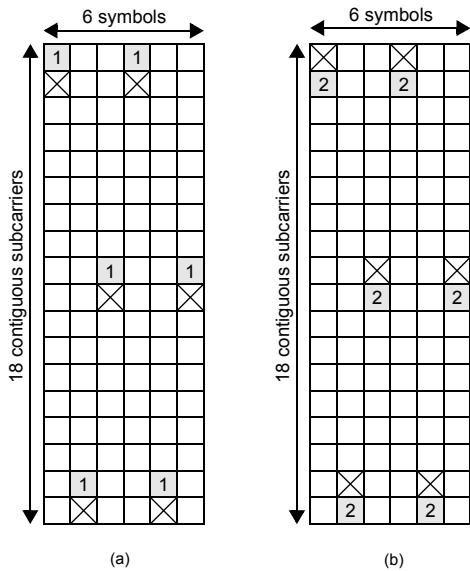
Figure 412—Pilot patterns used for 2 DL data streams

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Base pilot patterns used for one and two DL data streams in dedicated and common pilot scenarios are shown in Figure 411 and Figure 412 respectively, with the subcarrier index increasing from top to bottom and the OFDM symbol index increasing from left to right. The numbers on the pilot locations indicate the stream they correspond to. Subfigure (a) and Subfigure (b) in Figure 412 are used on DL data stream 0 and DL data stream 1, respectively, where 'X' stands for the null symbol, which means that no pilot or data is allocated on that time-frequency resource. For the subframe consisting of 5 symbols, the last OFDM symbol

in the figure is deleted. For the subframe consisting of 7 symbols, the first OFDM symbol in the figure is added as 7th symbol.

The interlaced pilot patterns are generated by cyclic shifting the base pilot patterns. The interlaced pilot patterns are used by different BSs for one and two streams. Interlaced pilot patterns for one stream is shown in Figure 413 and interlaced pilot patterns on stream 0 and stream 1 for two streams are shown in Figure 414 and Figure 415, respectively. Each BS chooses one of the three pilot pattern sets (pilot pattern set 0, 1, and 2) as shown in Figure 413 and Figure 414. The index of the pilot pattern set used by a particular BS with Cell_ID = k is denoted by p_k. The index of the pilot pattern set is determined by the Cell_ID according to the following equation:

$$p_k = mod(k, 3) \tag{189}$$

Figure 413—Interlaced pilot patterns for 1 pilot stream
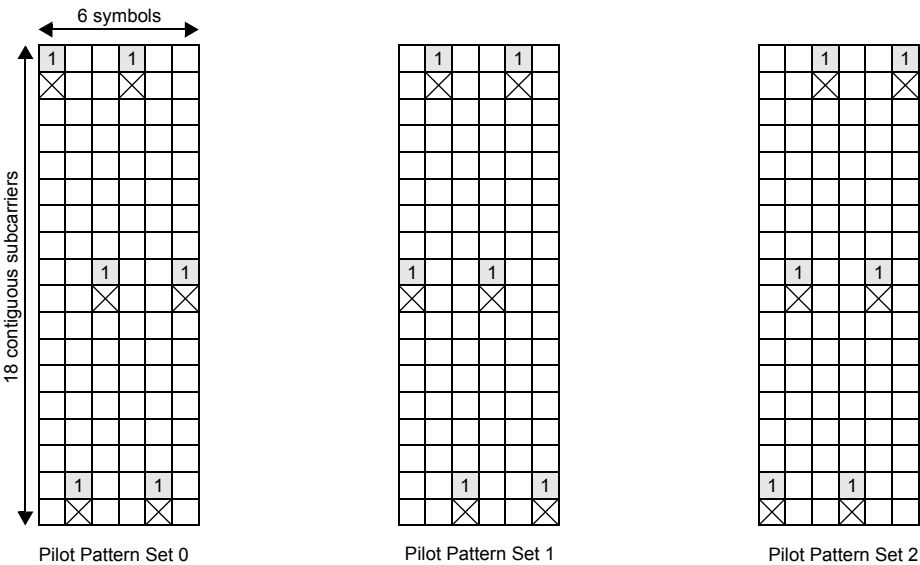
Figure 414—Interlaced pilot patterns on stream 0 for 2 data streams
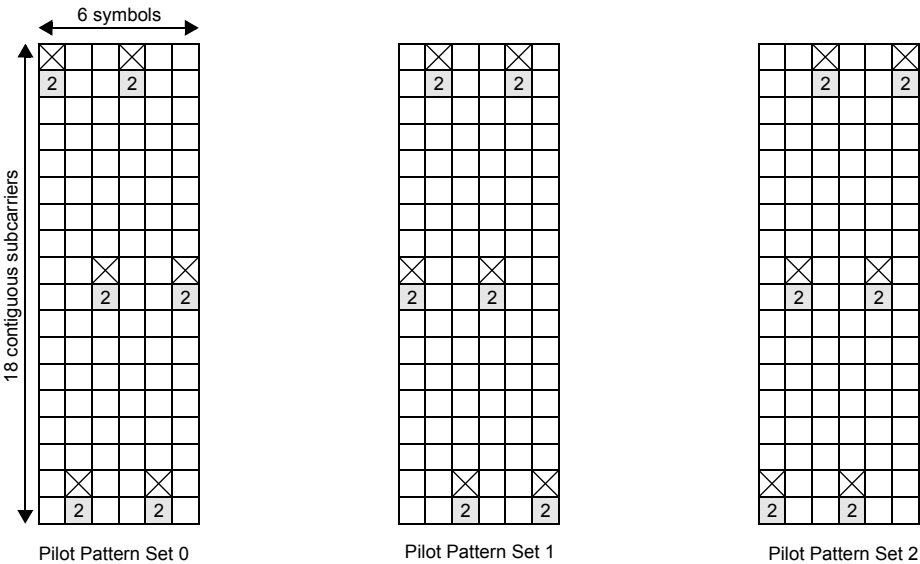
Figure 415—Interlaced pilot patterns on stream 1 for 2 data streams

The pilot patterns on stream 0 - stream 3 for four pilot streams are shown in Figure 416 and Figure 415 respectively, with the subcarrier index increasing from top to bottom and the OFDM symbol index increasing from left to right. Subfigure (a) in Figure 416 and Figure 415 show the pilot pattern for four pilot streams in subframe with six OFDM symbols; Subfigure (b) in Figure 416 and Figure 415 show the pilot pattern for four pilot streams in subframe with five OFDM symbols; Subfigure (c) in Figure 416 and Figure 415 show the pilot pattern for four pilot streams in subframe with seven OFDM symbols.

6 symbols   5 symbols   7 symbols

18 contiguous subcarriers

(a)			(b)			(c)
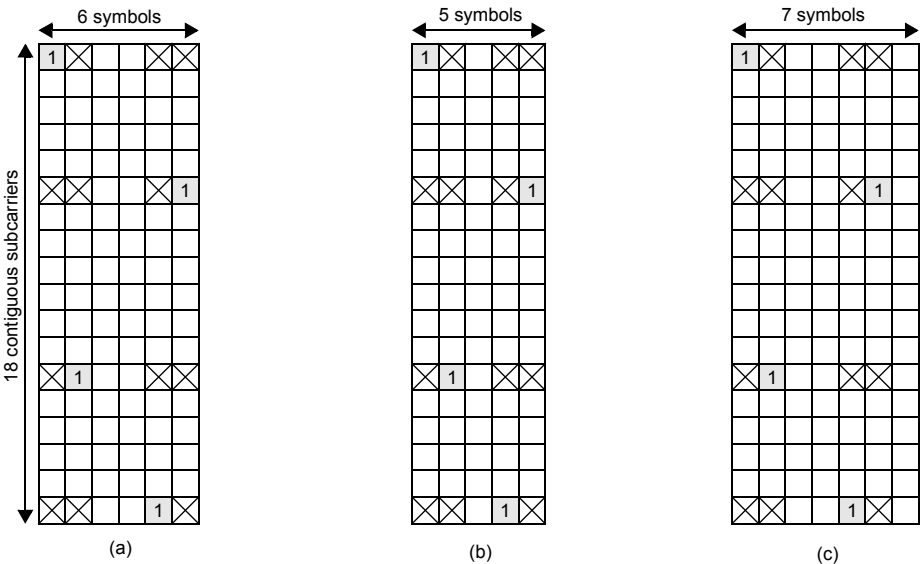
Figure 416—Pilot patterns on stream 0 for 4 data streams

6 symbols   5 symbols   7 symbols

18 contiguous subcarriers

(a)			(b)			(c)
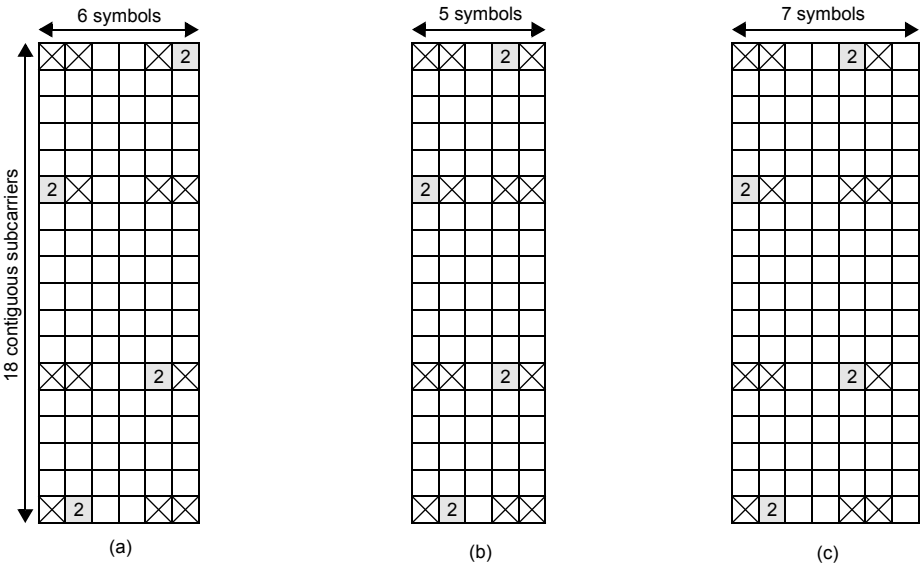
Figure 417—Pilot patterns on stream 1 for 4 data streams

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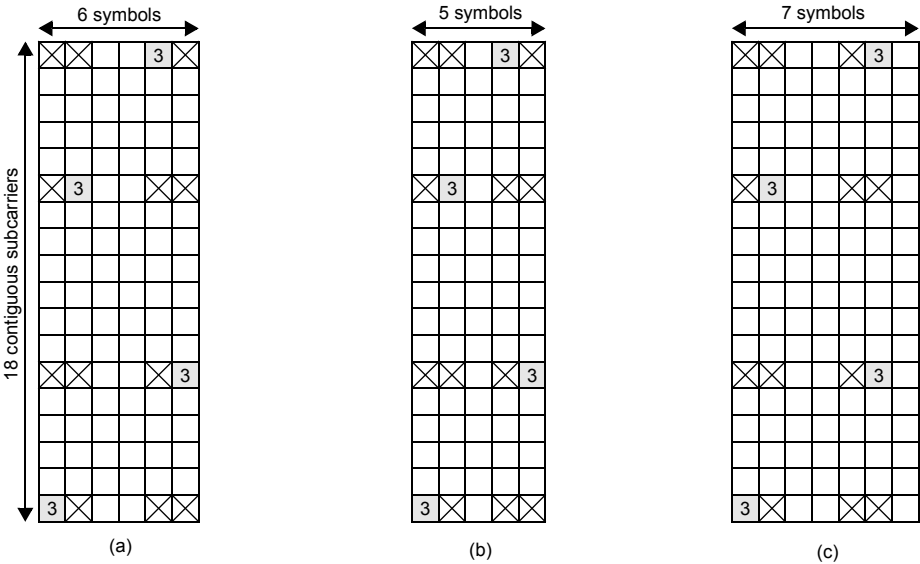
Figure 418—Pilot patterns on stream 2 for 4 data streams
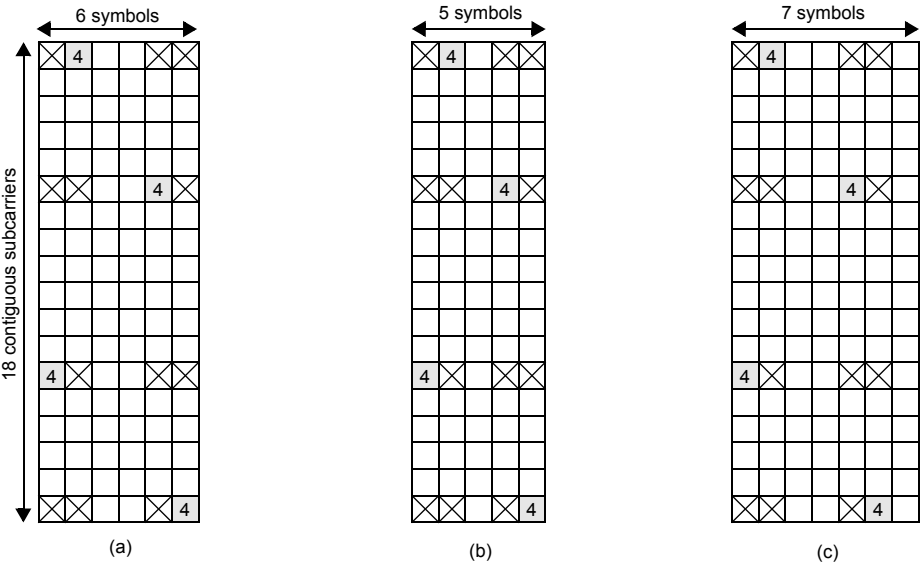
Figure 419—Pilot patterns on stream 3 for 4 data streams

15.3.6 Downlink control structure

15.3.6.1 Advanced Preamble

15.3.6.2 DL Control Channels

DL control channels convey information essential for system operation. Information on DL control channels is transmitted hierarchically over different time scales from the superframe level to the subframe level.

In mixed mode operation (WirelessMAN-OFDMA/Advanced Air Interface), an AMS can access the system without decoding WirelessMAN-OFDMA FCH and MAP messages.

15.3.6.2.1 Superframe Header

The Superframe Header (SFH) carries essential system parameters and system configuration information. The SFH is located in the first subframe within a superframe.

The SFH is TDM with A-Preamble.

The PHY structure for resource allocation of the SFH is described in Section <<15.3.5>>. The SFH is transmitted within a predefined frequency partition called the SFH frequency partition. The SFH frequency partition consists of $N_{PRU,SFH}$ PRUs within a 5 MHz physical bandwidth.

The PRUs in the SFH frequency partition uses the 2 stream pilot pattern defined in <<15.3.5>>. The PRUs in the SFH frequency partition are permuted to generate $N_{PRU,SFH}$ distributed LRUs.

The SFH is divided into two parts: Primary Superframe Header (P-SFH) and Secondary Superframe Header (S-SFH).

Table 653 inludes the parameters and values for resource allocation of the SFH.

Table 653—Parameters and values for resource allocation of SFH

Parameters	Description	Value
$N_{DLRU,SFH}$	The number of distributed LRUs which are occupied by SFH. Note that $N_{DLRU,SFH} = N_{DLRU,P\text{-}SFH} + N_{DLRU,S\text{-}SFH}$	TBD (<= 24 (i.e. 5 MHz))
$N_{DLRU,P\text{-}SFH}$	The number of distributed LRUs which are occupied by P-SFH	Fixed (value is TBD)
$N_{DLRU,S\text{-}SFH}$	The number of distributed LRUs which are occupied by S-SFH	Variable (maximum value is TBD)

If $N_{DLRU,SFH}$ is less than 24, the other DLRUs of the SFH frequency partition are allocated for data or other control transmission.

Figure 420 illustrates an example of the subcarrier to resource unit mapping in the SFH frequency partition when assuming a 10 MHz system bandwidth.
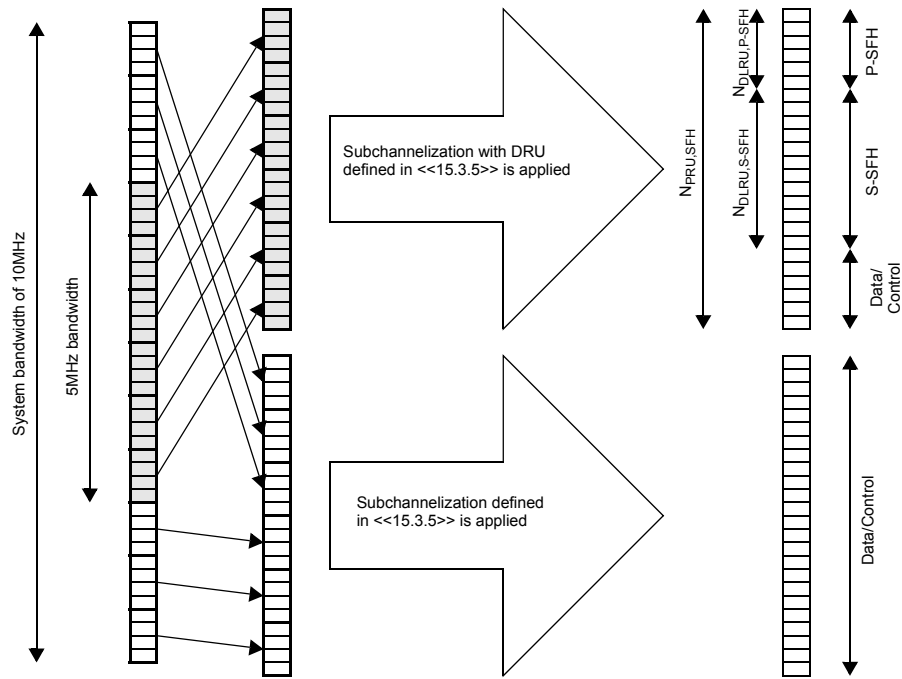
Figure 420—Example of SFH subcarier to resource unit mapping

Figure 2: Example of subcarrier to resource unit mapping in the SFH frequency partition

15.3.6.2.1.1 Primary Superframe Header

The Primary Superframe Header (P-SFH) shall be transmitted in every superframe.

The first $N_{DLRU,P-SFH}$ distributed LRUs of SFH frequency partition are allocated for P-SFH transmission. $N_{DLRU,P-SFH}$ is a fixed value.

15.3.6.2.1.2 Secondary Superframe Header

The Secondary Superframe Header (S-SFH) may be transmitted in every superframe

If the S-SFH is present, the S-SFH shall be mapped to the $N_{DLRU,S-SFH}$ distributed LRUs following the $N_{DLRU,P-SFH}$ distributed LRUs.

The information transmitted in S-SFH is divided into different sub-packets.

15.3.6.2.2 Advanced MAP (A-MAP)

The Advanced MAP (A-MAP) carries unicast service control information. Unicast service control information consists of user-specific control information and non-user-specific control information. User-specific control information is further divided into assignment information, HARQ feedback information, and power control information, and they are transmitted in the assignment A-MAP, HARQ feedback A-MAP, and power control A-MAP, respectively. All the A-MAPs share a region of physical resources called A-MAP region.

A-MAP regions shall be located $N_{\text{subframe,A-MAP}}$ subframes apart in a frame. If an A-MAP region is allocated in subframe i, the next A-MAP region shall be allocated in subframe $i+N_{\text{subframe,A-MAP}}$. In particular, for a frame with $N_{\text{subframe,DL}}$ DL subframes, A-MAP regions shall be present in subframe i, where $i = j \cdot N_{subframe,\,A\text{-}MAP}$ and j is any non-negative integer such that $j \cdot N_{subframe,\,A\text{-}MAP} < N_{subframe,\,DL}$. DL data allocations corresponding to the A-MAP region can correspond to resources in any subframes between successive A-MAP regions. The values of $N_{\text{subframe,A-MAP}}$ can be 1 or 2. Other values of $N_{\text{subframe,A-MAP}}$ (3 and 4) are FFS. For example, for $N_{\text{subframe,A-MAP}} = 2$, an A-MAP region in subframe i can point to resource allocation in subframe i or $i+1$ and the next A-MAP region is in subframe $i+2$.

Figure 421 illustrates the location of a MAP region for $N_{subframe,\text{A-MAP}} = 1$ and 2 cases in the TDD mode.

Figure 421—Example A-map region location in TDD with 4:4 subframe DL:UL split

In the DL subframes where the A-MAP regions can be allocated, each frequency partition may contain an A-MAP region. An A-MAP region, if present, shall occupy the first few distributed LRUs in a frequency partition.

The structure of an A-MAP region is illustrated in the example in Figure 422. The resource occupied by each A-MAP physical channel may vary depending on the system configuration and scheduler operation.

An A-MAP region consists of $L_{\text{A-MAP}}$ distributed LRUs and the LRUs are formed from PRUs with N_{sym} symbols.
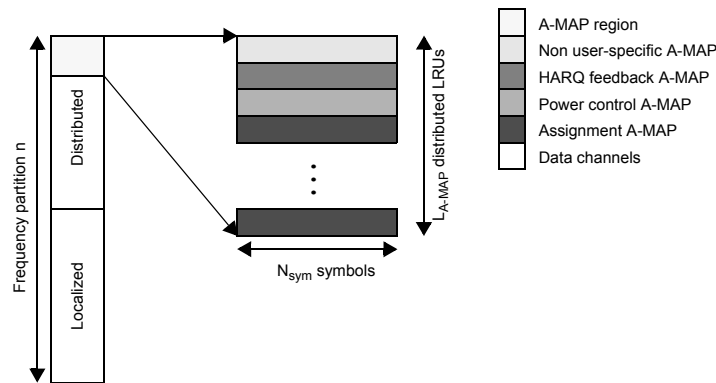
Figure 422—Structure of an A-MAP region

15.3.6.2.2.1 Non-user Specific A-MAP

Non-user-specific A-MAP consists of information that is not dedicated to a specific user or a specific group of users. It includes information required to decode other A-MAPs.

The resource occupied by non-user specific information is of fixed size.

15.3.6.2.2.2 Assignment A-MAP

Assignment A-MAP contains resource assignment information which is categorized into multiple types of resource assignment IEs (assignment A-MAP IE). Each assignment A-MAP IE is coded separately and carries information for one or a group of users.

The size of the assignment A-MAP is indicated by non-user-specific A-MAP.

The minimum logical resource unit in the assignment A-MAP is called MLRU, consisting of [$N_{MLRU} = 48$] data tones.

The assignment A-MAP IE shall be transmitted with one MLRU or multiple concatenated MLRUs in the A-MAP region. The number of logically contiguous MLRUs is determined based on the assignment IE size and channel coding rate, where channel coding rate is selected based on AMS' link condition.

15.3.6.2.2.3 HARQ Feedback A-MAP

HARQ feedback AMAP carries HARQ ACK/NACK information for uplink data transmission.

15.3.6.2.2.4 Power Control A-MAP

Power Control A-MAP carries fast power control command to AMS.

15.3.6.3 Resource Mapping of DL Control Channels

15.3.6.3.1 Superframe Header

15.3.6.3.1.1 Primary Superframe Header

Figure 423 shows the physical processing block diagram for the P-SFH.
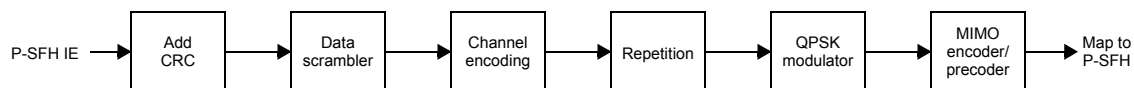
Figure 423—Physical processing block diagram for the P-SFH

The P-SFH IE shall be appended with $N_{CRC,P-SFH}$ bits CRC followed by scrambling with a cell-specific sequence. The cell-specific sequence is determined from the A-Preamble.

The resulting sequence of bits shall be encoded by the convolutional encoder described in <<reference to 15.3.x channel coding section>>. A coding rate of 1/2 is used.

The encoded sequences shall be repeated $N_{Rep,P-SFH}$ times.

The repeated bit sequences shall be modulated using QPSK.

The modulated symbols shall be mapped to two transmission streams using SFBC for two antennas. The two streams using SFBC may be precoded and mapped to more than two antennas described in section <<15.3.7.1.1>>.

Antenna specific symbols at the output of the MIMO encoder/precoder shall be mapped to the resource elements described in section <<15.3.6.2.1.1>>.

15.3.6.3.1.2 Secondary Superframe Header

Figure 424 shows the physical processing block diagram for the S-SFH.
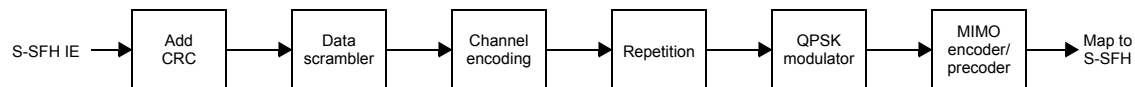
Figure 424—Physical processing block diagram for the S-SFH

The S-SFH IE shall be appended with a 16-bit CRC followed by scrambling with a cell-specific sequence. The cell-specific sequence is determined from the A-Preamble.

The resulting sequence of bits shall be encoded by the channel encoder. The channel encoder for S-SFH is described in <<15.3.x channel coding section>>. A code rate of 1/2 or 1/3 is used.

The encoded sequences shall be repeated $N_{Rep,S-SFH}$ times.

The repeated bit sequences shall be modulated using QPSK.

The modulated symbols shall be mapped to two transmission streams using SFBC for two antennas. The two streams using SFBC may be precoded and mapped to more than two antennas.

Antenna specific symbols at the output of the MIMO encoder/precoder shall be mapped to the resource elements described in section <<15.3.6.2.1>>.

15.3.6.3.2 Advanced MAP (A-MAP)

SFBC with precoding shall be used for the A-MAP region.

15.3.6.3.2.1 Non-user Specific A-MAP

The coding chain for non-user-specific A-MAP-IE to A-A-MAP symbols is shown in Figure 425.
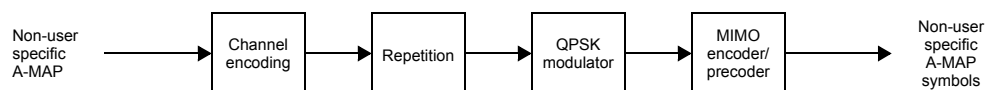
Figure 425—Chain of non-user specific A-MAP-IE to A-A-MAP symbols

The non-user specific A-MAP bit sequence shall be encoded with a fixed MCS.

The encoded sequences shall be repeated $N_{\text{Rep,NS-A-MAP}}$ times.

The repeated bit sequences shall be modulated using QPSK.

15.3.6.3.2.2 Assignment A-MAP

The Assignment A-MAP (A-A-MAP) shall include one or multiple A-A-MAP-IEs and each A-A-MAP-IE is encoded separately. Figure 424 describes the procedure for constructing A-A-MAP symbols.

A-A-MAP IE → Add CRC → Data scrambler → Channel encoding → Repetition → QPSK modulator → MIMO encoder/precoder → A-A-MAP symbols
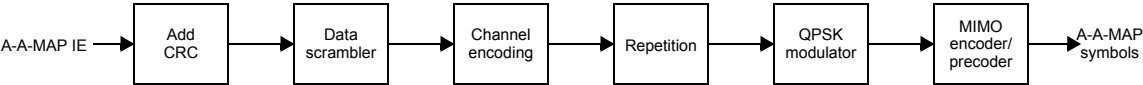
Figure 426—Chain of A-A-MAP-IE to A-A-MAP symbols

Each A-A-MAP IE shall be appended with 16-bit CRC.

The resulting sequence of bits shall be encoded by a TBCC channel encoder.

Depending on the assignment IE size, a rate matching function may be applied.

Coded bits can be repeated to improve the robustness of an A-A-MAP channel based on the link condition of a particular AMS.

After rate matching and repetition, the encoded bit sequences shall be modulated using QPSK. For a given system configuration, assignment A-MAP IEs can be encoded with two different effective code rates. The exact code rates are TBD.

15.3.6.3.2.3 HARQ Feedback A-MAP

HARQ feedback A-MAP (HF-A-MAP) contains HARQ-feedback-IEs for ACK/NACK feedback information to uplink data transmission.

HF-A-MAP-IEs → Repetition → Modulator → MIMO encoder/precoder → HF-A-MAP symbols
Repetition → Modulator →
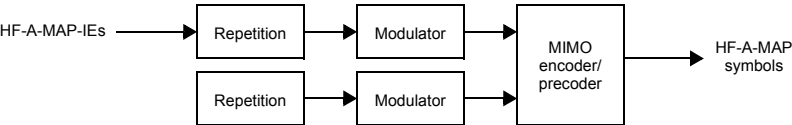
Figure 427—Chain of HF-A-MAP IE to HF-A-MAP symbols

Figure 427 shows the construction procedure of HF-A-MAP symbols from HF-A-MAP-IE.

15.3.6.3.2.4 Power Control A-MAP

Power Control A-MAP (PC-A-MAP) contains PC-A-MAP-IEs for closed-loop power control of the uplink transmission. The ABS shall transmit PC-A-MAP-IE to every AMS which operates in closed-loop power control mode.
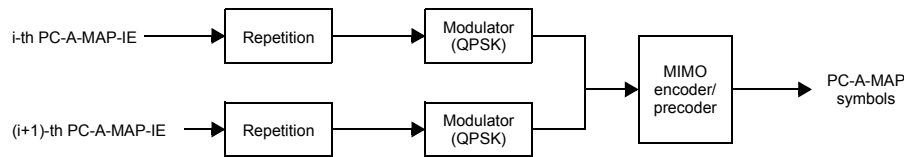
Figure 428—Chain of PC-A-MAP IE to PC-A-MAP symbols

Figure 428 shows the construction procedure of PC-A-MAP symbols from PC-A-MAP-IE.

The ith PC-A-MAP-IE shall have the size of 2 bits according to power correction value.

Repetition is then performed with $N_{rep,\,\text{PC-A-MAP-IE}}$, where $N_{rep,\,\text{PC-A-MAP-IE}}$ is the number of repetitions and explicitly signaled.

The repeated bit sequence shall be modulated as a QPSK symbol and scaled by $\sqrt{P_i},\,(0 \leq i < N_{\text{PC-A-MAP-IE}})$, where $N_{\text{PC-A-MAP-IE}}$ is the number of PC-A-MAP-IEs and $\sqrt{P_i}$ is the value determined by the management entity to satisfy the link performance.

15.3.6.4 DL Control Information Elements

15.3.6.4.1 Broadcast Control Information Elements

15.3.6.4.1.1 P-SFH IE

The P-SFH IE contains essential system information and it is mapped to the P-SFH. The format of the P-SFH IE is shown in Table 654.

Table 654—P-SFH IE format

Syntax	Size (bit)	Notes
P-SFH IE format () {		
LSB of Superframe number	TBD	
System Configuration Description change count	TBD	System Configuration Descriptor Change Count
S-SFH Size	TBD	
S-SFH Transmission Format	2	Indicate the transmission format (repetition) used for S-SFH.
Reserved	TBD	Note the size of P-FSH should be fixed

Table 654—P-SFH IE format

Syntax	Size (bit)	Notes
The reserved bits are for future extension		
}		

SCD Count

Incremented by one (modulo TBD) by the BS whenever any of the values of the S-SFH IEs changes. If the value of this count in a subsequent P-SFH IE remains the same, the AMS can quickly decide that the S-SFH IEs have not changed and may be able to disregard the S-SFH IEs.

15.3.6.4.1.2 S-SFH IE

The S-SFH IE is mapped to the S-SFH. Essential system parameters and system configuration information carried in the S-SFH are categorized into multiple S-SFH IEs. The S-SFH IEs are transmitted with different timing and periodicity.

S-SFH SP1 IE presented in Table 655 includes essential information needed for MS to select and access the network.

Table 655—S-SFH SP1 IE

Syntax	Size (bit)	Notes
S-SFH SP1 IE format () {		
MSBs of superframe number	TBD	Part of superframe number
S-SFH SP scheduling information	TBD	SP scheduling bitmap
S-SFH SP change bitmap	TBD	1 or multiple bits per SP
Additional broadcast information indicator	TBD	
HO information (Open BS/Close BS, UL load indicator, cell type)	TBD	For uncontrolled HO scenarios
Cell bar info	TBD	If Cell Bar bit=1, this cell is not allowed for any new initial entry
Reserved	TBD	The reserved bits are for future extension
}		

S-SFH SP2 contains information for network re-entry, see Table 656.

Table 656—S-SFH SP2 IE

Channel	Contents	Size (bits)
S-SFH Sub-packet 2	Sector ID	
	Periodicity of A-MAP	
	Sub-frame configuration (DL/UL ratio)	
	DL permutation configuration (CRU, DRU partitioning and signaling related to that)	
	UL permutation configuration (CRU, DRU partitioning and signaling related to that)	
	FFR partitioning info for DL region (static)	
	FFR partitioning info for UL region (static)	
	FFR UL target IoT per partition	
	Number of transmit antennas	
	MAC protocol revision	
	Downlink burst profile	
	BS EIRP	
	UL carrier frequency	
	UL bandwidth	
	UL A-MAP relevance	
	Uplink_Burst_Profile	

S-SFH SP3 contains information for initial network entry and network discovery, see Table 657.

Table 657—S-SFH SP3 IE

Channel	Contents	Size (bits)
S-SFH Sub-packet 3	Initial ranging channel information (initial ranging region location)	
	Initial ranging channel format	
	Initial ranging codes	
	Initial ranging backoff start	
	Initial ranging backoff end	
	Minimum level of power offset adjustment	
	Maximum level of power offset adjustment	
	Duplex mode (TDD, FDD, HFDD)	
	TTG	
	RTG	
	NSP IDs	
	MSB bytes of BSID	

S-SFH SP4 contains information for maintaining communication with the ABS (e.g., periodic ranging, bandwidth request, sounding, HARQ parameters, and fast feedback parameters), see Table 658.

Table 658—S-SFH SP4 IE

Channel	Contents	Size (bits)
S-SFH Sub-packet 4	Periodic ranging channel information (periodic ranging region location)	
	Periodic ranging codes	
	Periodic ranging backoff start	
	Periodic ranging backoff end	
	Bandwidth request channel information (bandwidth request region location)	
	Bandwidth request backoff start	
	Bandwidth request backoff end	
	Sounding Region	
	Fast Feedback Region	
	HARQ Ack Region	
	HARQ Ack delay	
	SP scheduling periodicity (excluding SP1) information	

S-SFH SP5 is transmitted in paging listening interval. It contains information for idle mode AMSs, see Table 659.

Table 659—S-SFH SP5 IE

Channel	Contents	Size (bits)
S-SFH Sub-packet 5	N_PGID	
	Paging Indicator Usage Flag	
	PGID List	
	If(Paging Indicator Usage Flag ==1) {	
	Paging Indicator Bitmap	
	}	

15.3.6.4.2 Unicast Control Information Elements

A-MAP IE is defined as the basic element of unicast service control.

15.3.6.4.2.1 Non-user-specific A-MAP IE

Non-user-specific A-MAP IE consists of information that is not dedicated to a specific user or a specific group of users. It includes information required to decode assignment A-MAP IE The size of the assignment A-MAP is indicated in the Non-user-specific A-MAP IE, in the unit of MLRUs. The detailed information included in non-user specific information is TBD. The non-user specific A-MAP IE is shown in Table 660.

Table 660—Non-user specific A-MAP IE

Syntax	Size [bits]	Notes
Assignment A-MAP size	TBD	Indicate the size of assignment A-MAP in units of one or multiple MLRUs.

15.3.6.4.2.2 DL basic assignment A-MAP IE

Table 661 describes the fields in a DL Basic Assignment A-MAP IE used for resource assignment in the DL.

Table 661—DL basic assignment A-MAP IE

Syntax	Size in bits	Description/Notes
A-MAP IE Type	[4]	TBD A-MAP IE types distinguish between UL/DL, SU/MU, OL/CL MIMO operation, persistent/non-persistent allocation, basic/extended IEs
MCS	[4]	Depends on supported modes, 16 modes assumed as baseline
MM	[4]	MIMO Mode TBD MIMO modes for the basic MIMO IE include commonly used modes. Additional modes may be specified in extended IEs.

Table 661—DL basic assignment A-MAP IE

Syntax	Size in bits	Description/Notes
Resource Allocation	Variable	Determines the start, length and number of subframes spanned the allocation.
Payload Size	TBD	Defines payload size if not included in resource allocation information. Clarification on the use of this field is required
Long TTI Length	TBD	Defines number of subframes spanned by allocations if not specified in resource allocation information.
Allocation Relevance	TBD	Defines allocation relevance if not specified in resource allocation information
Boosting	[3]	000: Normal (not boosted) 001: +6dB; 010: −6dB 011: +9dB; 100: +3dB 101: −3dB; 110: −9dB 111: −12dB
AI_SN	1	HARQ identifier sequence number
ACID	[4] [5]	HARQ channel identifier
SPID/CoRe Version	[3]	HARQ subpacket identifier for IR and Constellation Rearrangement version
Padding	variable	Padding to reach byte boundary
MCRC	[16]	16 bit CRC masked by Station ID

A-MAP IE Type: Defines the structure of the A-MAP IE for the bits in the A-MAP IE following the A-MAP IE type field. A-MAP IE Type distinguishes between UL/DL, SU/MU OL/CL MIMO operation, persistent/non-persistent, single user/group resource allocation, basic/extended IE.

MM: MIMO Mode includes indicators for OL/CL operation, SU/MU allocations, rate and the number of streams.

RA: Resource Allocation determines the start, length and number of subframes spanned the allocation.

PS: Payload size defines the size of the allocation, units TBD.

Long TTI Length: Indicator to signal allocations span multiple subframes in time.

SPID/CoRe Version: Signaling for HARQ IR including HARQ subpacket identifier for IR and Constellation Rearrangement version.

MCRC: 16 bit CRC masked by Station ID/Flow ID.

Padding/Reserved Bits: padding to the nearest byte boundary.

15.3.6.4.2.3 UL basic assignment A-MAP IE

Table 662 describes the fields in a UL Basic Assignment A-MAP IE used for resource assignment in the UL.

Table 662—UL basic assignment A-MAP IE

Syntax	Size in bits	Description/Notes
A-MAP IE Type	[4]	TBD types distinguish between UL/DL, MIMO/non-MIMO operation, persistent/non-persistent allocation, basic/extended IEs
MCS	[4]	Depends on supported modes, 16 modes assumed as baseline
MM	[4]	MIMO Mode TBD MIMO modes for the basic MIMO IE include commonly used modes. Additional modes may be specified in extended IEs.
Resource Allocation	*variable*	Determines the start, length and number of subframes spanned the allocation.
Payload Size	TBD	Defines payload size if not included in resource allocation information. Clarification on the use of this field is required
Long TTI Length	TBD	Defines number of subframes spanned by allocations if not specified in resource allocation information.
Allocation Relevance	TBD	Defines allocation relevance if not specified in resource allocation information
AI_SN	1	HARQ identifier sequence number
ACID	[4] [5]	HARQ channel identifier
Padding	variable	Padding to reach byte boundary
MCRC	[16]	16 bit CRC masked by Station ID

15.3.6.4.2.4 Group resource allocation A-MAP IE

Group control information is used to allocate resources and/or configure resources to one or multiple mobile stations within a user group. The group resource allocation A-MAP IE is shown in Table 663.

Group scheduling requires two operations

1) Assignment of an user to a group. In order to add a user to a group in the DL or UL, the ABS shall transmit a [Group Configuration MAC management message] [Group Configuration A-MAP IE]

2) Allocation of resources to users within a group. In order to assign resources to one or more users in a group, the ABS shall transmit the DL/UL Group Resource Allocation A-MAP IE. The DL/UL Group Resource Allocation A-MAP IE is included in user-specific resource assignment in an A-MAP region. The GRA A-MAP IE contains bitmaps to indicate scheduled users and signal resource assignment, MCS, resource size.

Table 663—DL/UL group resource allocation A-MAP IE

Syntax	Size in bits *	Description/Notes
A-MAP IE Type	[4]	TBD A-MAP IE types distinguish between UL/DL, SU/MU, OL/CL MIMO operation, persistent/non-persistent allocation, basic/extended IEs including GRA

Table 663—DL/UL group resource allocation A-MAP IE

Syntax	Size in bits *	Description/Notes
Resource Offset	[6][8]	Indicates starting LRU for resource assignment to this group
ACID	TBD	TBD Required for explicit assignment of a single ACID group. Not required if implicit cycling of ACIDs starting from an initial ACID value is used as in <<802.16e>>
HARQ ReTx Indicator	TBD	TBD Indicates whether this group resource assignment IE is for HARQ retransmissions or initial transmission.
User Bitmap Size	[2][5]	TBD Size of the user bitmap; may not be needed if user bitmap size is included in configuration message/A-MAP IE.
User Bitmap	Variable	Bitmap to indicate scheduled users in a group. The size of the bitmap is equal to the User Bitmap Size
Resource Allocation Bitmap descriptor	TBD	TBD MCS group type, packet/resource size type information or attributes required to decode resource assignment bitmap.
Resource Assignment Bitmap	Variable	Bitmap to indicate MCS/resource size for each scheduled user
Padding	Variable	Padding to reach byte boundary
MCRC	[16]	16 bit masked CRC

Group configuration A-MAP IE: The group configuration A-MAP IE is used for initiating and maintaining a group for resource assignment.

15.3.6.4.2.5 DL PA A-MAP IE

The DL persistent A-MAP IE is shown in Table 664.

Table 664—DL persistent A-MAP IE

Syntax	Size (bits)	Notes	
DL Persistent A-MAP IE () {	--	--	
AMAP type	4	DL Persistent A-MAP IE	
Number of allocations	5	Number of allocation specified	
RCID Type	2	0b00: Normal CID 0b01: RCID11 0b10: RCID7 0b11: RCID3	

Table 664—DL persistent A-MAP IE

Syntax	Size (bits)	Notes	
ACK Region Index	1	The index of the ACK region associated with all sub-bursts defined in this DL Persistent A-MAP IE	
While (data remaining) {	--	--	
Region ID use indicator	1	0: Region ID not used 1: Region ID used	
if (Region ID use indicator ==0) {			
Region information	TBD	TBD	
Information that specifies the region relevant to this persistent scheduling instance			
} else {	--	--	
Region ID	8	Index to the DL region defined in DL region definition S-SFH	
}	--	--	
For (j=0;j<Number of allocations; j++) {		For loop where each loop element specifies information for one allocation.	
Duration Indicator	[1]	If Duration Indicator is 1, it indicates that Duration is explicitly assigned for this subburst. Otherwise, this subburst will use the same Duration as the previous subburst. If j is 1 then this indicator shall be 1.	
MAP ACK Channel Index	TBD	TBD Depends on MAP ACK channel definition in UL control. Index to a MAP ACK channel within the Fast Feedback region. The value 111111 is reserved. When MAP ACK Channel Index = 111111, it indicates NO MAP ACK channel is assigned to this allocation.	
RCID_IE()	variable	Specifies the station ID in RCID format	
Persistent Flag	1	0 = non-persistent 1 = persistent	
If (Duration Indicator = 1) {	-	-	

Table 664—DL persistent A-MAP IE

Syntax	Size (bits)	Notes	
Duration	*TBD*	Duration in number of LRUs.	
}			
Resource Offset	TBD	Indicates the start of this persistent allocation in the allocation region.	
If (Persistent Flag = 1) {			
Allocation Period and N_ACID Indicator	1	If Allocation Period and N_ACID Indicator is 1, it indicates that allocation information (allocation period, Number of ACID (N_ACID) is explicitly assigned for this allocation. Otherwise, this allocation will use the same allocation period as the previous allocation. If j is 0 then this indicator shall be 1.	
If (Allocation Period and N_ACID Indicator = 1) {	-	-	
Allocation Period (AP)	5	Period of the persistent allocation is this field value plus 1 (unit is sub-frame/frame TBD)	
Number of ACID (N_ACID)	3	Number of HARQ channels associated with this persistent assignment is this field value plus 1	
}			
MAP NACK Channel Index	6	TBD Index to a shared MAP NACK channel within the Fast Feedback region. The value 111111 is reserved. When MAP NACK Channel Index = 111111, it indicates NO MAP NACK channel is assigned to this allocation.	
MAP ACK Channel Index	6	TBD Index to a MAP ACK channel within the Fast Feedback region.	

Table 664—DL persistent A-MAP IE

Syntax	Size (bits)	Notes	
Allocation MCS indicator	1	If Allocation MCS Indicator is 1, it indicates that MCS is explicitly assigned for this allocation. Otherwise, this allocation will use the same MCS as the previous sub-burst. If j is 0 then this indicator shall be 1.	
If (Allocation MCS indicator =1) {			
MCS	[6]	TBD Depends on supported modulation and coding schemes. Specifies the modulation, coding and repetition coding used for this allocation.	
}			
Allocation Boosting indicator	[1]	If Allocation Boosting Indicator is 1, it indicates that Boosting is explicitly assigned for this allocation. Otherwise, this allocation will use the same Boosting as the previous allocation. If j is 0 then this indicator shall be 1.	
If (Allocation Boosting indicator =1) {			
Boosting	[3]	Specifies the boosting used for this allocation	
}			
Allocation ACID indicator	1	If Allocation ACID Indicator is 1, it indicates that ACID is explicitly assigned for this allocation. Otherwise, this allocation will use the same ACID as the previous allocation. If j is 0 then this indicator shall be 1.	
If (Allocation ACID indicator =1) {			
ACID	[5]	Specifies the HARQ channel identifier used for this allocation	
}			
AI_SN	1	HARQ identifier sequence number	
SPID/CoRE Version	[3]	HARQ subpacket identifier for IR and Constellation Rearrangement version	

Table 664—DL persistent A-MAP IE

Syntax	Size (bits)	Notes	
}			
}			
Allocation Boosting indicator	[1]	If Allocation Boosting Indicator is 1, it indicates that Boosting is explicitly assigned for this allocation. Otherwise, this allocation will use the same Boosting as the previous allocation. If j is 0 then this indicator shall be 1.	
If (Allocation Boosting indicator ==1) {			
Boosting			
}			
Allocation ACID indicator			
If (Allocation ACID indicator ==1) {			
ACID	[4][5]	HARQ channel identifier	
}			
AI_SN	1	HARQ identifier sequence number	
SPID/CoRE Version	[3]	HARQ subpacket identifier for IR and Constellation Rearrangement version	
}			
Padding	*variable*	Padding to bytes boundary; padding value shall be set to zero.	
MCRC	[16]	16 bit masked CRC	
}			

Persistent Flag: The persistent flag shall be set to 1 if the assignment is persistent and shall be set to 0 if the assignment is non-persistent.

DRU Offset: The DRU offset shall be set to the first DRU in the time-frequency resource assignment with respect to the lowest numbered OFDM symbol and the lowest numbered subchannel in the Allocation region.

Duration Indicator: Duration Indicator flag determines whether or not Duration is specified for an allocation. If this flag is 1, it indicates that Duration is explicitly assigned for an allocation. Otherwise, the allocation has the same Duration as the previous allocation. This flag shall be 1 for the first allocation in a Allocation region.

Duration: Duration specifies the size (# DRUs) of an allocation/reallocation in an allocation region.

Allocation Period and N_ACID Indicator: If Allocation Period and Index Indicator is 1, it indicates that allocation period, ACK and NACK channel index (allocation period and Number of ACID (N_ACID) is explicitly assigned for an allocation. Otherwise, the allocation will use the same allocation period and N_ACID as the previous allocation. This flag shall be 1 for the first allocation in a Allocation region.

Allocation Period: The allocation period (ap) shall be set to one less than the period of the persistent allocation, in units of sub-frames/frames. For example, as illustrated below, if ap=0b00011, then the period of the persistent allocation is four frames, and the time-frequency resource assignment is valid in frames N, N+4, N+8, etc. An illustration of periodic allocation is shown in Figure 429.
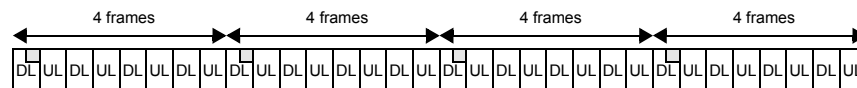
Figure 429—Ilustration of periodic allocation

N_ACID: The values of ACID field (N0) and N_ACID field (N) are used together to specify an implicit cycling of HARQ channel identifiers as follows. N0 is used as the HARQ channel identifier corresponding to the first occurrence of the persistent allocation. For each next allocation this value is incremented modulo (N + 1).

As illustrated in Figure 430, if N_ACID = 0b011 (meaning the period is equal to 4), and if ACID = 2, the HARQ channel identifier follows the pattern 2, 3, 4, 5, 2, 3, 4, 5, etc.
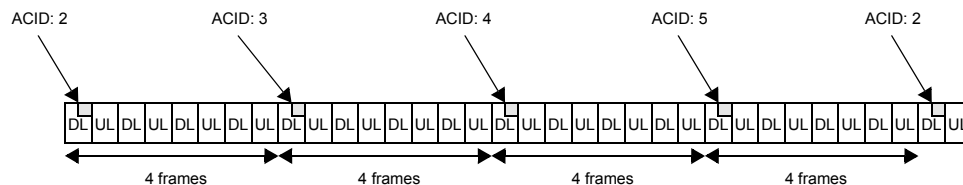
Figure 430—Ilustration of periodic allocation

ACID: The ACID field shall be set to the initial value of HARQ channel identifier as described above.

AI_SN: The AI_SN field value shall be set to the initial ARQ identifier sequence number for each HARQ channel. The AI_SN toggles between 0 and 1 for each particular HARQ channel. For example, if the period equals 4 frames, N_ACID = 4, ACID = 2, and AI_SN = 0, the ACID follows the pattern 2, 3, 4, 5, 2, 3, 4, 5, etc, and the AI_SN follows the pattern 0, 0, 0, 0, 1, 1, 1, 1, etc.

ACK_channel: The ACK_channel field shall be set to the number of the ACK channel within the HARQ ACK Region. The mobile station shall use the indicated ACK channel for transmitting acknowledgment information for each packet received using the time-frequency resource referred to by this persistent allocation.

MAP NACK Channel Index: The MAP NACK channel index is persistently allocated within the Fast Feedback region. The mobile station shall used the indicated MAP NACK channel to report MAP decoding error in frames where it as a persistent resource allocation assigned with this instance of the persistent IE.

The value 111111 is reserved. When MAP NACK Channel Index = 111111, it indicates NO MAP NACK channel is assigned to this allocation.

MAP ACK Channel Index: The MAP ACK channel is allocated non-persistently within the Fast Feedback region. The mobile station shall use the indicated MAP ACK channel to report successful receipt of the persistent allocation IE. The value 111111 is reserved. When MAP ACK Channel Index = 111111, it indicates NO MAP ACK channel is assigned to this allocation

15.3.6.4.2.6 DL PA A-MAP IE

15.3.6.4.2.7 HARQ Feedback A-MAP IE

HARQ Feedback A-MAP IE includes one bit and corresponding value for HARQ ACK/NACK information is shown in Table 665. If HF-A-MAP IE has the 0b0 or 0b1, it shall be interpreted as ACK information or NACK information, respectively.

Table 665—HF-A-MAP-IE

Syntax	Size (bit)	Notes
HF-A-MAP IE format {		
HF-A-MAP IE value	1	0b0 : ACK feedback info. 0b1 : NACK feedback info.
}		

15.3.6.4.2.8 Power Control A-MAP IE

The PC-A-MAP IE includes two bits and corresponding values for power correction is shown in Table 666, e.g., if the power correction value is 0b00, it shall be interpreted as tone power (power density) should be reduced by 0.5dB

Table 666—PC-A-MAP IE format

Syntax	Size (bit)	Notes
PC-A-MAP IE format {		
Power correction value	2	0b00 = -0.5 dB 0b01 = 0.0 dB 0b10 = 0.5 dB 0b11 = 1.0 dB
}		

15.3.7 Downlink MIMO

15.3.7.1 Downlink MIMO architecture and data processing

The architecture of downlink MIMO at the transmitter side is shown in Figure 431.
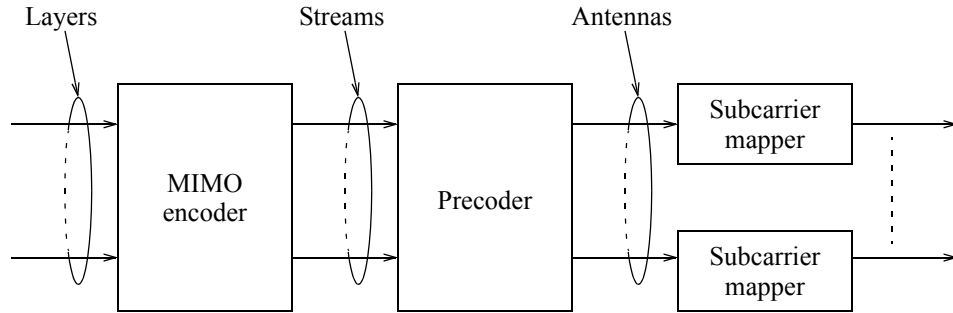
Figure 431—DL MIMO architecture

The MIMO encoder block maps L layers $(L \geq 1)$ onto M_t streams $(M_t \geq L)$, which are fed to the Precoder block. A layer is defined as a coding and modulation path fed to the MIMO encoder as an input. A stream is defined as an output of the MIMO encoder which is passed to the precoder.

For SU-MIMO, only one user is scheduled in one Resource Unit (RU), and only one FEC block exists at the input of the MIMO encoder (vertical MIMO encoding at transmit side).

For MU-MIMO, multiple users can be scheduled in one RU, and multiple FEC blocks exist at the input of the MIMO encoder (horizontal MIMO encoding at transmit side).

The Precoder block maps stream(s) to antennas by generating the antenna-specific data symbols according to the selected MIMO mode.

The subcarrier mapping blocks map antenna-specific data to the OFDM symbol

15.3.7.1.1 Layer to stream mapping

Layer to stream mapping is performed by the MIMO encoder. The MIMO encoder is a batch processor that operates on M input symbols at a time.

The input to the MIMO encoder is represented by an $M \times 1$ vector as specified in Equation (190)

$$\mathbf{s} = \begin{bmatrix} s_1 \\ s_2 \\ M \\ s_M \end{bmatrix} \tag{190}$$

Where s_i is the i-th input symbol within a batch.

Layer to stream mapping of the input symbols is done in the space dimension first. The output of the MIMO encoder is an $M_t \times N_F$ MIMO STC matrix as given in Equation (191), which serves as the input to the precoder.

$$x = S(s) \tag{191}$$

Where,

M_t is the number of streams

N_F is the number of subcarriers occupied by one MIMO block

x is the output of the MIMO encoder

s is the input layer vector

$S(s)$ is an STC matrix

And,

$$\mathbf{x} = \begin{bmatrix} x_{1,1} & x_{1,2} & \Lambda & x_{1,N_F} \\ x_{2,1} & x_{2,2} & \Lambda & x_{2,N_F} \\ M & M & O & M \\ x_{M_T,1} & x_{M_T,2} & \Lambda & x_{M_T,N_F} \end{bmatrix} . \tag{192}$$

For SU-MIMO transmissions, the rate is defined as in Equation (193)

$$R = \frac{M}{N_F} \tag{193}$$

15.3.7.1.1.1 SFBC encoding

The input to the MIMO encoder is represented by a 2 × 1 vector.

$$\mathbf{s} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix} . \tag{194}$$

The MIMO encoder generates the SFBC matrix.

$$\mathbf{x} = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix} \tag{195}$$

Where $\mathbf{x}$ is a 2x2 matrix.

The SFBC matrix, $\mathbf{x}$, occupies two consecutive subcarriers.

15.3.7.1.1.2 Vertical encoding

The input and the output of MIMO encoder is represented by an $M \times 1$ vector.

$$\mathbf{x} = \mathbf{s} = \begin{bmatrix} s_1 \\ s_2 \\ M \\ s_M \end{bmatrix} . \tag{196}$$

Where s_i is the i-th input symbol within a batch.

For vertical encoding, $s_i...s_M$ belong to the same layer.

15.3.7.1.1.3 Horizontal encoding

The input and output of the MIMO encoder is represented by an $M \times 1$ vector.

$$\mathbf{x} = \mathbf{s} = \begin{bmatrix} s_1 \\ s_2 \\ M \\ s_M \end{bmatrix} \tag{197}$$

Where s_i is the i-th input symbol within a batch.

For horizontal encoding, $s_i...s_M$ belong to different layers.

Horizontal encoding is only used for MU-MIMO mode.

15.3.7.1.2 Stream to antenna mapping

Stream to antenna mapping is performed by the precoder. The output of the MIMO encoder is multiplied by an $N_t \times M_t$ precoder, $\mathbf{W}$. The output of the precoder is denoted by an $N_t \times N_F$ matrix, z. The mapping can be defined in Equation (198).

$$\mathbf{z} = \mathbf{W}\mathbf{x} = \begin{bmatrix} z_{1,1} & z_{1,2} & \Lambda & z_{1,N_F} \\ z_{2,1} & z_{2,2} & \Lambda & z_{2,N_F} \\ M & M & O & M \\ z_{N_t,1} & z_{N_t,2} & \Lambda & z_{N_t,N_F} \end{bmatrix} \tag{198}$$

Where N_t is the number of transmit antennas and $z_{j,k}$ is the output symbol to be transmitted via the j-th physical antenna on the k-th subcarrier.

15.3.7.1.2.1 Non-adaptive precoding

With non-adaptive precoding, the precoding matrix is an $N_t \times M_t$ matrix $\mathbf{W}(k)$, where N_t is the number of transmit antennas, M_t is the numbers of streams, and k is the physical index of the subcarrier where $\mathbf{W}(k)$ is applied. The matrix $\mathbf{W}$ is selected from a subset of size N_W precoders of the base codebook for a given rank. The matrix $\mathbf{W}$ changes every $N_1 P_{SC}$ contiguous physical subcarriers according to equation (10), and it does not depend on the subframe number. $\mathbf{W}$ belongs to the subset of the base codebook specified in Section 15.3.7.2.6.6.2.4.1. The $N_t \times M_t$ precoding matrix $\mathbf{W}(k)$ applied on subcarrier k is selected as the codeword of index i in the open-loop codebook subset of rank M_t, where i is given by

$$i = \mathrm{mod}\left(\left\lceil k/(N_1 P_{SC}) \right\rceil - 1, N_W\right) + 1 \tag{199}$$

In OL Region [TBD], the matrix $\mathbf{W}$ changes every NP_{sc} contiguous physical subcarriers. The default value of N is N_1. N_2 is optional [TBD]. Use of N_2 does not require additional signaling.

15.3.7.1.2.2 Adaptive precoding

With adaptive precoding, the precoder $\mathbf{W}$ is derived from the feedback of the MS.

For codebook-based precoding (codebook feedback), there are 3 feedback modes: Base mode, adaptive mode and differential mode, which are described in 15.3.7.2.6.6.1.

For TDD sounding-based precoding, the value of $\mathbf{W}$ is derived from the MS sounding feedback. The sounding channel is defined in "Unquantized MIMO feedback for closed-loop transmit precoding" on page 91.

15.3.7.1.3 Downlink MIMO modes

There are five MIMO transmission modes for unicast DL MIMO transmission as listed in Table 667.

.

Table 667—MIMO modes

Mode index	Description	Reference
Mode 0	OL SU-MIMO (SFBC with non-adaptive precoder)	
Mode 1	OL SU-MIMO (SM with non-adaptive precoder)	
Mode 2	CL SU-MIMO (SM with adaptive precoder)	
Mode 3	OL MU-MIMO (SM with non-adaptive precoder)	
Mode 4	CL MU-MIMO (SM with adaptive precoder)	
Mode 5 -7	n/a	n/a

Some parameters for each DL MIMO mode are shown in Table 668.

Table 668—DL MIMO parameters

	N_t	$Rate$	M_t	N_F	L
MIMO mode 0	2	1	2	2	1
	4	1	2	2	1
	8	1	2	2	1

Table 668—DL MIMO parameters

	N_t	Rate	M_t	N_F	L
MIMO mode 1 and MIMO mode 2	2	1	1	1	1
	2	2	2	1	1
	4	1	1	1	1
	4	2	2	1	1
	4	3	3	1	1
	4	4	4	1	1
	8	1	1	1	1
	8	2	2	1	1
	8	3	3	1	1
	8	4	4	1	1
	8	5	5	1	1
	8	6	6	1	1
	8	7	7	1	1
	8	8	8	1	1
MIMO mode 3 and MIMO mode 4	2	n.a.	2	1	2
	4	n.a.	2	1	2
	4	n.a.	3	1	3
	4	n.a.	4	1	4
	8	n.a.	2	1	2
	8	n.a.	3	1	3
	8	n.a.	4	1	4

15.3.7.2 Transmission schemes for data channels

15.3.7.2.1 Encoding, precoding and mapping of SU-MIMO

15.3.7.2.1.1 Encoding of MIMO modes

15.3.7.2.1.1.1 MIMO mode 0

SFBC encoding of section "SFBC encoding" on page 68 shall be used with MIMO mode 0.

15.3.7.2.1.1.1 MIMO mode 1

Vertical encoding of section "Vertical encoding" on page 68 shall be used with MIMO mode 1. The number of streams is , $M_t \le min(N_t, N_r)$ where N_r is the number of receive antennas and M_t is no more than 8.

15.3.7.2.1.1.1 MIMO mode 2

Vertical encoding of section "Vertical encoding" on page 68 shall be used with MIMO mode 2. The number of streams is , $M_t \le min(N_t, N_r)$ where M_t is no more than 8.

15.3.7.2.1.2 Precoding of MIMO modes

15.3.7.2.1.2.1 MIMO mode 0

Non-adaptive precoding of section "Non-adaptive precoding" on page 69 with M_t=2 streams shall be used with MIMO mode 0.

15.3.7.2.1.2.1 MIMO mode 1

Non-adaptive precoding of section "Non-adaptive precoding" on page 69 with M_t streams shall be used with MIMO mode 1.

15.3.7.2.1.2.1 MIMO mode 2

Adaptive precoding of section "Adaptive precoding" on page 70 shall be used with MIMO mode 2.

15.3.7.2.2 Encoding, precoding and mapping of MU-MIMO

Multi-user MIMO schemes are used to enable a resource allocation to communicate data to two or more MSs. Multi-user transmission with one stream per user is supported for MU-MIMO.

MU-MIMO includes the MIMO configuration of 2Tx antennas to support up to 2 MSs, and 4Tx or 8Tx antennas to support up to 4 MSs, with 1 stream per MS.

Both OL MU-MIMO (mode 3) and CL MU-MIMO (mode 4) are supported

15.3.7.2.2.1 Encoding of MIMO mode 3

Horizontal encoding of section "Horizontal encoding" on page 69 shall be used with MIMO mode 3.

15.3.7.2.2.2 Encoding of MIMO mode 4

Horizontal encoding of section "Horizontal encoding" on page 69 shall be used with MIMO mode 4

15.3.7.2.2.3 Precoding of MIMO modes

15.3.7.2.2.3.1 MIMO mode 3

In OL MU MIMO, the precoder **W** is predefined and fixed over time. The definition of **W** is the same as OL SU MIMO (mode 0 and mode 1).

15.3.7.2.2.3.1 MIMO mode 4

In CL MU MIMO, the precoder **W** is an $N_t \times M$ matrix for each subcarrier. It is used to communicate to M MSs simultaneously. The form and derivation of the precoding matrix does not need to known at the MS. The BS determines the precoding matrix based on the feedback received from the MS.

The BS shall construct the precoding matrix **W** as represented in Equation (200).

$$\mathbf{W}(k) = [\mathbf{v}_1(k) \quad v_2(k) \quad \Lambda \quad \mathbf{v}_M(k)] \tag{200}$$

Where, $v_i(k)$ is the precoding vector for the i-th MS on the k-th subcarrier.

15.3.7.2.3 Mapping of data subcarriers

15.3.7.2.3.1 MIMO mode 0

15.3.7.2.3.2 MIMO mode 1, 2

15.3.7.2.3.3 MIMO mode 3, 4

15.3.7.2.4 Mapping of pilot subcarriers

15.3.7.2.5 Usage of MIMO modes

Table 669 shows permutations supported for each MIMO mode. The definition of DRU, mini-band based CRU, and subband based CRU are in subclause [TBD].

Table 669—Supported Permutation for each DL MIMO mode

	DRU	**Mini-band based** CRU (diversity allocation)	Mini-band and Subband based CRU (localized allocation)
MIMO mode 0	Yes	Yes	No
MIMO mode 1	Yes, with M_t=2	Yes	Yes
MIMO mode 2	No	Yes, with M_t=1	Yes
MIMO mode 3	No	No	Yes
MIMO mode 4	No	Yes	Yes

Mini band based CRU diversity allocation represents a resource allocation composed of non-contiguous minibands.

All pilots are precoded regardless of number of transmit antennas and allocation type.

15.3.7.2.5.1 Broadcast information

Some parameters necessary for DL MIMO operation shall be broadcast by the BS. The broadcast information is carried by SFH or in DCD/UCD.

15.3.7.2.5.2 Unicast information

Some parameters necessary for DL MIMO operation shall be unicast by the BS to a specific MS. The unicast information is carried by A-MAP IEs or feedback allocation IEs

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15.3.7.2.6 Feedback mechanisms and operation

15.3.7.2.6.1 Donwlink post-processing CINR measurement feedback

The reported channel quality indicator has two types: wideband CQI, subband CQI.

The wideband CQI is one average CQI over the whole band.

The subband CQI is one average CQI over the subband.

For MU-MIMO feedback modes, the CQI is calculated at the MS assuming that the interfering users are scheduled by the serving BS using rank-1 precoders orthogonal to each other and orthogonal to the rank-1 precoder represented by the reported PMI.

15.3.7.2.6.2 MIMO mode feedback selection

15.3.7.2.6.3 MIMO feedback information

Table 670—MIMO feedback information

	Feedback information type	Description
	Rank information	For MIMO modes 1 and 2
	Subband selection	
	Stream index (TBD)	For MIMO mode 3, indicating which streams are preferred.
Long period feedback	Quantized Correlation matrix	For adaptive codebook feedback mode or long term wideband beamforming [TBD]
	Time Correlation coefficient information [TBD]	For differential codebook feedback mode
	PMI report for serving cell [TBD]	For long-term wideband beamforming
	PMI report for neighboring cell	For PMI coordination among multiple BSs
	CQI	
Short period feedback	CQI	
	PMI report for serving cell	For short-term beamforming with MIMO modes 2 and 4
Event-driven feedback	Preferred MFM (MIMO feedback mode), etc.	

15.3.7.2.6.4 MIMO feedback modes

Each MIMO transmission mode can have one or several kind of MIMO feedback modes. When allocating a feedback channel, the MIMO feedback mode shall be indicated to the MS, and the MS will feedback information accordingly.

The description of MIMO feedback modes and corresponding supported MIMO transmission modes is shown in Table 671. The detailed description of feedback and MS processing are in the following subsections.

Table 671—MIMO feedback modes

Feedback Mode	Description	Feedback content	Type of RU	Supported MIMO transmission mode	Parameters

15.3.7.2.6.5 Donwlink signaling support of DL-MIMO modes

15.3.7.2.6.6 Quantized MIMO feedback for closed-loop transmit precoding

15.3.7.2.6.6.1 Quantized feedback modes

An MS feedbacks a Preferred Matrix Index (PMI) to support DL precoding.

There are three types of codebook feedback modes.

The operation of the codebook feedback modes for the PMI is summarized below:

1) **The base mode**: the PMI feedback from a MS shall represent an entry of the base codebook. It shall be sufficient for the BS to determine a new precoder.

2) **The adaptive mode**: the PMI feedback from a MS shall represent an entry of the transformed base codebook according to long term channel information.

3) **The differential mode**: the PMI feedback from a MS shall represent an entry of the differential codebook or an entry of the base codebook at PMI reset times. The feedback from a MS provides a differential knowledge of the short-term channel information. This feedback represents information that is used along with other feedback information known at the BS for determining a new precoder.

Mobile station shall support the base and adaptive mode and may support the differential mode.

The adaptive and differential feedback modes are applied to the base codebook or to a subset of the base codebook.

15.3.7.2.6.6.2 Base mode for codebook-based feedback

The base codebook is a unitary codebook. A codebook is a unitary codebook if each of its matrices consists of columns of a unitary matrix.

The MS selects its preferred matrix from the base codebook based on the channel measurements. The MS feedbacks the index of the preferred codeword, and the BS computes the precoder **W** according to the index. Both BS and MS use the same codebook for correct operation.

For the base mode, the PMI feedback from a mobile station shall represent an entry of the base codebook, where the base codebooks are defined as follows for two, four, and eight transmit antennas at the BS.

Table 672—DL MIMO control parameters

Parameters	Description	Value	Control Channel (IE)	Notes
			Broadcast Information	
N_t	Number of transmit antennas at the BS	0b00: 2 0b01: 4 0b10: 8	SFH (system information)	N_t must be known before decoding the DL A-MAP IE
OL_Region[TBD]	OL MIMO region, which signaling is used to indicate MS where is the pre-defined OL MIMO region and number of streams (1 or 2)	TBD	Broadcast information	
SU_CT	SU base codebook type		Broadcast information	SU base codebook subset indication
MU_CT (TBD)	MU base codebook type		Broadcast information	MU base codebook subset indication
BC_SI	Rank-1 base codebook subset indication	BitMAP (Same size as rate-1 codebook for each number of transmit antenna)	Broadcast information	Rate-1 codebook element restriction/recommendation information It shall be ignored if CCE = 0b0
MaxMt (TBD	Maximum number of streams	0b00: 2 0b01: 3 0b10: 4 0b11: reserved	Broadcast information	If MFM indicates a MU feedback mode: the maximum number of users scheduled on each RU
			Unicast Information	

Table 672—DL MIMO control parameters

Parameters	Description	Value	Control Channel (IE)	Notes
MEF	MIMO encoder f0rmat	0b00: SFBC 0b01: Vertical encoding 0b10: Horizontal encoding 0b11: n/a	A-MAP IE (unicast)	MIMO encoder format [MEF bitfield may not be explicitly indicated in DL A-MAP IE].
M_t	Number of streams in transmission	0b000: 1 0b001: 2 0b010: 3 0b011: 4 0b100: 5 0b101: 6 0b110: 7 0b111: 8 ($M_t <= N_t$)	A-MAP IE (unicast)	Number of streams in the transmission. When MEF=0b00: Mt =2 MEF=0b10, $M_t <= 4$. [Bit-field length is variable, depending on the number of Tx at BS]
RU allocation (TBD	RU [and stream] indocator for the burst of data	TBD	A-MAP IE (unicast)	Refer to DL control group.
SI(TBD)	*Index of pilot stream allocation*	0b00: 1 0b01: 2 0b10: 3 0b11: 4	A-MAP IE (unicast)	SI shall be indicated if MEF = 0b010 [Bit-field length is variable, depending on the number of Tx at BS RU allocation and SI can be merged together depending on other DG's decision
Feedback Allocation IE				
MFM	MIMO feedback mode	Refer to Table 671	Feedback allocation IE (unicast)	To decide the feedback content and related MS processing
DLRU (TBD)	Downlink RU, indicating which RUs or which type of RU (DRU or miniband-based CRU) to work on for feedback	TBD (Tree structure, bit map etc)	Feedback allocation IE (unicast)	To process CQI (PMI) estimation for the indicated RUs. Refer to other DG
FT	MIMO feedback type	0b00:codebook 0b01:sounding	Feedback allocation IE (unicast)	
CM	Codebook feedback mode	0b00:standard 0b01:adaptive 0b10:differential	Feedback allocation IE (unicast)	Enabled when FT = 0b00
CCE	Codebook Coordination Enable	0b0:disable 0b1:enable		CCE = 0b0: MS finds PMI within whole broadcasted codebook type entry. CCE = 0b1: When MS finds rate-1 PMI, it finds within broadcasted codebook entries indicated by BC_ST, [SU_CT and MU_CT]

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The notation C(N_t, M_t, NB) denotes the codebook, which consists of 2^{NB} complex, matrices of dimension N_t by M_t, and M_t denotes the number of streams.

The notation C(N_t, M_t, NB, i) denotes the i-th codebook entry of C(N_t, M_t, NB).

15.3.7.2.6.6.2.1 Base codebook for two transmit antennas

15.3.7.2.6.6.2.1 SU-MIMO base codebook

The codebook for two transmit antenna is constructed using a similar methodology as described in section 8.4.11.15 of WirelessMAN-OFDMA, with the exception that the first codeword $\mathbf{v}_1$ is defined as an N_t by M_t unitary matrix

$$\mathbf{v}_1 = \frac{1}{\sqrt{N_t}} \begin{bmatrix} 1 & 1 & \Lambda & 1 \\ e^{j\frac{2\pi}{N_t}} & e^{j\frac{2\pi}{N_t}2} & & e^{j\frac{2\pi}{N_t}M_t} \\ M & M & O & \\ e^{j\frac{2\pi}{N_t}(N_t-1)} & e^{j\frac{2\pi}{N_t}2(N_t-1)} & & e^{j\frac{2\pi}{N_t}M_t(N_t-1)} \end{bmatrix} \tag{201}$$

All codeword matrices $\mathbf{v}_i$ for $i = 2,3\ldots,2^{NB}$ in V(N_t, M_t, NB) codebook can be derived from the first codeword matrix $\mathbf{v}_1$ using the following equations:

$$\tilde{\mathbf{v}}_i = H(s)Q^{i-1}H^H(s)\mathbf{v}_1 \tag{202}$$

$$\mathbf{v}_i = \tilde{\mathbf{v}}_i \cdot e^{-j\varphi_1} \tag{203}$$

where phase φ_1 is a phase of the first entry of the first column of codeword $\tilde{v}_i$. Operation $H(\ )$ generates unitary matrix as follows

$$H(\mathbf{v}) = \begin{cases} \mathbf{I}, & \mathbf{v} = \mathbf{e}_1 \\ \mathbf{I} - \dfrac{2\mathbf{w}\mathbf{w}^H}{\|\mathbf{w}^H\mathbf{w}\|}, & \text{otherwise} \end{cases} \tag{204}$$

where $w = v - e_1, e_1 = \begin{bmatrix} 1, 0, \ldots, 0 \end{bmatrix}^T$.

Matrix Q^i is defined as follows:

$$Q^i = diag\begin{bmatrix} e^{\frac{2\pi}{2^L}u_1 i}, & e^{\frac{2\pi}{2^L}u_2 i}, & \ldots, & e^{\frac{2\pi}{2^L}u_{N_t} i} \end{bmatrix} , \tag{205}$$

The parameters for generation of the codebooks for two transmit antenna $N_t = 2$ and number of streams M_t =1, 2 are listed in Table 673.

Table 673—Generating parameters for two transmit antenna codebook

Nt	Mt	NB	L	$u = \lfloor u_1, u_2, ..., u_{N_t} \rfloor$ **in** $Q^i(u)$	**s in** $H(\mathbf{s})$
2	1	3	3	[1, 2]	[1, 0]
2	2	2	3		

The indexes from 4 to 7 are not used in 3-bits downlink PMI feedback for M_t =2 codebook.

15.3.7.2.6.6.2.1.2 MU-MIMO base codebook

The base codebook for MU-MIMO is the same as the rank 1 base codebook for SU-MIMO, defined in 15.3.7.2.6.6.2.1.1

15.3.7.2.6.6.2.2 Base codebook for four transmit antennas

15.3.7.2.6.6.2.2.1 SU-MIMO base codebook

The base codebooks of SU-MIMO with four transmit antennas consist of rank-1 codebook C(4,1,6), rank-2 codebook C(4,2,6), rank-3 codebook C(4,3,4) and rank-4 codebook C(4,4,3). Table 674, Table 675, Table 676and Table 677 are included to illustrate the rank-1,2,3,4 base codebooks.

Table 674—C(4,1,6)

Binary Index	m		C(4,1,6,m)		
000000	0	0.5000	-0.5000	0.5000	-0.5000
000001	1	-0.5000	-0.5000	0.5000	0.5000
000010	2	-0.5000	0.5000	0.5000	-0.5000
000011	3	0.5000	0.0000 - 0.5000i	0.5000	0.0000 - 0.5000i
000100	4	-0.5000	0.0000 - 0.5000i	0.5000	0.0000 + 0.5000i
000101	5	-0.5000	0.0000 + 0.5000i	0.5000	0.0000 - 0.5000i
000110	6	0.5000	0.5000	0.5000	0.5000
000111	7	0.5000	0.0000 + 0.5000i	0.5000	0.0000 + 0.5000i
001000	8	0.5000	0.5000	0.5000	-0.5000
001001	9	0.5000	0.0000 + 0.5000i	-0.5000	0.0000 + 0.5000i
001010	10	0.5000	-0.5000	0.5000	0.5000
001011	11	0.5000	0.0000 - 0.5000i	-0.5000	0.0000 - 0.5000i
001100	12	0.5000	0.3536 + 0.3536i	0.0000 + 0.5000i	-0.3536 + 0.3536i
001101	13	0.5000	-0.3536 + 0.3536i	0.0000 - 0.5000i	0.3536 + 0.3536i
001110	14	0.5000	-0.3536 - 0.3536i	0.0000 + 0.5000i	0.3536 - 0.3536i

Table 674—C(4,1,6)

Binary Index	*m*	*C*(4,1,6,*m*)			
001111	15	0.5000	0.3536 - 0.3536i	0.0000 - 0.5000i	-0.3536 - 0.3536i
010000	16	0.5000	-0.4619 - 0.1913i	0.3536 + 0.3536i	-0.1913 - 0.4619i
010001	17	0.3117	0.6025 + 0.1995i	-0.4030 - 0.4903i	-0.1122 - 0.2908i
010010	18	0.3117	-0.6025 - 0.1995i	-0.1122 - 0.2908i	0.4030 + 0.4903i
010011	19	0.3058	0.1901 - 0.6052i	0.1195 + 0.2866i	0.4884 - 0.4111i
010100	20	0.5000	-0.1913 + 0.4619i	-0.3536 - 0.3536i	0.4619 - 0.1913i
010101	21	0.5000	0.1913 - 0.4619i	-0.3536 - 0.3536i	-0.4619 + 0.1913i
010110	22	0.5000	0.4619 + 0.1913i	0.3536 + 0.3536i	0.1913 + 0.4619i
010111	23	0.3082	0.0104 + 0.3151i	0.4077 + 0.4887i	-0.4783 + 0.4145i
011000	24	0.3117	0.3573 - 0.2452i	0.6025 - 0.1995i	-0.1578 + 0.5360i
011001	25	0.3117	0.2452 + 0.3573i	-0.6025 + 0.1995i	0.5360 + 0.1578i
011010	26	0.3082	-0.3666 + 0.2426i	0.6092 - 0.1842i	0.1615 - 0.5298i
011011	27	0.3117	-0.2452 - 0.3573i	-0.6025 + 0.1995i	-0.5360 - 0.1578i
011100	28	0.3117	0.4260 + 0.0793i	0.1995 + 0.6025i	0.2674 + 0.4906i
011101	29	0.3117	-0.0793 + 0.4260i	-0.1995 - 0.6025i	0.4906 - 0.2674i
011110	30	0.3117	-0.4260 - 0.0793i	0.1995 + 0.6025i	-0.2674 - 0.4906i
011111	31	0.3117	0.0793 - 0.4260i	-0.1995 - 0.6025i	-0.4906 + 0.2674i
100000	32	0.5636	-0.3332 - 0.2672i	0.1174 + 0.5512i	-0.3308 - 0.2702i
100001	33	0.5587	0.3361 + 0.2735i	-0.3361 - 0.2735i	-0.1135 - 0.5471i
100010	34	0.5587	-0.3361 - 0.2735i	-0.1135 - 0.5471i	0.3361 + 0.2735i
100011	35	0.5587	0.2735 - 0.3361i	0.1135 + 0.5471i	0.2735 - 0.3361i
100100	36	0.3082	-0.4887 + 0.4077i	-0.6092 - 0.1842i	0.2837 - 0.1205i
100101	37	0.5636	0.2673 - 0.3331i	-0.1222 - 0.5501i	-0.2673 + 0.3331i
100110	38	0.5636	0.3691 + 0.5142i	0.3331 + 0.2673i	0.0862 + 0.3032i
100111	39	0.5587	-0.2990 + 0.0880i	0.3361 + 0.2735i	-0.5216 + 0.3616i
101000	40	0.5587	0.0880 - 0.2990i	0.3361 - 0.2735i	-0.3616 + 0.5216i
101001	41	0.5587	0.2990 + 0.0881i	-0.3362 + 0.2735i	0.5216 + 0.3616i
101010	42	0.5587	-0.0880 + 0.2990i	0.3361 - 0.2735i	0.3616 - 0.5216i
101011	43	0.5587	-0.2990 - 0.0880i	-0.3361 + 0.2735i	-0.5216 - 0.3616i
101100	44	0.5636	0.2741 - 0.1559i	0.2672 + 0.3332i	0.1081 + 0.6236i
101101	45	0.5636	0.1559 + 0.2741i	-0.2672 - 0.3332i	0.6236 - 0.1081i
101110	46	0.5587	-0.2737 + 0.1492i	0.2735 + 0.3361i	-0.1132 - 0.6245i

Table 674—C(4,1,6)

Binary Index	*m*	C(4,1,6,*m*)			
101111	47	0.5587	-0.1492 - 0.2737i	-0.2735 - 0.3361i	-0.6245 + 0.1132i
110000	48	0.5000	-0.4619 + 0.1913i	0.3536 - 0.3536i	-0.1913 + 0.4619i
110001	49	0.3117	0.4030 + 0.4903i	-0.6025 - 0.1995i	-0.1122 - 0.2908i
110010	50	0.3117	-0.4029 - 0.4904i	-0.1184 - 0.2883i	0.6067 + 0.1865i
110011	51	0.3082	0.4887 - 0.4077i	0.1205 + 0.2837i	0.1842 - 0.6092i
110100	52	0.5000	0.1913 + 0.4619i	-0.3536 + 0.3536i	-0.4619 - 0.1913i
110101	53	0.5000	-0.1913 - 0.4619i	-0.3536 + 0.3536i	0.4619 + 0.1913i
110110	54	0.5000	0.4619 - 0.1913i	0.3536 - 0.3536i	0.1913 - 0.4619i
110111	55	0.3117	-0.2452 + 0.3573i	0.6025 + 0.1995i	-0.5360 + 0.1578i
111000	56	0.3117	0.3117 - 0.0000i	0.4030 - 0.4903i	-0.4030 + 0.4903i
111001	57	0.3117	-0.0000 + 0.3117i	-0.4030 + 0.4903i	0.4903 + 0.4030i
111010	58	0.3082	-0.3152 - 0.0036i	0.4076 - 0.4888i	0.4040 - 0.4872i
111011	59	0.3082	0.0036 - 0.3152i	-0.4076 + 0.4888i	-0.4872 - 0.4040i
111100	60	0.3117	0.2204 + 0.2204i	0.4903 + 0.4030i	0.0618 + 0.6317i
111101	61	0.3117	-0.2204 + 0.2204i	-0.4903 - 0.4030i	0.6317 - 0.0618i
111110	62	0.3082	-0.2154 - 0.2302i	0.4887 + 0.4077i	-0.0451 - 0.6313i
111111	63	0.3082	0.2254 - 0.2204i	-0.4888 - 0.4076i	-0.6302 + 0.0588i

Table 675—C(4,2,6)

$$C(4, 2, 6, m) = \begin{bmatrix} C(4, 1, 6, i) \\ C(4, 1, 6, j) \end{bmatrix}$$

Binary index	m	i,j	Binary index	m	i,j	Binary index	m	i,j	Binary index	m	i,j
000000	0	6,0	010000	16	0,4	100000	32	12,14	110000	48	32,34
000001	1	6,1	010001	17	0,5	100001	33	12,15	110001	49	34,35
000010	2	6,2	010010	18	0,33	100010	34	12,31	110010	50	35,7
000011	3	0,1	010011	19	1,3	100011	35	13,14	110011	51	40,11
000100	4	0,2	010100	20	1,34	100100	36	5,23	110100	52	41,43
000101	5	1,2	010101	21	1,55	100101	37	14,15	110101	53	44,46
000110	6	7,4	010110	22	2,3	100110	38	14,47	110110	54	45,47
000111	7	7,5	010111	23	8,9	100111	39	17,2	110111	55	49,6

Table 675—C(4,2,6)

$C(4, 2, 6, m) = \begin{bmatrix} C(4, 1, 6, i) \\ C(4, 1, 6, j) \end{bmatrix}$												
001000	8	3,4	011000	24	2,39	101000	40	17,3	111000	56	52,53
001001	9	3,5	011001	25	8,11	101001	41	18,19	111001	57	56,10
001010	10	6,4	011010	26	8,27	101010	42	18,6	111010	58	56,58
001011	11	6,5	011011	27	9,10	101011	43	24,9	111011	59	57,11
001100	12	7,1	011100	28	9,42	101100	44	25,10	111100	60	57,59
001101	13	7,2	011101	29	10,11	101101	45	28,13	111101	61	60,14
001110	14	8,10	011110	30	10,43	101110	46	29,14	111110	62	61,15
001111	15	13,15	011111	31	12,13	101111	47	30,15	111111	63	61,63

Table 676—C(4,3,4)

$C(4, 3, 4, m) = \begin{bmatrix} C(4, 1, 6, i) \\ C(4, 1, 6, j) \\ C(4, 1, 6, k) \end{bmatrix}$												
Binary index	m	i,j,k	Binary index	m	i,j,k	Binary index	m	i,j,k	Binary index	m	i,j,k
000000	0	6,0,1	000100	4	7,3,4	001000	8	6,0,4	001100	12	8,9,10
000001	1	6,0,2	000101	5	7,3,5	001001	9	6,4,5	001101	13	8,10,11
000010	2	6,1,2	000110	6	7,4,5	001010	10	7,3,1	001110	14	12,13,15
000011	3	0,1,2	000111	7	3,4,5	001011	11	7,1,2	001111	15	13,14,15

Table 677—C(4,4,3)

$C(4, 4, 3, m) = \begin{bmatrix} C(4, 1, 6, i) \\ C(4, 1, 6, j) \\ C(4, 1, 6, k) \\ C(4, 1, 6, p) \end{bmatrix}$									
Binary index	m	i,j,k,p	Binary index	m	i,j,k,p	Binary index	m	i,j,k,p
000000	0	6,0,1,2	000010	2	6,0,4,5	000100	4	8,9,10,11
000001	1	7,3,4,5	000011	3	7,3,1,2	000101	5	12,13,14,15

In terms of the chordal distance, the hierarchical structure of C(4,1,6) is depicted in Figure 432. In this hierarchical structure, it is shown that C(4,1,6) consists of 16 codeword clusters. Each codeword cluster has four codewords, of which one codeword is from Layer 1 and the three other codewords are from Layer 2. For any

given Layer 2 codeword, its chordal distance to all other Layer 1 codewords of different clusters is always much larger than that distance to the Layer 1 codeword of its same cluster
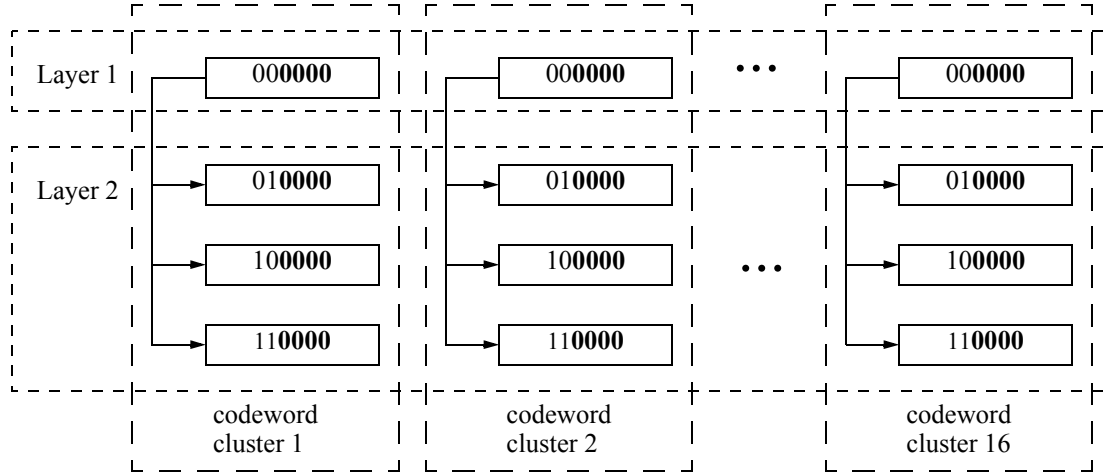
Figure 432—Chordal distance map of C(4,1,6)

As a potential benefit, this hierarchical structure can facilitate codeword searching. More specifically, codeword searching in C(4,1,6) can start from all Layer 1 codewords. Only when a Layer 1 codeword satisfies a certain criterion, associated Layer 2 codewords within the same cluster need to be searched.

The binary indices of the codewords in cluster, $i, i \in [0, ..., 15]$ is given by Table 678.

Table 678—Binary indices oft he codewords in cluster *i*

Codeword in cluster i	Layer 1 codeword	Layer 2 codewords		
		Codeword 1	Codeword 2	Codeword 3
Binary index	$00x_{i3}x_{i2}x_{i1}x_{i0}$	$01x_{i3}x_{i2}x_{i1}x_{i0}$	$10x_{i3}x_{i2}x_{i1}x_{i0}$	$11x_{i3}x_{i2}x_{i1}x_{i0}$
$i = x_{i3} \times 2^3 + x_{i2} \times 2^2 + x_{i1} \times 2 + x_{i0}, x_{ij} \in [0, 1], i \in [0, ..., 15], j \in [0, 1, 2, 3]$				

15.3.7.2.6.6.2.2.2 MU-MIMO base codebook

The base codebook for MU-MIMO is same as the rank 1 base codebook for SU-MIMO, defined in 15.3.7.2.6.6.2.2.1.

15.3.7.2.6.6.2.3 Base codebook for eight transmit antennas

15.3.7.2.6.6.2.3.1 SU-MIMO base codebook

The base codebook is constructed from two matrices V8(:,:,1) and V8(:,:,2), which are constructed as described below

$$T1 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

$$T2 = \begin{bmatrix} 1 & 1 \\ \dfrac{1+j}{\sqrt{2}} & -\dfrac{1+j}{\sqrt{2}} \end{bmatrix}$$

$$T3 = \begin{bmatrix} 1 & 1 \\ j & -j \end{bmatrix}$$

$$T4 = \begin{bmatrix} 1 & 1 \\ \dfrac{-1+j}{\sqrt{2}} & -\dfrac{-1+j}{\sqrt{2}} \end{bmatrix}$$

Define

$$\mathbf{H}_i(m1, m2) \equiv \mathbf{H}_i(\mathbf{T}_{m1}, \mathbf{T}_{m2})$$
$$= \left[\mathbf{T}_i(:,1) \otimes \mathbf{T}_{m1}, \ \mathbf{T}_i(:,2) \otimes \mathbf{T}_{m2} \right] \tag{206}$$

$$\mathrm{H}_{i,k,l}(\mathbf{T}_{m1}, \mathbf{T}_{m2}, \mathbf{T}_{m3}, \mathbf{T}_{m4}) \equiv \mathrm{H}_{i,k,l}(m1, m2, m3, m4)$$
$$= \left(\mathbf{T}_i(:,1) \otimes \left[\mathrm{H}_k(m1, m2) \right], \ \mathbf{T}_i(:,2) \otimes \left[\mathrm{H}_l(m3, m4) \right] \right) \tag{207}$$
$$= \mathrm{H}_i\left(\mathrm{H}_k(m1, m2), \mathrm{H}_l(m3, m4) \right)$$

The two rank-8 matrices used for rank-2 to rank-8 transmission for SU-MIMO are:

$$V8(:,:,1) = \frac{1}{\sqrt{8}} H_{1,1,3}(1,3,2,4) = \frac{1}{\sqrt{8}} \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & j & -j & \dfrac{(1+j)}{\sqrt{2}} & -\dfrac{(1+j)}{\sqrt{2}} & \dfrac{(-1+j)}{\sqrt{2}} & -\dfrac{(-1+j)}{\sqrt{2}} \\ 1 & 1 & -1 & -1 & j & j & -j & -j \\ 1 & -1 & -j & j & \dfrac{(-1+j)}{\sqrt{2}} & -\dfrac{(-1+j)}{\sqrt{2}} & \dfrac{(1+j)}{\sqrt{2}} & -\dfrac{(1+j)}{\sqrt{2}} \\ 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 \\ 1 & -1 & j & -j & -\dfrac{(1+j)}{\sqrt{2}} & \dfrac{(1+j)}{\sqrt{2}} & -\dfrac{(-1+j)}{\sqrt{2}} & \dfrac{(-1+j)}{\sqrt{2}} \\ 1 & 1 & -1 & -1 & -j & -j & j & j \\ 1 & -1 & -j & j & -\dfrac{(-1+j)}{\sqrt{2}} & \dfrac{(-1+j)}{\sqrt{2}} & -\dfrac{(1+j)}{\sqrt{2}} & \dfrac{(1+j)}{\sqrt{2}} \end{bmatrix} \tag{208}$$

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$$V8(:,:,2)=\frac{1}{\sqrt{8}}H_{3,2,4}(1,3,2,4)=\frac{1}{\sqrt{8}}\begin{bmatrix} 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & -1 & j & -j & \frac{(1+j)}{\sqrt{2}} & -\frac{(1+j)}{\sqrt{2}} & \frac{(-1+j)}{\sqrt{2}} & -\frac{(-1+j)}{\sqrt{2}} \\ \frac{(1+j)}{\sqrt{2}} & \frac{(1+j)}{\sqrt{2}} & -\frac{(1+j)}{\sqrt{2}} & -\frac{(1+j)}{\sqrt{2}} & \frac{(-1+j)}{\sqrt{2}} & \frac{(-1+j)}{\sqrt{2}} & -\frac{(-1+j)}{\sqrt{2}} & -\frac{(-1+j)}{\sqrt{2}} \\ \frac{(1+j)}{\sqrt{2}} & -\frac{(1+j)}{\sqrt{2}} & -\frac{(-1+j)}{\sqrt{2}} & \frac{(-1+j)}{\sqrt{2}} & -1 & 1 & j & -j \\ j & j & j & j & -j & -j & -j & -j \\ j & -j & -1 & 1 & -\frac{(-1+j)}{\sqrt{2}} & \frac{(-1+j)}{\sqrt{2}} & \frac{(1+j)}{\sqrt{2}} & -\frac{(1+j)}{\sqrt{2}} \\ \frac{(-1+j)}{\sqrt{2}} & \frac{(-1+j)}{\sqrt{2}} & -\frac{(-1+j)}{\sqrt{2}} & -\frac{(-1+j)}{\sqrt{2}} & \frac{(1+j)}{\sqrt{2}} & \frac{(1+j)}{\sqrt{2}} & -\frac{(1+j)}{\sqrt{2}} & \frac{(1+j)}{\sqrt{2}} \\ \frac{(-1+j)}{\sqrt{2}} & -\frac{(-1+j)}{\sqrt{2}} & \frac{(1+j)}{\sqrt{2}} & -\frac{(1+j)}{\sqrt{2}} & j & -j & 1 & -1 \end{bmatrix} \quad (209)$$

The third base matrix, V8(:,:,3), is used for rank-1 transmission for MU-MIMO. The j-th column vector of the base matrix V8(:,:,3) is given by

$$V_8(:,j,3)=\frac{1}{\sqrt{8}}\begin{bmatrix} 1 \\ e^{j\pi\sin(\theta_j)} \\ e^{j2\pi\sin(\theta_j)} \\ e^{j3\pi\sin(\theta_j)} \\ e^{j4\pi\sin(\theta_j)} \\ e^{j5\pi\sin(\theta_j)} \\ e^{j6\pi\sin(\theta_j)} \\ e^{j7\pi\sin(\theta_j)} \end{bmatrix} \quad (210)$$

where the set $\theta_j, j = 1, ..., 16$ is given by:

$$\theta_j = ((j-1)+1/2)\times\frac{\pi}{24}-\frac{\pi}{3} \quad (211)$$

The 4bits 8Tx base codebook is constructed from the three 8×8 base matrices and is specified in Table 679 and Table 680. Note that only the column indices of the corresponding base matrices are shown in Table 673 for brevity.

Table 679—Rank 1 of SU MIMO 4bit 8Tx base codebook

Codebook Matrix Index (CMI)	Base Matrix	C(8,1,4)

Table 679—Rank 1 of SU MIMO 4bit 8Tx base codebook

1		V8(:,1,3)
2		V8(:,2,3)
3		V8(:,3,3)
4		V8(:,4,3)
5		V8(:,5,3)
6		V8(:,6,3)
7		V8(:,7,3)
8	V8(:,:,3)	V8(:,8,3)
9		V8(:,9,3)
10		V8(:,10,3)
11		V8(:,11,3)
12		V8(:,12,3)
13		V8(:,13,3)
14		V8(:,14,3)
15		V8(:,15,3)
16		V8(:,16,3)

Table 680—Ranks 2 to 8 of SU MIMO 4 bit 8Tx base codebook

Codebook Matrix Index (CMI)	Base Matrix	C(8,2,4)	C(8,3,4)	C(8,4,4)	C(8,5,4)	C(8,6,4)	C(8,7,4)	C(8,8,4)
1		15	1 3 5	1537	12357	123567	1234567	12345678
2		2 6	2 4 6	2648	12468	124568	1234568	n/a
3		3 7	2 3 7	3726	23467	234678	1234678	n/a
4		4 8	1 4 8	4815	13458	134578	1234578	n/a
5		5 3	3 5 7	5372	23567	234567	2345678	n/a
6		4 6	4 6 8	6481	14568	134568	1345678	n/a
7		2 7	2 6 7	7264	24678	124678	1245678	n/a
8		8 1	1 5 8	8153	13578	123578	1235678	n/a
9	V8(:,:,1)							
		1 2 3	1234	12345	123456	1234567	12345678	
10		2 4	1 2 4	1246	12456	124567	1245678	n/a
11		2 3	2 3 4	2437	23478	123478	1234578	n/a
12		1 4	1 3 4	1348	13478	134678	1234678	n/a
13		5 8	5 7 8	3578	23578	235678	1235678	n/a
14		6 7	6 7 8	4678	14678	145678	1345678	n/a
15		5 7	5 7 6	5678	35678	345678	2345678	n/a
16		6 8	5 6 8	1568	13568	123568	1234568	n/a

15.3.7.2.6.6.2.3.2 MU-MIMO base codebook

The base codebook for MU-MIMO is same as the rank 1 base codebook for SU-MIMO, defined in 15.3.7.2.6.6.2.3.1

15.3.7.2.6.6.2.4 Codebook subset selection

In codebook-based precoding, the precoding matrix W(k) shall be derived from PMI within the base code-book or a subset thereof. Subset information such as BC_SI, SU_CT, or MU_CT [TBD] is transmitted in [TBD].

Base Codebook Subset Indication (BC_SI) field determines which element of rank-1 codebook element is restricted or recommended for PMI feedback in case of MIMO mode 2 and 4. If the i-th element of BC_SI is set to 0, then i -th element of rank-1 codebook, C(Nt, 1, NB, i), is restricted for PMI feedback. This field shall be ignored when Codebook Coordination Enable (CCE) is set to 0b0. CCE is transmitted in [Feedback_Allocation_IE].

15.3.7.2.6.6.2.4.1 OL MIMO subset

15.3.7.2.6.6.2.4.2 CL MIMO subset

15.3.7.2.6.6.2.4.2.1 CL MIMO subset for four transmit antennas

Codebook subset selection for four transmit antennas is specified in Table 681.

Table 681—Subset selection of the base codebok for four transmit antennas

Rank	One	Two	Three	Four
Subset selection	C(4,1,6,m) m = 0 to15	C(4,2,6,m) m = 0 to15	C(4,3,4,m) m = 0 to15	C(4,4,3,m) m = 0 to5

15.3.7.2.6.6.2.4.3 CL MU-MIMO subset

15.3.7.2.6.6.3 Adapative codebook based feedback mode

The base codebooks and their subsets for SU and MU MIMO can be transformed as a function of the BS transmit correlation matrix. A quantized representation of the BS transmit correlation matrix shall be feed-back by the MS as instructed by the BS

For the adaptive mode, the PMI feedback from a mobile station shall represent an entry of the transformed base codebook according to long term channel information.

In adaptive mode, both BS and MS transform the base codebook to a transformed codebook using the correlation matrix.

The transformation for codewords of rank 1 is of the form in Equation (212)

$$\widetilde{\mathbf{V}}_i = \frac{\mathbf{R}\mathbf{v}_i}{\|\mathbf{R}\mathbf{v}_i\|} \tag{212}$$

The transformation for codewords of rank > 1 is of the form in Equation (213)

$$\widetilde{\mathbf{V}}_i = \mathrm{orth}\!\left(\mathbf{R}\,\mathbf{V}_i\right) \tag{213}$$

Where,

        $\mathbf{X}$ is the input matrix (or vector),

        $\mathbf{V}_i$ is the i-th codeword of the base codebook,

        $\tilde{V}_i$ is the i-th codeword of the transformed codebook,

R is the $N_t \times N_t$ transmit correlation matrix.

orth(**X**) converts the input matrix (or vector) **X** to an orthogonal matrix with orthogonal column(s) that span the same subspace as the columns of **X**. The correlation matrix **R** contains the averaged directions for pre-coding.

After obtaining the transformed codebook, both MS and BS shall use the transformed codebook for the feed-back and precoding process.

The correlation matrix R shall be feedbacked to support adaptive mode of codebook-based precoding.

R is feedbacked every Nx superframes (Nx is TBD) and one correlation matrix is valid for whole band.

During some time period and in the whole band, the correlation matrix is measured as

$$\mathbf{R} = \mathrm{E}(\mathbf{H}_{ij}^{H}\mathbf{H}_{ij}) \tag{214}$$

Where $\mathbf{H}_{ij}$ is the correlated channel matrix in the i-th OFDM symbol period and j-th subcarriers.

The measured correlation matrix has the format of

$$\mathbf{R} = \begin{pmatrix} r_{11} & r_{12} \\ \mathrm{conj}(r_{12}) & r_{22} \end{pmatrix} \quad (N_T = 2) \tag{215}$$

$$\mathbf{R} = \begin{pmatrix} r_{11} & r_{12} & r_{13} & r_{14} \\ \mathrm{conj}(r_{12}) & r_{22} & r_{23} & r_{24} \\ \mathrm{conj}(r_{13}) & \mathrm{conj}(r_{23}) & r_{33} & r_{34} \\ \mathrm{conj}(r_{14}) & \mathrm{conj}(r_{24}) & \mathrm{conj}(r_{34}) & r_{44} \end{pmatrix} \quad (N_T = 4) \tag{216}$$

where the diagonal entries are positive and the non-diagonal entries are complex. Because of the symmetriy of the correlation matrix, only the upper triangular elements shall be feedbacked after quantization.

R matrix is normalized by the maximum element (amplitude), and then quantized to reduce the feedback overhead.

The equation of normalization is

$$\bar{R} = \frac{R}{max(abs(r_{ij}))} \qquad (i, j = 1, ..., N_t) \tag{217}$$

The normalized diagonal elements are quantized by 1 bit, and the normalized complex elements are quan-tized by 4 bits.

The equation for quantization is

$$q = a \cdot e^{(j \cdot b \cdot 2\pi)} \tag{218}$$

a=[0.6 0.9] and *b*=0 for diagonal entries

Table 682—

Diagonal Entries	a	b	q
q_1	0.6	0	0.6000
q_2	0.9	0	0.9000

a=[0.1 0.5] and *b*=[0 1/8 1/4 3/8 1/2 5/8 3/4 7/8] for non-diagonal upper trangular entries

Table 683—

non-Diagonal Entries	a	b	q
q_1	0.1	0	0.1000
q_2	0.1	1/8	0.0707 + 0.0707i
q_3	0.1	1/4	0.0000 + 0.1000i
q_4	0.1	3/8	-0.0707 + 0.0707i
q_5	0.1	1/2	-0.1000 + 0.0000i
q_6	0.1	5/8	-0.0707 - 0.0707i
q_7	0.1	3/4	-0.0000 - 0.1000i
q_8	0.1	7/8	0.0707 - 0.0707i
q_9	0.5	0	0.5000
q_{10}	0.5	1/8	0.3536 + 0.3536i
q_{11}	0.5	1/4	0.0000 + 0.5000i
q_{12}	0.5	3/8	-0.3536 + 0.3536i
q_{13}	0.5	1/2	-0.5000 + 0.0000i
q_{14}	0.5	5/8	-0.3536 - 0.3536i
q_{15}	0.5	3/4	-0.0000 - 0.5000i
q_{16}	0.5	7/8	0.3536 - 0.3536i

The total overhead is 6 bits for 2 transmit antennas and 28 bits for 4 transmit antenna. The MS and BS shall use the same transformation based on the correlation matrix fed back by the MS.

15.3.7.2.6.6.4 Differential codebook-based feedback mode

15.3.7.2.6.7 Unquantized MIMO feedback for closed-loop transmit precoding

15.3.7.2.6.7.1 UL sounding

To assist the BS in determining the precoding matrix to use for SU-MIMO or MU-MIMO, the BS may request the MS transmit a sounding signal in an UL sounding channel. The BS may translate the measured UL channel response to an estimated DL channel response. The transmitter and receiver hardware of BS and MS shall be calibrated.

The UL sounding channel defined in subclause [TBD] is used in MIMO transmission

15.3.7.2.6.7.2 Analog feedback

15.3.7.3 Transmission schemes for control channels

15.3.7.3.1 Superframe header (SFH)

For two BS transmit antennas, the P-SFH and the S-SFH shall be transmitted using SFBC.

The input to the MIMO encoder is represented by a 2 × 1 vector.

$$\mathbf{s} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix} \tag{219}$$

The MIMO encoder generates the SFBC matrix.

$$\mathbf{x} = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix} \tag{220}$$

The two-stream pilot pattern defined in 15.3.5.x is used for SFH transmission.

15.3.7.3.2 Advanced MAP (A-MAP)

MIMO mode 0 shall be used for transmission of the A-MAP.

Two stream pilot pattern defined in 15.3.5.x shall be used for A-MAP transmission.

15.3.7.4 MIMO transmission schemes for E-MBS

15.3.8 Uplink physical structure

Each uplink subframe is divided into 4 or fewer frequency partitions; each partition consists of a set of physical resource units across the total number of OFDMA symbols available in the subframe. Each frequency partition can include contiguous (localized) and/or non-contiguous (distributed) physical resource units. Each frequency partition can be used for different purposes such as fractional frequency reuse (FFR). Figure 433 illustrates the uplink physical structure in the example of two frequency partitions with frequency partition 2 including both contiguous and distributed resource allocations.
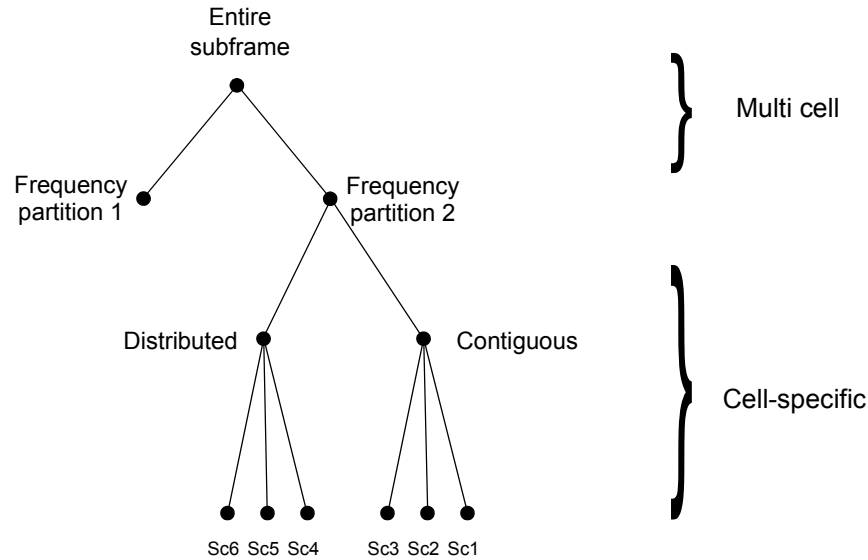
Figure 433—Example of uplink physical structure

15.3.8.1 Physical and logical resource unit

A physical resource unit (PRU) is the basic physical unit for resource allocation that comprises P_{sc} consecutive subcarriers by N_{sym} consecutive OFDMA symbols. P_{sc} is 18 and N_{sym} is 6 for type-1 subframes, 7 for type-2 subframes, and 5 for type-3 subframes. A logical resource unit (LRU) is the basic logical unit for distributed and localized resource allocations. An LRU has P_{sc} x N_{sym} subcarriers.

The LRU size for control channel transmission should be same as for data transmission. Multiple users are allowed to share one control LRU. The effective number of data subcarriers in an LRU depends on the number of allocated pilots and control channel presence.

15.3.8.1.1 Distributed resource unit

The distributed resource unit (DRU) contains a group of subcarriers which are spread across the distributed resource allocations within a frequency partition. The size of the DRU equals the size of a PRU, i.e., P_{sc} subcarriers by N_{sym} OFDMA symbols. The minimum unit for forming the DRU is a tile. The uplink tile size is 6 x N_{sym}, where the value of N_{sym} depends on the subframe type.

15.3.8.1.2 Contiguous resource unit

The localized resource unit, also known as contiguous resource unit (CRU contains a group of subcarriers which are contiguous across the resource allocations. The size of the CRU equals the size of a PRU, i.e., P_{sc} subcarriers by N_{sym} OFDMA symbols.

15.3.8.2 Multi-cell resource mapping

The UL multi-cell resource mapping consists of subband partitioning, miniband permutation and frequency partitioning and is defined in the following subclauses.

15.3.8.2.1 Subband Partitioning

The PRUs are first divided into subbands and minibands; a subband comprises N_1 adjacent PRUs and a miniband N_2 adjacent PRUs where $N_1=4$ and $N_2=1$. Subbands are suitable for frequency selective allocations as they provide a continuous allocation of PRUs in frequency. Minibands are suitable for frequency diverse allocation and are permuted in frequency.

The number of subbands is denoted by K_{SB}. The number of PRUs allocated to subbands is $L_{SB} = N_1*K_{SB}$. A 4 or 3-bit (TBD) field called *Uplink Subband Allocation Count* (USAC) determines the value of K_{SB} depending on system bandwidth. The USAC is transmitted in the SFH. The remaining PRUs are allocated to minibands. The number of minibands in an allocation is denoted by K_{MB}. The number of PRUs allocated to minibands is $L_{MB} = N_2*K_{MB}$. The total number of PRUs is $N_{PRU} = L_{SB} + L_{MB}$. Mappings between USAC and KSB are shown in Table 684 and Table 685.

Table 684—Mapping between USAC and KSB for 10 or 20MHz

USAC	# of subbands allocated (KSB)	USAC	# of subbands allocated (KSB)
0	0	8	10
1	1	9	12
2	2	10	14
3	3	11	16
4	4	12	18
5	5	13	20
6	6	14	22
7	8	15	24

Table 685—Mapping between USAC and KSB for 5MHz

USAC	# of subbands allocated (KSB)	USAC	# of subbands allocated (KSB)
0	0	4	4
1	1	5	5
2	2	6	6
3	3	7	N.A

The PRUs are partitioned and reordered into two groups of subband PRUs, PRU$_{SB}$, and miniband PRUs, PRU$_{MB}$. The set of PRU$_{SB}$ is numbered from 0 to (L_{SB}-1) and the set of PRU$_{MB}$ from 0 to (L_{MB}-1).

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Equation (221) defines the mapping of PRUs into PRU_{SB}s. Equation (222) defines the mapping of PRUs to PRU_{MB}s. Figure 434 illustrates the PRU to PRU_{SB}s and PRU_{MB}s mapping for a 5 MHz bandwidth with K_{SB} equal to 3.

$$PRU_{SB}[j] = PRU[i]; \qquad 0 \leq j \leq L_{SB} - 1 \tag{221}$$

$$PRU_{MB}[k] = PRU[i]; \quad k = 0, 1, \ldots, L_{MB} - 1 \tag{222}$$
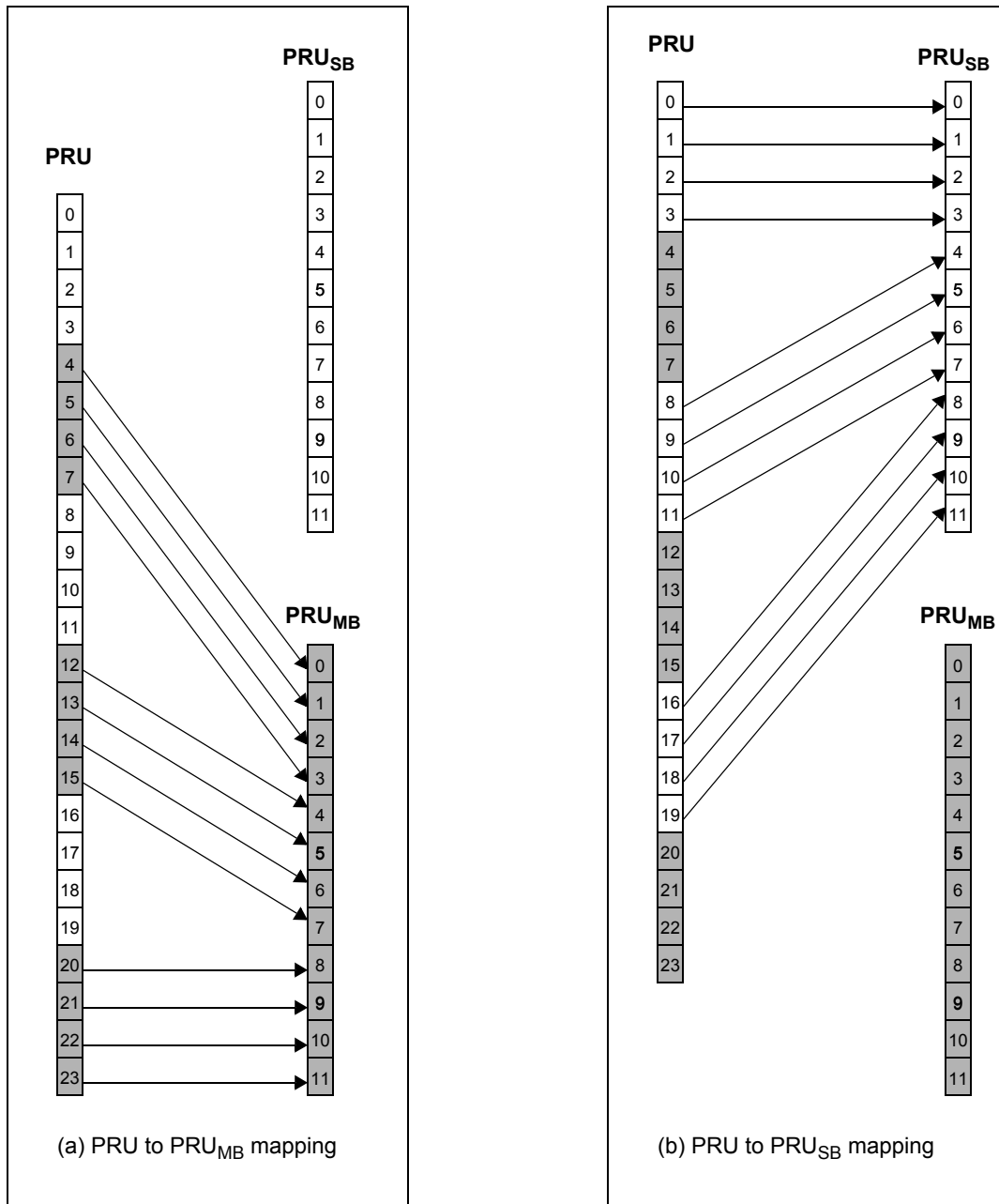
Figure 434—PRU to PRU$_{SB}$ and PRU$_{MB}$ mapping for BW of 5 MHz and K_{SB}=3

15.3.8.2.2 Miniband permutation

The miniband permutation maps the PRU$_{MB}$s to permuted-PRU$_{MB}$s (PPRU$_{MB}$s) to insure allocation of frequency diverse PRUs to each frequency partition. Equation (223) provides a mapping from PRU$_{MB}$s to PPRU$_{MB}$s.

$$PPRU_{MB}[j] = PRU_{MB}[i]; \qquad 0 \le j \le L_{MB} - 1 \tag{223}$$
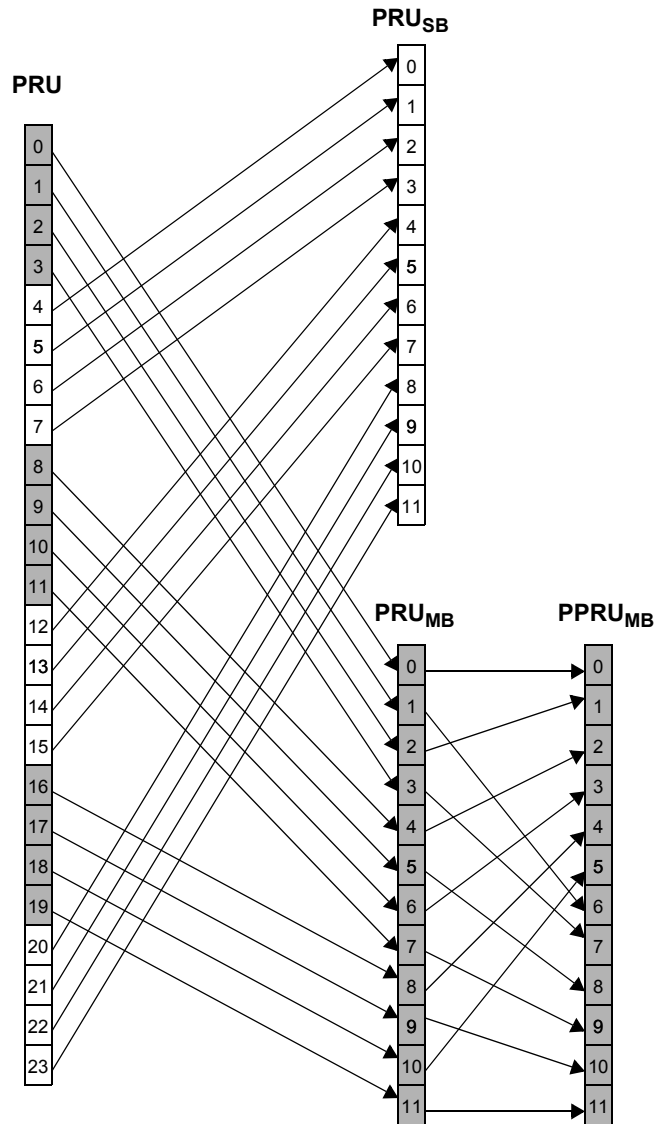
Figure 435—Mapping of PRU$_{SB}$ to PRU$_{SB}$ and PPRU$_{MB}$ for BW 5MHz, K_{SB}=3

15.3.8.2.3 Frequency partitioning

The PRU$_{SB}$ and PPRU$_{MB}$ are allocated to one or more frequency partitions. By default, only one partition is present. The maximum number of frequency partitions is 4 (TBD). The frequency partition configuration is transmitted in the SFH in a 4 or 3-bit composite field called the *Uplink Frequency Partition Configuration* (UFPC), depending on system bandwidth. Frequency Partition Count (FPCT) defines the number of frequency partitions. Frequency Partition Size (FPSi) defines the number of PRUs allocated to FPi. FPCT and FPSi are determined from FPC as shown in Table 686 and Table 687.

The Frequency Partition Subband Count (FPSC) occupies the remaining 3 bits and define the number of subbands allocated to FPi for i>0.

The UFPC consists of *Frequency Partition Count* (FPCT), *Frequency Partition Size* (FPS) and *Frequency Partition Subband Count* (FPSC) fields. The FPCT occupies the first 2 bits and defines the number of frequency partitions to be from 1 to 4. The FPS occupies the next 6 bits and defines the number of PRUs, in minibands (N_2) of PRUs, allocated to FPi for $i>0$. The FPSC occupies the remaining 4 bits and defines the number of subbands allocated to FPi for $i>0$.

Table 686—Mapping between UFPC and frequency partitioning for 10 or 20MHz

UFPC	Freq. Partitioning (FP0:FP1:FP2: FP3)	FPCT	FPCT	FPSi (i>0)
0	1 : 0 : 0 : 0	1	NPRU	0
1	0 : 1 : 1 : 1	3	0	NPRU * 1/3
2	1 : 1 : 1 : 1	4	NPRU * 1/4	NPRU * 1/4
3	3 : 1 : 1 : 1	4	NPRU * 3/6	NPRU * 1/6
4	5 : 1 : 1 : 1	4	NPRU * 5/8	NPRU * 1/8
5-15	Reserved			

Table 687—Mapping between FPC and frequency partitioning for 5MHz

UFPC	Freq. Partitioning (FP0:FP1:FP2: FP3)	FPCT	FPCT	FPSi (i>0)
0	1 : 0 : 0 : 0	1	NPRU	0
1	0 : 1 : 1 : 1	3	0	NPRU * 1/3
2	1 : 1 : 1 : 1	4	NPRU * 1/4	NPRU * 1/4
3	3 : 1 : 1 : 1	4	NPRU * 3/6	NPRU * 1/6
4	5 : 1 : 1 : 1	4	NPRU * 5/8	NPRU * 1/8
5-7	Reserved			

The number of subbands and minibands in the ith frequency partition are denoted by $K_{\text{SB,FP}i}$ and $K_{\text{MB,FP}i}$ respectively.

$$K_{SB,FPi} = \begin{cases} K_{SB} - (FPCT - 1) \cdot FPSC & i = 0 \\ FPSC & i > 0 \end{cases} \quad (224)$$

$$K_{MB,FPi} = \begin{cases} K_{MB} - (FPCT-1) \cdot (FPS - FPSC \cdot N_1/N_2) & i = 0 \\ FPS - FPSC \cdot N_1/N_2 & i > 0 \end{cases} \quad (225)$$

The numbers of subband PRUs and miniband PRUs in each frequency partition are $L_{SB,FPi} = N_1 \cdot K_{SB,FPi}$ and $L_{MB,FPi} = N_2 \cdot K_{MB,FPi}$ respectively.

The mapping of subband PRUs and miniband PRUs to the frequency partition i is given in the following equations:

$$PRU_{FPi}(j) = \begin{cases} PRU_{SB}(k_1) & 0 \le j < L_{SB,FPi} \\ PPRU_{MB}(k_2) & L_{SB,FPi} \le j < (L_{SB,FPi} + L_{MB,FPi}) \end{cases} \quad (226)$$

Where $k_1 = \sum\limits_{m=0}^{i-1} L_{SB,FPj} + j$ and $k_2 = \sum\limits_{m=0}^{i-1} L_{MB,FPm} + j - L_{SB,FPi}$.

Figure 436 depicts the frequency partitioning for BW of 5 MHz, $K_{SB} = 3$, FPCT = 2, FPS = 12, and FPSC = 1.
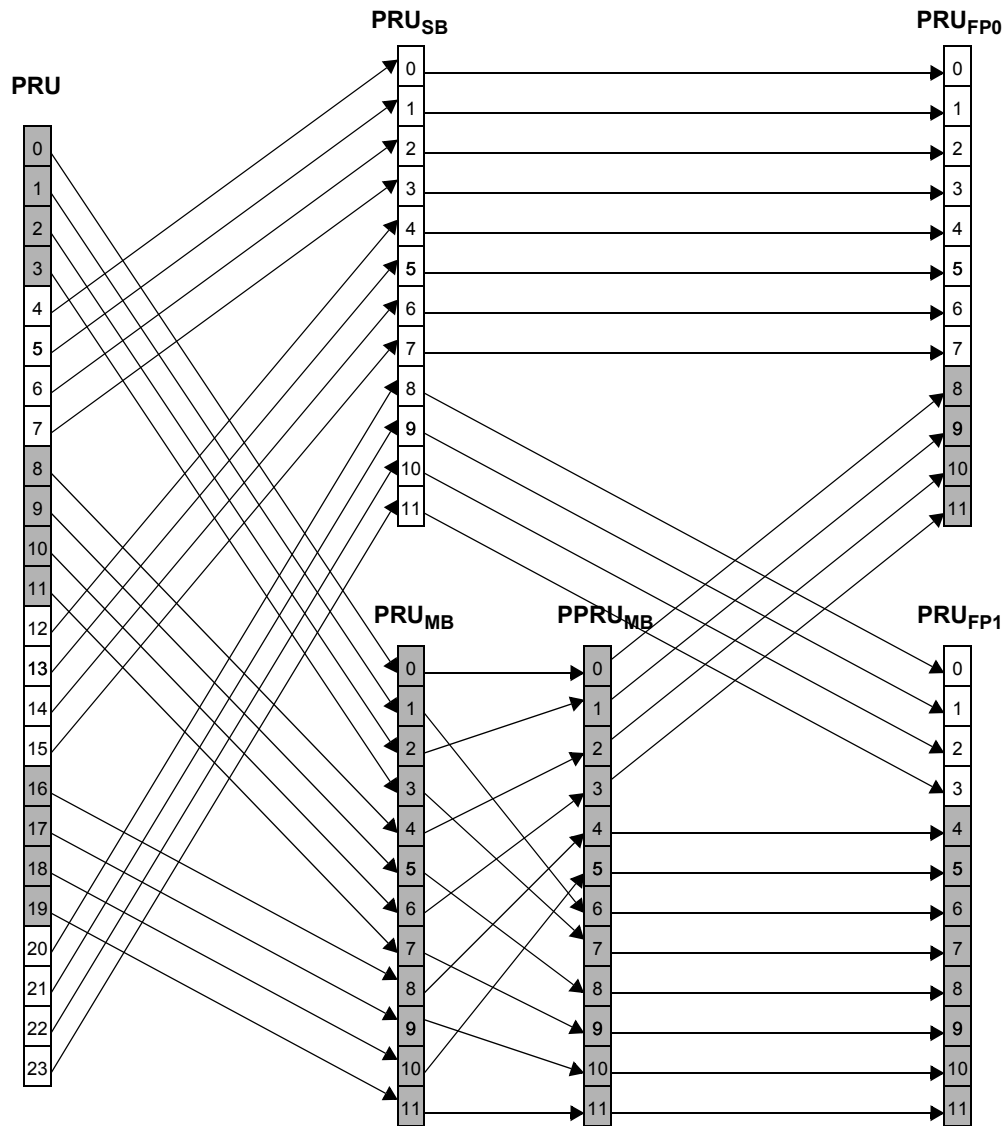
Figure 436—Frequency partitioning

15.3.8.3 Cell-specific resource mapping

PRU$_{FPi}$s are mapped to LRUs. All further PRUs and tile permutations are constrained to the PRUs within the frequency partition.

15.3.8.3.1 CRU/DRU allocation

The partition between CRUs and DRUs is done on a sector specific basis. [4]-bit uplink subband-based CRU allocation size ($UCAS_{SB,i}$) field is sent in the SFH for each allocated frequency partition. $UCAS_{SB,i}$ indicates the number of allocated subband-based CRUs for partition FPi in the unit of subband size. And [6]-bit uplink miniband-based CRU allocation size ($UCAS_{MB}$) is sent in the SFH only for partition FP0, which indicates the number of allocated miniband-based CRUs for partition FP0.

The number of CRUs in each frequency partition is denoted by $L_{CRU,FPi}$ calculated as shown in Equation (227)

$$L_{DRU,FPi} = \begin{cases} UCAS_{SB,i} \cdot N_i + UCAS_{MB} & \text{for } i=0 \\ UCAS_{SB,i} \cdot N_i & \text{for } 0 < i < UFPCT \end{cases} \tag{227}$$

The number of DRUs in each frequency partition is denoted by $L_{DRU,FPi}$, calculated as shown in Equation (228)

$$L_{DRU,FPi} = UFPS_i \cdot N_2 - L_{CRU,FPi} \qquad \text{for } 0 \le i \le UFPCT \tag{228}$$

The mapping of PRU_{FPi} to CRU_{FPi} is given by Equation (229):

$$CRU_{FPi}[j] = \begin{cases} PRU_{FPi}[j] & 0 \le j \le UCAS_{SB,i} \cdot N_1 \\ PRU_{FPi}[k + UCAS_{SB,i} \cdot N_1] & UCAS_{SB,i} \cdot N_1 \le j < L_{CRU,FPi} \end{cases}, 0 \le i < UFPCT \tag{229}$$

where $k = s[j - UCAS_{SB,i} \cdot N_1]$. $s[]$ is the CRU/DRU-allocation sequence (TBD), and

$0 \le s[j] < UFPS_i \cdot N_2 - UCAS_{SB,i} \cdot N_1$.

The mapping of PRU_{FPi} to DRU_{FPi} is given by Equation (230):

$$DRU_{FPi}[j] = PRU_{FPi}[k + UCAS_{SB,i} \cdot N_1] \qquad 0 \le i < UFPCT, 0 \le j < L_{DRU,FPi} \tag{230}$$

where $k = s^c[j]$. $s^c[]$ is the sequence which is obtained by renumbering the remainders of the PRUs, which are not allocated for CRU, from 0 to $L_{DRU,FPi}-1$.

15.3.8.3.2 Tile permutation

Each of the DRUs of an UL frequency partition is divided into 3 tiles of 6 adjacent subcarriers over N_{sym} symbols. The tiles within a frequency partition are collectively tile-permuted to obtain frequency-diversity across the allocated resources.

The tile permutation that allocates physical tiles of DRUs to logical tiles of subchannels is performed in the following manner:

$$Tile(s, n, t) = L_{DRU,FPi} \cdot n + g(PermSeq(), s, n, t) \tag{231}$$

where:

   $Tiles(s,n,t)$ is the tile index of the nth tile in the sth distributed LRU of the tth subframe.

n is the tile index, 0 to 2, in a distributed LRU.

t is the subframe index with respect to the frame.

s is the distributed LRU index, 0 to $L_{DRU, FPi}$-1.

PermSeq() is the permutation sequence of length $L_{DRU,FPi}$ and is determined by SEED={*IDcell**1367} mod 210. The permutation sequence is generated by the random sequence generation algorithm specified in Section <<15.3.5.3.4>>.

$g(PermSeq(),s,n,t) = \{PermSeq[(n + 107 * s + t) \bmod L_{DRU,FPi}]+UL\_PermBase\} \bmod L_{DRU,FPi}$

where *UL_PermBase* is an integer ranging from 0 to 31 (TBD), which is set to preamble *IDcell*.

15.3.8.3.3 Resource allocation and tile permutation for control channels

The distributed LRUs in each of uplink frequency partition may be further divided into data, bandwidth request and feedback channels. The feedback channels can be used for both HARQ ACK/NAK and fast feedback. The allocation order of data channels and UL control channels are TBD.

15.3.8.3.3.1 Bandwidth request channels

The number of bandwidth request channels in frequency partition FP_i, $L_{BWR,FPi}$, is indicated by the (TBD)-bit field UL_BWREQ_SIZE in the S-SFH (TBD) in the unit of LRUs.

$$L_{BWR, FPi} = \text{UL\_BWREQ\_SIZE} \tag{232}$$

Bandwidth request channels are not necessarily present in all subframes and the allocation can differ from subframe to next.

In MZone, the bandwidth request channels are of same size as LRUs, i.e. three 6-by-6 tiles. In LZone with PUSC, the bandwidth request channels consist of three 4-by-6 tiles. The bandwidth request channels use LRUs constructed from the tile permutation specified in <<Section 15.3.6.3.3>>.

15.3.8.3.3.2 Feedback Channels

Let UL_FEEDBACK_SIZE distributed LRUs in frequency partition FP_i be reserved for feedback channels in the units of LRU. The number of feedback channels in frequency partition FP_i, is $L_{FB,FPi}$.

$$L_{FB, FPi} = N_{fb} \cdot \text{UL\_FEEDBACK\_SIZE} \tag{233}$$

where N_{fb} is 3 in MZone and 4 in LZone with PUSC.

The feedback channels are formed by 3 permuted 2-by-6 mini-tiles. The mini-tile reordering process applied to each distributed LRU is described below and illustrated in <<Figure UL- 1>>.

1) The uplink tiles in the distributed LRUs reserved for feedback channels are divided into 2-by-6 feedback mini-tiles (FMTs). The FMTs so obtained are numbered from 0 to $3 \cdot L_{FB, FPi} - 1$.

2) A mini-tile reordering is applied to the available 2-by-6 FMTs as specified by Equation (234) and Equation (235) to obtain the reordered FMTs (RFMTs).

3) Each group of three consecutive RFMTs forms a feedback channel.

The closed form expressions for the FMT reordering function used in step 2 above are as Equation (234) in MZone and Equation (235) in the LZone with PUSC:

$$MiniTile(s, n) = 9 \cdot floor\left(\frac{s}{3}\right) + mod(s, 3) + 3 \cdot n \tag{234}$$

$$MiniTile(s, n) = 6 \cdot floor\left(\frac{s}{2}\right) + mod(s, 2) + 2 \cdot n \tag{235}$$

Where

$MiniTile(s,n)$ is the nth mini-tile of the sth feedback channel.

n is the mini-tile index in a feedback channel. n can take a value of 0, 1 or 2.

s is the feedback channel index. s can take an integer value in the range 0 to $L_{FB,FPi}$-1.

HARQ feedback channels

Each feedback channel constructed according to Section <<15.3.8.3.4.2>> can be used to transmit six HARQ feedback channels. The number of HARQ feedback channels is denoted by $L_{HFB,FPi}$.

A HARQ feedback channel is formed by three reordered 2-by-2 HARQ mini-tiles (RHMT). The HMTs reordering process and the construction of HARQ feedback channel are described below and illustrated in Figure 437.

1) Each 2x6 RFMT is divided into three consequitivly indexed 2-by-2 HMTs. The HMTs so obtained are numbered from 0 to $3 \cdot L_{HFB, FPi} - 1$.

2) A HMT reordering is applied to the HMTs as specified by Equation (236) to obtain the reorderd HMTs (RHMTs).

3) Each group of three consecutive RHMTs forms a HARQ feedback channel.

The closed form expression for the HMT reordering function used in step 2 above is as Equation (236).

$$HMT(k, m) = 9 \cdot floor\left(\frac{k'}{3}\right) + mod(k' + m, 3) + 3 \cdot m \tag{236}$$

where

$HMT(k,m)$ is the m-th HMT of the k-th HARQ feedback channel.

m is the HMT index in a HARQ feedback channel. m can take a value 0, 1 or 2.

k is the HARQ feedback channel index. k can take an integer value in the range 0 to $L_{HFB,FPi}$ -1.

$k' = \lfloor k/2 \rfloor$

[Editor's note: figure in C802.16m-09/0386r1 is not clear. Re-draw and submit.]

Figure 437—Example of UL resource allocation for UL control channels

Figure 437 is an example of UL resource allocation for UL control channels. The displayed order of data channels and control channels is for illustrative purpose only.

15.3.8.3.4 Logical Resource Unit Mapping

Both contiguous and distributed LRUs are supported in the uplink. The CRUs are directly mapped into contiguous LRUs. Precoding and/or boosting applied to the data subcarriers will also be applied to the pilot subcarriers. The DRUs are permuted as described in 15.3.8.3.2 to form distributed LRUs.

15.3.8.3.5 WirelessMAN-OFDMA Systems Support

When frame structure is supporting the WirelessMAN-OFDMA MSs in PUSC zone by FDM manner as defined in 15.3.3.4, a new symbol structure and subchannelization defined in the subclause are used.

15.3.8.3.5.1 Basic Symbol Structure for FDM based UL PUSC Zone Support

The subcarriers of an OFDMA are partitioned into $N_{g,left}$ left guard subcarriers, $N_{g,right}$ right guard subcarriers, and N_{used} used subcarriers. The DC subcarrier is not loaded. The N_{used} subcarriers are divided into multiple PUSC tiles. Basic symbol structures for various bandwidths are shown in Table 688, Table 689, and Table 690.

Table 688—512 FFT OFDMA UL subcarrier allocations for DRU

Parameters	Value	Comments
Number of DC subcarriers	1	Index 256 (counting from 0)
$N_{g,left}$	52	Number of left guard subcarriers
$N_{g,right}$	51	Number of right guard subcarriers
N_{used}	409	Number of all subcarriers used in WirelessMAN-OFDMA PUSC zone within a symbol, including DC carrier

Table 689—1024 FFT OFDMA UL subcarrier allocations for DRU

Parameters	Value	Comments
Number of DC subcarriers	1	Index 512 (counting from 0)
$N_{g,left}$	92	Number of left guard subcarriers
$N_{g,right}$	91	Number of right guard subcarriers
N_{used}	841	Number of all subcarriers used in WirelessMAN-OFDMA PUSC zone within a symbol, including DC carrier

Table 690—2048 FFT OFDMA UL subcarrier allocations for DRU

Parameters	Value	Comments
Number of DC subcarriers	1	Index 1024 (counting from 0)

Table 690—2048 FFT OFDMA UL subcarrier allocations for DRU

Parameters	Value	Comments
$N_{g,left}$	184	Number of left guard subcarriers
$N_{g,right}$	183	Number of right guard subcarriers
N_{used}	1681	Number of all subcarriers used in WirelessMAN-OFDMA PUSC zone within a symbol, including DC carrier

15.3.8.3.5.2 Resource Block for FDM based UL PUSC Zone Support

When supporting FDM based UL PUSC zone, a tile consists of 4 consecutive subcarriers and 6 OFDMA symbols, as shown in <<Figure y-1>>.
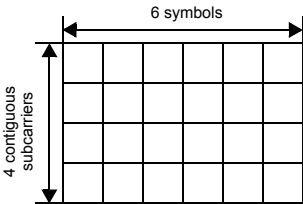
Figure 438—Resource block for FDM based UL PUSC zone support

15.3.8.3.5.3 Subchannelization for FDM based UL PUSC Zone Support

When supporting FDM based UL PUSC zone, UL subchannelization shall conform the following rules:

1) For the WirelessMAN-OFDMA system bandwidth, all usable subcarriers given in Table 688, Table 689, and Table 690 are divided into PUSC tiles.

2) UL PUSC subchannelization is performed as described in section <<8.4.6.2.2>>.

3) Available subchannels for Advanced Air Interface MS shall be specified through subchannel bitmap broadcasted by [system descriptor, TBD].

4) All PUSC tiles of specified subchannels from step 3 are extended in time domain from 3 OFDM symbols to N_{sym} OFDM symbols, where N_{sym} is dependent of subframe type.

5) Based on specified subchannels of step 3 with symbol extension tiles of step 4, DRUs for Advanced Air Interface are made up.

6) Repeat step 4 and step 5 for remained OFDMA symbols of every uplink subframe.

Overall process of subcarrier to subchannel mapping is shown in Figure 439.
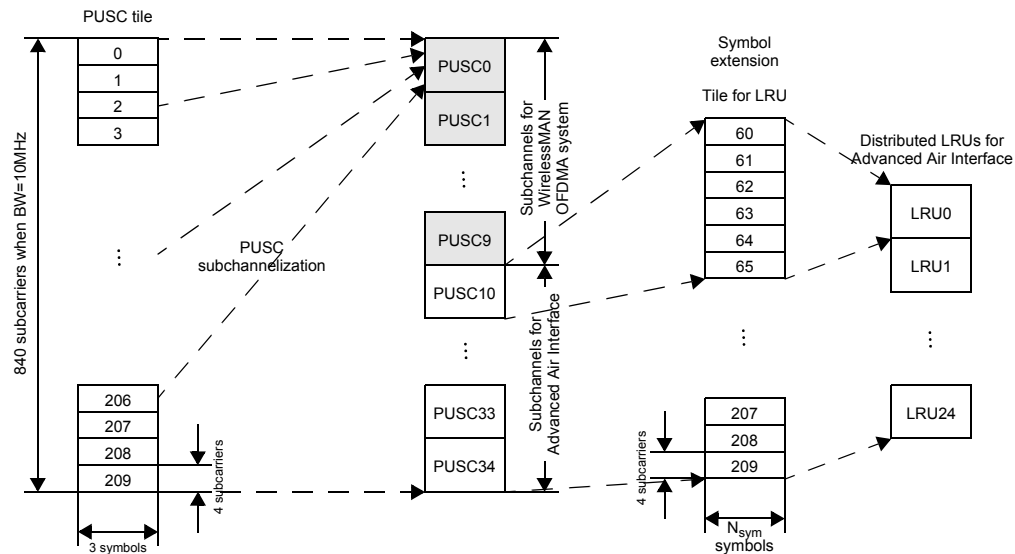
Figure 439—Example of subchannelization for FDM base UL PUSC zone support

15.3.8.4 Pilot structure

Uplink pilot is dedicated to each user and can be precoded or beamformed in the same way as the data subcarriers of the resource allocation. The pilot structure is defined for up to 4 transmission streams.

The pilot pattern may support variable pilot boosting. When pilots are boosted, each data subcarrier should have the same Tx power across all OFDM symbols in a resource block. The boosting values are TBD.

Figure 444 shows the pilot structure for contiguous LRUs where the number of streams is one, two, three or four. Note that the pilot patterns for UL contiguous LRUs are same as in the downlink case. Figure 440 and Figure 441 show the pilot structure for distributed LRUs where the number of streams is one or two, respectively. Figure 442 and Figure 443 contain the one and two-stream pilot patterns for the distributed PUSC LRU.
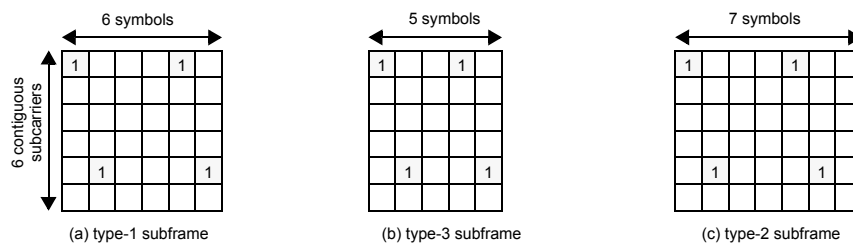
Figure 440—Pilot patterns of 1-Tx stream for distributed LRUs

6 symbols

5 symbols

7 symbols

6 contiguous
subcarriers

(a) type-1 subframe

(b) type-3 subframe

(c) type-2 subframe
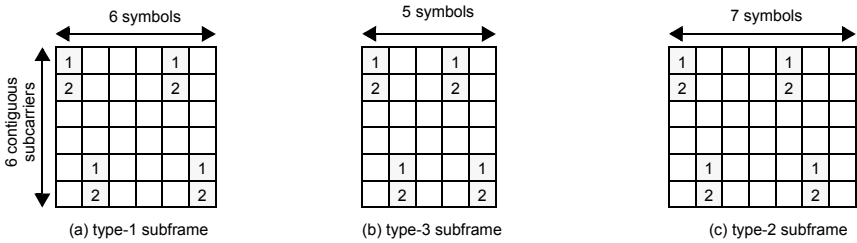
Figure 441—Pilot patterns of 2-Tx streams for distributed LRUs

6 symbols

4 contiguous
subcarriers
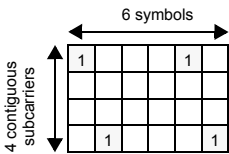
Figure 442—Pilot pattern of 1-Tx stream for distributed PUSC LRUs

6 symbols

4 contiguous
subcarriers
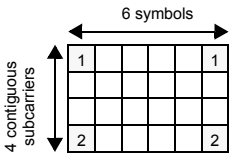
Figure 443—Pilot pattern of 2-Tx stream for distributed PUSC LRUs

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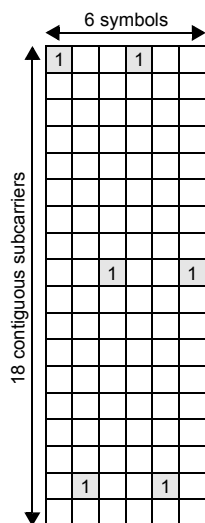
Figure 444—Pilot patterns for contiguous LRUs for 1 Tx stream
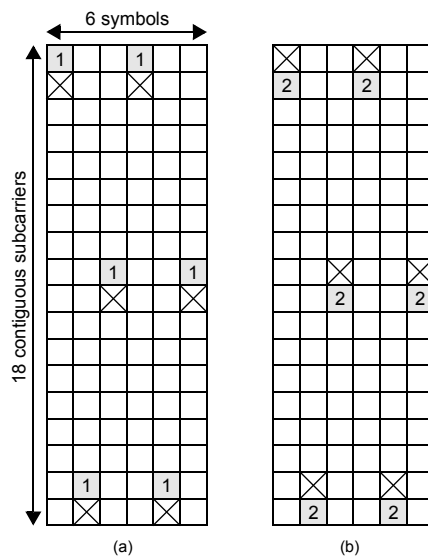
Figure 445—Pilot patterns for contiguous LRUs for 2 Tx streams
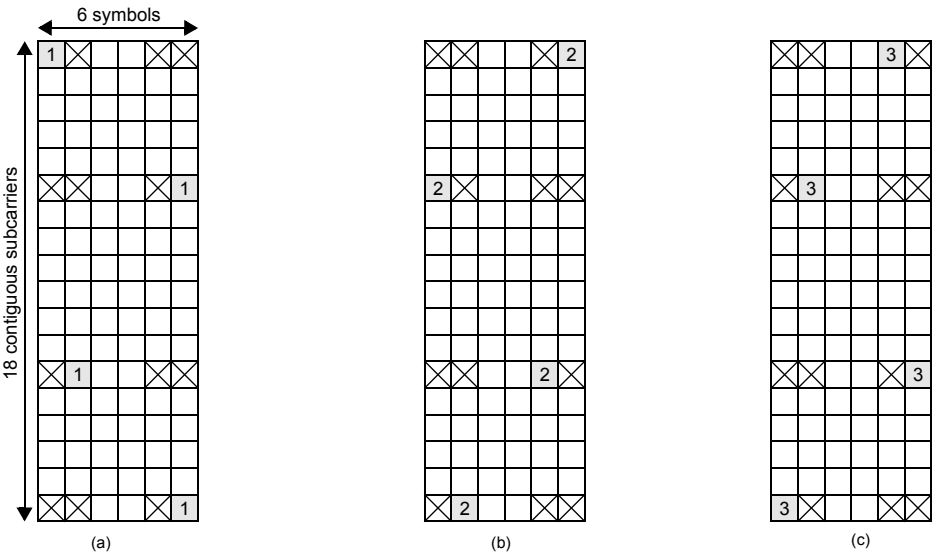
Figure 446—Pilot patterns for contiguous LRUs for 3 Tx streams
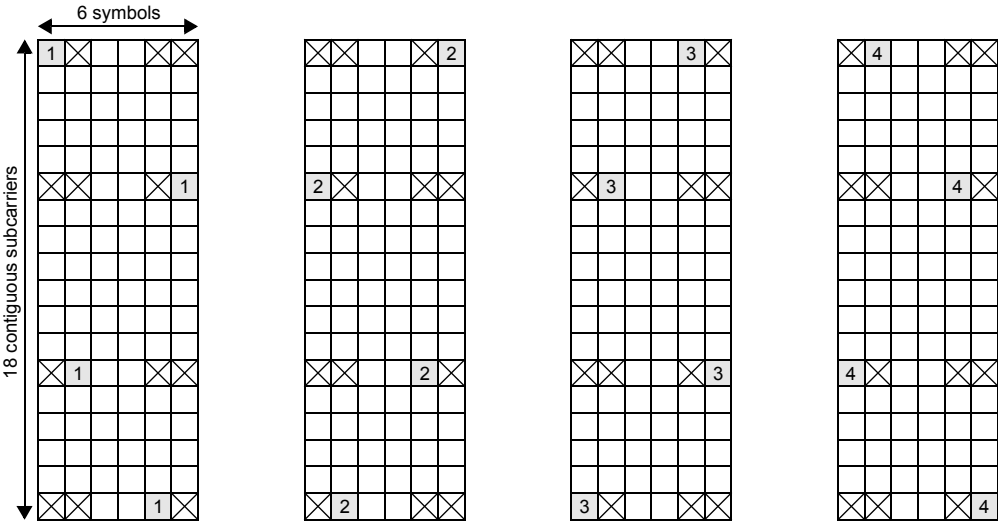
Figure 447—Pilot patterns for contiguous LRUs for 4 Tx streams
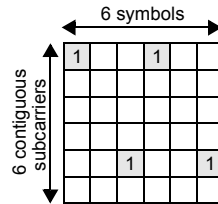
Figure 448—Pilot patterns for distributed LRUs of 1 stream
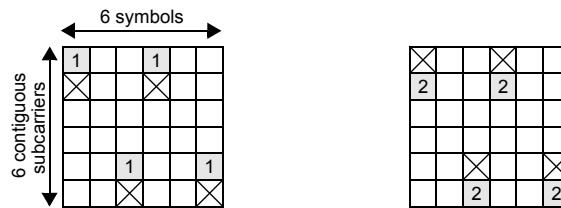
Figure 449—Pilot patterns for distributed LRUs for 2 Tx streams

15.3.9 Uplink control channel

15.3.9.1 Physical uplink control channel

15.3.9.1.1 Fast feedback control channel

The DRUs are permuted by UL tile permutation as described in Section <<15.3.5.4>> to form distributed LRUs for for both data and control resource/channel. A UL feedback mini-tile (FMT) is defined as 2 contiguous subcarriers by 6 OFDM symbols. The UL feedback control channels are formed by applying the UL mini-tile permutation to the LRUs allocated to the control resource. The fast feedback channels are comprised of 3 RFMTs. The details of feedback mini-tile permutation and the subchannelization of Fast feedback are described in section <<15.3.8.3.4.2>>.

15.3.9.1.1.1 Primary fast feedback channel

The primary fast feedback channel is comprised of 3 RFMTs. The construction process of primary fast feedback channels is described in section <<15.3.8.3.4.2>>.

15.3.9.1.1.2 Secondary fast feedback channel

The secondary fast feedback channel has the same physical control channel structure as the primary fast feedback channel. The secondary fast feedback channels are comprised of 3 RFMTs. The construction process of secondary fast feedback is described in section <<15.3.8.3.4.2>>.

15.3.9.1.2 HARQ feedback control channel

Each UL HARQ feedback resource consists of three distributed UL reordered feedback mini-tiles (RFMTs), where the UL FMT is defined as 2 contiguous subcarriers by 6 OFDM symbols. The procedures for allocation of resources for transmission of UL control information and the formation of control channels for such transmission are described in section <<15.3.8.3.4.2>>. A total resource of three distributed 2x6 RFMTs supports 6 UL HARQ feedback channels. The 2x6 RFMTs are further divided into UL HARQ mini-tiles (HMT). A UL HARQ mini-tile has a structure of 2 subcarriers by 2 OFDM symbols.

15.3.9.1.3 Sounding channel

Uplink channel sounding provides the means for the ABS to determine UL channel response for the purpose of UL closed-loop MIMO transmission and UL scheduling. In TDD systems, the ABS can also use the estimated UL channel response to perform DL closed-loop transmission to improve system throughput, coverage and link reliability. In this case ABS can translate the measured UL channel response to an estimated DL channel response when the transmitter and receiver hardware of ABS and AMS are appropriately calibrated.

15.3.9.1.3.1 Sounding PHY structure

The sounding signal occupies a single OFDMA symbol in the UL sub-frame. The sounding symbol in the UL sub-frame is located in the first symbol. Each UL sub-frame can contain only one sounding symbol. Multiple UL subframes in a 5-ms radio frame can be used for sounding. The number of subcarriers for the sounding in a PRU is 18 adjacent subcarriers.

15.3.9.1.4 Ranging channel

The UL ranging channel is used for UL synchronization. The UL ranging channel can be further classified into ranging channel for non-synchronized mobile stations and synchronized mobiles stations. The ranging channel for synchronized AMSs is used for periodic ranging. The ranging channel for non-synchronized AMSs is used for initial access and handover.

15.3.9.1.4.1 Ranging channel structure for non-synchronized AMSs

The ranging channel for non-synchronized AMSs is used for initial network entry and association and for ranging against a target BS during handover.

A physical ranging channel for non-synchronized AMSs consists of the ranging preamble (RP) with length of T_{RP} depending on the ranging subcarrier spacing Δf_{RP}, and the ranging cyclic prefix (RCP) with length of T_{RCP} in the time domain.

A ranging channel occupies a localized bandwidth corresponding to the [1 or 2] subbands.

Power control operation described in subclause [TBD] applies to ranging signal transmission.

Figure 450 illustrates the ranging channel structures in the time domain.

time

copy samples   copy samples

T_{RCP} T_{RP} T_{RCP} T_{RP}

(a) Structure 1

time

copy samples

T_{RCP} T_{RP}
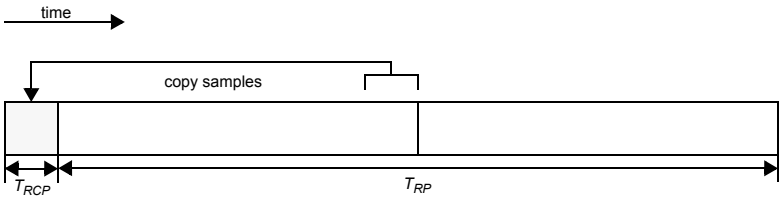
(b) Structure 2
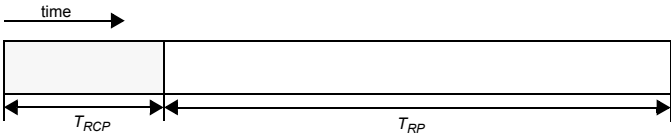
time

T_{RCP} T_{RP}

(c) Structure 3

Figure 450—Ranging channel structures in the time domain

Table 691 contains ranging channel formats and parameters.

Table 691—Ranging channel formats and parameters

Format No.	Ranging Channel Format	TRCP	TRP	?fRP
0	Structure 1			
1	Structure 2			
2	Structure 3			
…	…			

111

In the ranging channel Format 0, the repeated RCPs and RPs are used as a single time ranging opportunity within a subframe in Figure 450. Format 1 consists of a single RCP and repeated RPs within a subframe. Format 2 consists of a single RCP and RP.

For the ranging opportunity of the non-synchronized AMS, each AMS randomly chooses one of ranging preamble sequences from the available ranging sequence set in a cell defined in TBD Ranging preamble codes.

15.3.9.1.4.2 Ranging channel for synchronized AMSs

The ranging channel for synchronized AMSs is used for periodic ranging. The transmission of ranging channel for synchronized AMSs shall be sent only by the AMSs that have already synchronized to the system.

Power control operation described in subclause [TBD] applies to ranging signal transmission.

15.3.9.1.5 Bandwidth request channel

In the LZone with PUSC, a BW REQ tile is defined as four contiguous subcarriers by six OFDM symbols. The number of BW REQ tiles per BW REQ channel is three or six. Each BW REQ tile carries a BW REQ access sequence only.

In the Mzone, a BW REQ tile is defined as six contiguous subcarriers by six OFDM symbols. Each BW REQ channel consists of three distributed BW-REQ tiles. Each BW REQ tile carries a BW REQ access sequence and a BW REQ message. The AMS may transmit the access sequence only and leave the resources for the quick access message unused.

15.3.9.2 Uplink control channels physical resource mapping

15.3.9.2.1 Fast feedback control channel

There are two types of UL fast feedback control channels: primary fast feedback channel (PFBCH) and secondary fast feedback channels (SFBCH).

15.3.9.2.1.1 Primary fast feedback control channel

The primary fast feedback channels are comprised of three distributed FMTs. Figure 451 illustrates the mapping of the PFBCH.
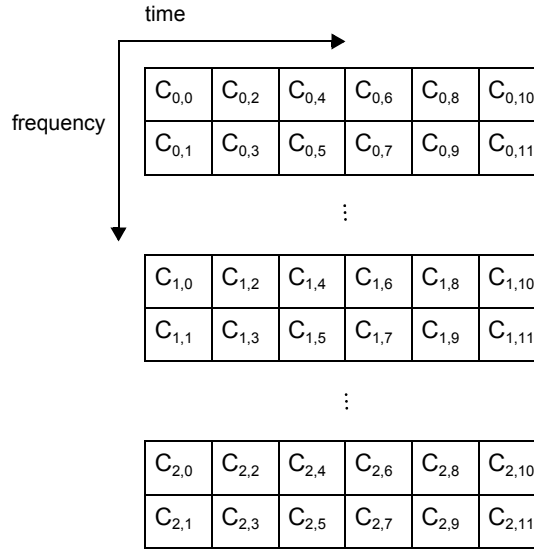
Figure 451—PFBCH comprised of three distributed 2x6 UL FMTs
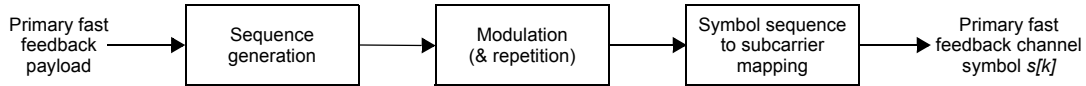
Figure 452—Mapping of information in the PFBCH

The process of composing the PFBCH is illustrated in Figure 452. The *l* PFBCH payload bits are used to generate PFBCH sequence according to Table 692. The resulting bit sequence is modulated, repeated and mapped to uplink PFBCH symbol *s*[*k*]. The mapping of primary fast feedback channel symbol *s*[*k*] to the UL FMTs is given by Table 237. This set of sequence can carrier up to six information bits.

$$C_{i,j} = s[K_i[j]] \text{, for } i = 0, 1, 2 \text{ , } 0 \le j \le 11 \tag{237}$$

where

$K_i[j]$ denotes the jth element of K_i

$K_0 = \{0,1,2,3,4,5,6,7,8,9,10,11\}$

$K_1 = \{9,10,11,3,4,5,0,1,2,6,7,8\}$

$K_2 = \{3,4,5,6,7,8,9,10,11,0,1,2\}$

Table 692—Sequences for PFBCH

Index	Sequence	Index	Sequence
0	111111111111	32	101011001001
1	101111010110	33	111011100000
2	011010111101	34	001110001011
3	001010010100	35	011110100010
4	101010101010	36	100111111010
5	111010000011	37	110111010011
6	001111101000	38	000010111000
7	011111000001	39	010010010001
8	110011001100	40	111110011100
9	100011100101	41	101110110101
10	010110001110	42	011011011110
11	000110100111	43	001011110111
12	100110011001	44	101010011111
13	110110110000	45	111010110110
14	000011011011	46	001111011101
15	010011110010	47	011111110100
16	101011111100	48	111111001010
17	111011010101	49	101111100011
18	001110111110	50	011010001000
19	011110010111	51	001010100001
20	111110101001	52	110010101111
21	101110000000	53	100010000110
22	011011101011	54	010111101101
23	001011000010	55	000111000100
24	100111001111	56	100110101100
25	110111100110	57	110110000101
26	000010001101	58	000011101110
27	010010100100	59	010011000111
28	110010011010	60	110011111001
29	100010110011	61	100011010000

Table 692—Sequences for PFBCH

Index	Sequence	Index	Sequence
30	010111011000	62	010110111011
31	000111110001	63	000110010010

15.3.9.2.1.2 Secondary fast feedback control channel

The SFBCH is comprised of 3 distributed FMTs with [2] [4] pilots allocated in each FMT. Pilot sequence is TBD.

The SFBCH symbol generation procedure is shown in Figure 453. First, the SFBCH payload information bits $a_0 a_1 a_2 \ldots a_{l-1}$ are encoded to N bits $b_0 b_1 b_2 \ldots b_{N-1}$ using the linear block codes described in Section <<15.3.9.2.1.2.1>>.

For $l \leq 12$, information bits $a_0 a_1 a_2 \ldots a_{l-1}$ are encoded using the linear block code $(N, 1)$.

For $12 < l \leq 24$, information bits $a_0 a_1 a_2 \ldots a_{l-1}$ are split into 2 parts:

Part A consists of $a_0 a_1 a_2 \ldots a_{\left\lfloor \frac{1}{2} \right\rfloor - 1}$

Part B consists of $a_{\left\lfloor \frac{1}{2} \right\rfloor} a_{\left\lfloor \frac{1}{2} \right\rfloor + 1} a_{\left\lfloor \frac{1}{2} \right\rfloor + 2} \ldots a_{l-1}$.

Part A is encoded to $N/2$ bits $b_0 b_1 b_2 \ldots b_{\frac{N}{2}-1}$ using linear block code $\left(\frac{N}{2}, \left\lfloor \frac{l}{2} \right\rfloor \right)$ and Part B is encoded to $N/2$ bits $b_{\frac{N}{2}} b_{\frac{N}{2}+1} b_{\frac{N}{2}+2} \ldots b_{N-1}$ using a linear block code $\left(\frac{N}{2}, l - \left\lfloor \frac{l}{2} \right\rfloor \right)$. The coded sequence $b_0 b_1 b_2 \ldots b_N$ is then modulated to $N/2$ symbols $c_0 c_1 c_2 \ldots c_{\frac{N}{2}-1}$ using QPSK. The value of N is TBD. The modulated symbols $c_0 c_1 c_2 \ldots c_{\frac{N}{2}-1}$ and pilot sequence (TBD) are combined to form sequence $d_0 d_1 d_2 \ldots d_{35}$ and are mapped to the data subcarriers of the SFBCH FMTs as shown in Figure 454.
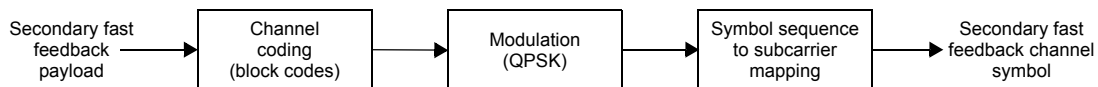
Figure 453—Mapping of information in the SFBCH
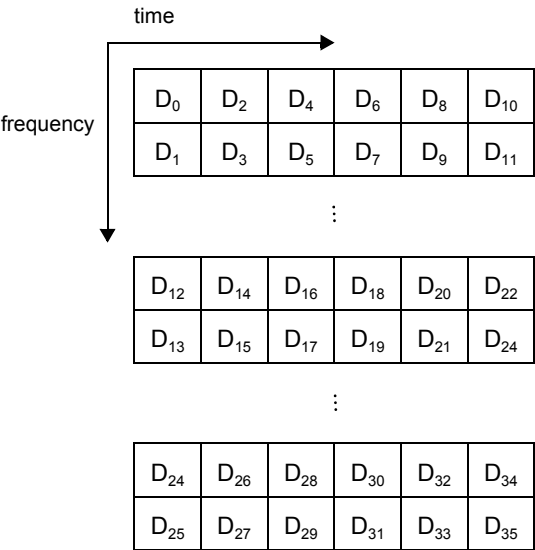
Figure 454—SFBCH comprising of three distributed 2x UL FMTs

Channel coding for secondary fast feedback control channel

The $k(7 \leq K \leq 12)$ information bits in the SFBCH shall be encoded using linear block codes with codeword length N. Let the K information bits be denoted by $a_0 a_1 a_2 ... a_{K-1}$ and the N bits codeword is denoted by $b_0 b_1 b_2 ... b_{N-1}$. The codeword is obtained as a linear combination of the N basis sequences denoted as $v_{i,n}$ where $n = 0, 1, 2, ..., N-1$ in Table 693.

Table 693—Basis sequences

i	vi,0	vi,1	vi,2	vi,3	vi,4	vi,5	vi,6	vi,7	vi,8	vi,9	vi,10	vi,11
0												
1												
2												
…												
N-1												

15.3.9.2.2 HARQ feedback control channel
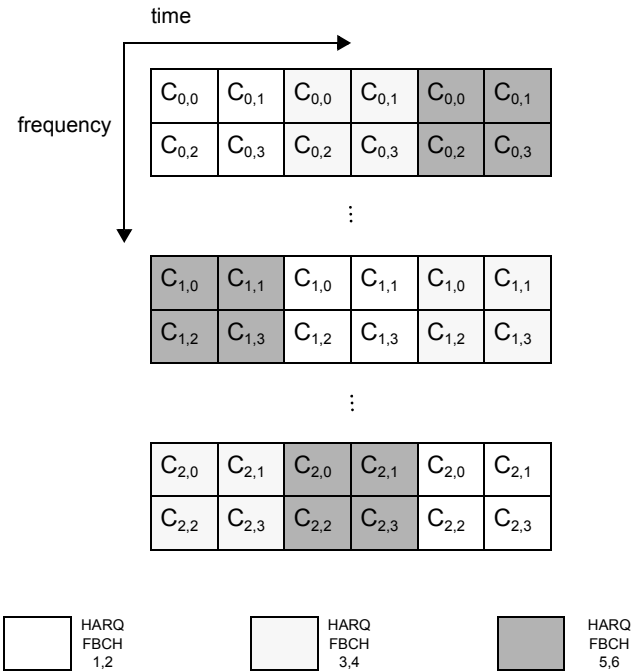
The HARQ feedback control channel resource of three distributed FMTs shall be further divided into nine HARQ mini-tiles (HMTs), each having a structure of two subcarriers by two OFDM symbols. Each pair of HARQ feedback channels are allocated three HMTs, identified by similar patterns in the structure shown in Figure 455. The orthogonal sequence ($C_{i,0}$, $C_{i,1}$, $C_{i,2}$, $C_{i,3}$, where i=0,1 and 2) as shown in <<Table UL- 4>> is mapped to each HMT to form HARQ feedback channels, where and i denotes HMT index. Each group of three RFMTs can therefore support six HARQ feedback channels.

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When each channel carries one bit of HARQ feedback, two sequences are used to signal each ACK or NACK feedback. In one unit, four sequences are used for two HARQ channels, 1st and 2nd HARQ feedback channel. The support and details of two-bit HARQ feedback scenatios are TBD. The sequence and mapping of the HARQ feedback are show in Table 694.

Figure 455—2x2 HMT structure

Table 694—Orthogonal sequences for UL HARQ feedback channel

Sequence index	Orthogonal sequence	1-bit Feedabck	2-bit Feedback (per HMT channel)
0	[+1 +1 +1 +1]	Even numbered channel ACK	ACK/ACK
1	[+1 -1 +1 -1]	Even numbered channel NACK	ACK/NACK
2	[+1 +1 -1 -1]	Odd numbered channel ACK	NACK/ACK
3	[+1 -1 -1 +1]	Odd numbered channel NACK	NACK/NACK

15.3.9.2.3 Sounding channel

15.3.9.2.3.1 Sounding sequence

15.3.9.2.3.2 Multiplexing for multi-antenna and multi-AMS

The uplink sounding channels of multiple AMS and multiple antennas per AMS can be multiplexed through *[Option 1: decimation separation or cyclic shift separation][Option2: decimation separation]* in each

sounding allocation. Also, in case of multiple UL subframes for sounding, time division separation can be applied by assigning different AMS to different UL subframe. For cyclic shift separation each AMS occupies all subcarriers within sounding allocation and uses the different sounding waveform *[Editor's note: remove this sentence if Option 2 will be adopted]*. For frequency decimation separation each AMS uses decimated subcarrier subset from the sounding allocation set with different frequency offset. For antenna switching capable AMS, ABS can command the AMS to switch the physical transmit antenna(s) for sounding transmission. The details for supporting antenna switching on sounding is TBD.

15.3.9.2.4 Ranging channel

15.3.9.2.4.1 Ranging channel for non-synchronized AMSs

Ranging preamble codes

The ranging preamble codes are classified into initial ranging and handover ranging preamble codes. The initial ranging preamble codes shall be used for initial network entry and association. Handover ranging preamble codes shall be used for ranging against a target ABS during handover. For a ranging code opportunity, each AMS randomly chooses one of the ranging preamble codes from the available ranging preamble codes set in a cell.

Ranging channel configurations

Ranging signal transmission

<<Eqn. UL- 7>> specifies the transmitted signal voltage to the antenna, as a function of time, during ranging channel format.

$$s(t) = f_{ranging}() \tag{238}$$

where

$f_{ranging()}$ is a TBD function.

15.3.9.2.5 Bandwidth request channel

Contention based random access is used to transmit bandwidth request information on this control channel.The bandwidth request (BW REQ) channel contains resources for the AMS to send a BW REQ access sequence and an optional quick access message. Prioritized bandwidth requests are supported on this channel. The mechanism for such prioritization is TBD.

15.3.9.3 Uplink control information content

The UL control channels carry multiple types of control information to support air interface procedures. Information carried in the control channels is classified into the following categories:

1) Channel quality feedback

2) MIMO feedback

3) HARQ feedback (ACK/NACK)

4) Uplink synchronization signals

5) Bandwidth requests

6) E-MBS feedback.

15.3.9.3.1 Fast feedback control channel

The UL fast feedback channel shall carry channel quality feedback and MIMO feedback. There are two types of UL fast feedback control channels: primary fast feedback channel (PFBCH) and secondary fast feedback channels (SFBCH). The UL fast feedback channel starts at a pre-determined location, with the size defined in a DL broadcast control message. Fast feedback allocations to an AMS can be periodic and the allocations are configurable.

15.3.9.3.1.1 Primary fast feedback control channel

The UL PFBCH carries 4 to 6 bits of information, providing wideband channel quality feedback and MIMO feedback.

15.3.9.3.1.2 Secondary fast feedback control channel

The UL SFBCH carries narrowband CQI and MIMO feedback information. The number of information bits carried in the SFBCH ranges from 7 to 24. The number of bits carries in the fast feedback channel can be adaptive.

15.3.9.3.2 HARQ feedback control channel

15.3.9.3.3 Bandwidth request channel

15.3.10 Uplink MIMO transmission schemes

15.3.10.1 Uplink MIMO architecture and data processing

The architecture of uplink MIMO at the transmitter side is shown in Figure 456.

Figure 456—UL MIMO architecture

The MIMO encoder block maps a single layer ($L = 1$) onto M_t ($M_t \geq L$) streams, which are fed to the Precoder block. A layer is defined as a coding and modulation path fed to the MIMO encoder as an input. A stream is defined as an output of the MIMO encoder which is passed to the precoder.

For SU-MIMO and Collaborative spatial multiplexing (MU-MIMO), only one FEC block exists in the allocated RU (vertical MIMO encoding at transmit side).

The Precoder block maps stream(s) to antennas by generating the antenna-specific data symbols according to the selected MIMO mode.

The MIMO encoder and precoder blocks shall be omitted when the MS has one transmit antenna.

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The subcarrier mapping blocks map antenna-specific data to the OFDM symbol.

15.3.10.1.1 Layer to stream mapping

Layer to stream mapping is performed by the MIMO encoder. The uplink MIMO encoder is identical to the downlink MIMO encoder described in section "Layer to stream mapping" on page 67.

15.3.10.1.1.1 SFBC encoding

Uplink SFBC encoding is identical to the downlink SFBC encoding described in section "SFBC encoding" on page 68.

15.3.10.1.1.2 Vertical encoding

Uplink vertical encoding is identical to the downlink vertical encoding described in section "Vertical encoding" on page 68.

15.3.10.1.2 Stream to antenna mapping

Stream to antenna mapping is performed by the precoder. The uplink mapping is identical to the downlink mapping described in section "Stream to antenna mapping" on page 69.

15.3.10.1.2.1 Non-adaptive precoding

There is no precoding if there is only one transmit antenna at the MS.

With non-adaptive precoding, the precoder **W** is predefined and selected from the base codebook. The changes of the precoder **W** is [TBD].

The base codebook is defined in [TBD]. Details of selected codebook are [TBD].

15.3.10.1.2.2 Adaptive precoding

There is no precoding if there is only one transmit antenna at the MS.

With adaptive precoding, the precoder **W** is derived at the BS or at the MS, as instructed by the BS.

With 2Tx or 4Tx at the MS in FDD and TDD systems, unitary codebook based adaptive precoding is supported. In this mode, a MS transmits a sounding signal on the uplink to assist the precoder selection at the BS. The BS shall signal the uplink precoding matrix index to be used by the MS in the UL A-MAP IE.

With 2Tx or 4Tx at the MS in TDD systems, adaptive precoding based on the measurements of downlink reference signals is supported. The MS chooses the precoder based on the downlink measurements. The form and derivation of the precoding matrix does not need to be known at the BS.

15.3.10.1.3 Uplink MIMO transmission modes

There are five MIMO transmission modes for UL MIMO transmission as listed in Table 695.

Table 695—Uplink MIMO modes

Mode Index	Description	Reference
Mode 0	OL SU-MIMO (SFBC with non-adaptive precoder)	
Mode 1	OL SU-MIMO (SM with non-adaptive precoder)	
Mode 2	CL SU-MIMO (SM with adaptive precoder)	
Mode 3	OL collaborative spatial multiplexing (MU-MIMO)	
Mode 4	CL collaborative spatial multiplexing (MU-MIMO)	
Mode 5-7	n/a	n/a

15.3.10.2 Transmission schemes for data channels

15.3.10.2.1 Encoding, precoding and mapping of SU-MIMO

15.3.10.2.1.1 Encoding of MIMO modes

15.3.10.2.1.1.1 MIMO mode 0

SFBC encoding of section "SFBC encoding" on page 120 shall be used with MIMO mode 0.

15.3.10.2.1.1.2 MIMO mode 1

Vertical encoding of section "Vertical encoding" on page 120 shall be used with MIMO mode 1. The number of streams is $M_t \le min(N_T, N_r)$, where M_t is no more than 4.

15.3.10.2.1.1.3 MIMO mode 2

Vertical encoding of section "Vertical encoding" on page 120 shall be used with MIMO mode 2. The number of streams is, $M_t \le min(N_T, N_r)$, where M_t is no more than 4.

15.3.10.2.1.2 Precoding of MIMO modes

15.3.10.2.1.2.1 MIMO mode 0

Non-adaptive precoding with M_t=2 streams of section "Non-adaptive precoding" on page 120 shall be used with MIMO mode 0.

15.3.10.2.1.1.1 MIMO mode 0

Non-adaptive precoding of section 15.3.10.1.2.1 shall be used with MIMO mode 1.

15.3.10.2.1.1.1 MIMO mode 0

Adaptive precoding of section 15.3.10.1.2.2 shall be used with MIMO mode 2.

15.3.10.2.2 Encoding, precoding and mapping of collaborative spatial multiplexing (MU-MIMO)

MSs can perform collaborative spatial multiplexing onto the same RU. In this case, the BS assigns different pilot patterns for each MS

15.3.10.2.2.1 Encoding of MIMO mode 3

Vertical encoding of section "Vertical encoding" on page 120 shall be used with MIMO mode 3.

15.3.10.2.2.2 Encoding of MIMO mode 4

Vertical encoding of section 15.3.10.1.1.2 shall be used with MIMO mode 4.

15.3.10.2.2.3 Precoding of MIMO modes

15.3.10.2.2.3.1 MIMO mode 3

Non-adaptive precoding of section "Non-adaptive precoding" on page 120 shall be used with MIMO mode 3.

15.3.10.2.2.3.1 MIMO mode 4

Adaptive precoding of section "Adaptive precoding" on page 120 shall be used with MIMO mode 4.

15.3.10.2.3 Mapping of data subcarriers

15.3.10.2.3.1 MIMO mode 0

15.3.10.2.3.2 MIMO mode 1 and mode 2

15.3.10.2.3.3 MIMO mode 3 and mode 4

15.3.10.2.4 Mapping of pilot subcarriers

15.3.10.2.5 Usage of MIMO modes

The following table shows the permutations supported for each MIMO mode. The definition of tile based DRU, mini-band based CRU, and subband based CRU are in 15.3.5.x

Table 696—Supported permutation for each UL MIMO mode

	Tile based DRU	Mini-band based CRU (diversity allocation)	Mini-band based CRU Sub-band based CRU (localized allocation)
MIMO mode 0	Yes	Yes	No
MIMO mode 1	Yes	Yes	Yes
MIMO mode 2	Yes	Yes	Yes
MIMO mode 3	Yes	Yes	Yes

15.3.10.2.6 Downlink signaling support of UL-MIMO modes

15.3.10.2.6.1 Broadcast information

The BS shall send parameters listed in Table 697w hich are necessary for UL MIMO operation in a control channel with a broadcast CID. The parameters may be transmitted depending on the type of operation.

Table 697—Broadcast information for UL MIMO operation

Parameter	Description	Value	Notes

15.3.10.2.6.2 Unicast information

The BS shall send parameters listed in Table 698, which are necessary for MIMO operation, by unicast in a control channel to a specific MS. The parameters may be transmitted depending on the type of operation.

Table 698—Unicast information for UL MIMO operation.

Parameter	Description	Value	Control channel (IE)	Notes
MEF	MIMO Encoding Format	0b00: SFBC 0b01: Vertical encoding 0b10: CSM 0b11: No encoding [One TX antenna MS]	A-MAP IE (unicast)	MIMO encoder format [MEF bit-field may not be explicitly indicated in DL A-MAP IE]
M_t	Number of streams	0b00: 1 0b01: 2 0b10: 3 0b11: 4 ($M_t <= N_t$)	A-MAP IE (unicast)	Number of streams in the MS transmission.
RU allocation (TBD)	LRU allocation	TBD	A-MAP IE (unicast)	Refer to DL control group
$MaxM_t$	Total number of streams in the LRU	0b00: 1 0b01: 2 0b10: 3 0b11: 4	A-MAP IE (unicast)	Enabled when MEF=0b10 indicates the total number of streams in the LRU
SI	First pilot index	0b00: 1 0b01: 2 0b10: 3 0b11: 4	A-MAP IE (unicast)	Enabled when MEF=0b10. 1 bit for 2Tx, 2 bit for 4Tx
PF	Precoding flag	0b0: non adaptive pre-coding 0b1: adaptive codebook precoding	A-MAP IE (unicast)	Disabled when MEF=0b11

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Table 698—Unicast information for UL MIMO operation.

Parameter	Description	Value	Control channel (IE)	Notes
PMI	Precoding matrix index	TBD	A-MAP IE (unicast)	Enabled when PF = 0b1 [Bit-field length is variable, depending on the number of code matrices]

15.3.10.3 Codebook for closed-loop transmit precoding

15.3.10.3.1 Base codebook for two transmit antenna

15.3.10.3.1.1 SU-MIMO base codebook

The base codebook of uplink 2 Tx is the same as the downlink 2 Tx base codebook (SU MIMO base codebook), defined in 15.3.7.2.6.6.2.1.1.

15.3.10.3.1.2 MU-MIMO base codebook

The base codebook for UL collaborative spatial multiplexing MIMO is same as base codebook for SU-MIMO, defined in "SU-MIMO base codebook" on page 124.

15.3.10.3.2 Base codebook for four transmit antennas

15.3.10.3.2.1 SU-MIMO base codebook

The codebooks for UL MIMO with four transmit antenna MS are constructed using the methodology described in section 15.3.7.2.6.6.2.1.1, for two transmit antenna case.

The parameters for the generation of codebooks for four transmit antenna $N_t = 4$ and number of streams M_t =1, 2, 3, 4 are listed in Table 699.

Table 699—Generating parameters for four transmit antenna codebook

Nt	Mt	NB	L	$u = \lfloor u_1, u_2, ..., u_{N_t} \rfloor$ in $Q^i(u)$	$\mathbf{s}$ in $H(\mathbf{s})$
4	1	6	6		
4	2	6	6	[18, 55, 22, 6]	[1, 0, 0, 0]
4	3	6	6		
4	4	6	6		

15.3.10.3.2.2 MU-MIMO base codebook

The base codebook for UL collaborative spatial multiplexing MIMO is same as the base codebook for UL SU-MIMO, defined in "SU-MIMO base codebook" on page 124.

15.3.10.4 Transmission schemes for control channels

15.3.11 Multi-BS MIMO

15.3.12 Channel coding and HARQ

15.3.12.1 Channel coding

Channel coding procedures for downlink and uplink data channels are shown in Figure 457.

Figure 457—Channel coding procedure

15.3.12.1.1 Burst CRC encoding

Cyclic Redundancy Code (CRC) bits are used to detect errors in the received packets. A 16-bit burst CRC is appended to the data burst using the cyclic generator polynomial in Equation (239):

$$g_{DB-CRC}(D) = D^{16} + D^{12} + D^5 + 1 \tag{239}$$

Denote the bits of the input data burst by $d_1, d_2, d_3, ..., d_{N_{PL}}$ where d_1 is the MSB and N_{PL} is the size of the input data burst. Denote the parity bits produced by the burst CRC generator by $p_1, p_2, p_3, ..., p_{16}$. The burst CRC encoding is performed in a systematic form, which means that in GF(2), the polynomial in Equation (240):

$$d_1 D^{N_{PL}+15} + d_2 D^{N_{PL}+14} + ... + d_n D^{16} + p_1 D^{15} + p_2 D^{14} + ... + p_{15} D^1 + p_{16} \tag{240}$$

yields a remainder equal to 0 when divided by $g_{DB-CRC}(D)$.

The data burst, including the CRC, is further processed by the data randomizer as described in section 15.3.12.1.2.

15.3.12.1.2 Randomization

Data randomization shall be performed on the downlink and uplink data channel.

The randomization bits are generated using a PRBS generator as shown in Figure 458. The generator polynomial of the PRBS generator is $1 + X^{14} + X^{15}$. For each data burst, the beginning state of the PRBS is initialized to $[s_1\ s_2\ ...\ s_{15}] = [0\ 1\ 1\ 0\ 1\ 1\ 1\ 0\ 0\ 0\ 1\ 0\ 1\ 0\ 1]$ where s_1 is the LSB and s_{15} is the MSB. The data burst to be transmitted shall enter sequentially into the randomizer, MSB first. The data bits are XOR-ed with the output of the PRBS generator, with the MSB of the data burst XOR-ed with the first bit of the PRBS generator output.

Figure 458—Data randomizer with a PRBS generator

The output of the data randomizer is further processed by burst partition as described in section 15.3.12.1.3.

15.3.12.1.3 Burst partition

When the burst size including 16 burst CRC bits exceeds the maximum FEC block size, N_{FB_MAX}, the burst is partitioned into K_{FB} FEC blocks. The modulation order, the nominal code rate, the number of resource elements allocated for data transmission, the spatial multiplexing order, and the maximum FEC block size are denoted by N_{mod}, R_{FEC}, N_{RE}, N_{SM}, N_{FB_MAX}, respectively.

N_{mod} is the modulation order of the burst transmission, which is specified by MCS index

R_{FEC} is the nominal code rate of the burst transmission, which is specified by MCS index

N_{RE} is the number of resource elements allocated for burst transmission. The calculation of N_{RE} shall exclude the resource elements used by pilot channels

N_{SM} is the spatial multiplexing order of the resource elements allocated for burst transmission. The value of NSM depends on the MIMO transmission mode and is defined in section <<x.x.x.x>>.

N_{FB_MAX} is the maximum FEC block size, which equals to 4800 bits.

The nominal MCS used in a data transmission shall be selected from Table 700.

Table 700—MCS table for downlink and uplink data channel

MCS Index	Modulation	Code Rate
0000	QPSK	31/256
0001	QPSK	48/256
0010	QPSK	71/256
0011	QPSK	101/256
0100	QPSK	135/256
0101	QPSK	171/256
0110	16QAM	102/256
0111	16QAM	128/256
1000	16QAM	155/256

Table 700—MCS table for downlink and uplink data channel

MCS Index	Modulation	Code Rate
1001	16QAM	185/256
1010	64QAM	135/256
1011	64QAM	157/256
1100	64QAM	181/256
1101	64QAM	205/256
1110	64QAM	225/256
1111	64QAM	237/256

The size of the kth FEC block is denoted by $N_{\text{FB},k}$, $k = 0, 1, \ldots, K_{\text{FB-1}}$. The set of supported FEC block sizes is shown in Table 701.

Table 701—FEC block size table for downlink and uplink data channels

Index	NFB	Index	NFB	Index	NFB	Index	NFB	Index	NFB
0	48	30	328	60	720	90	1424	120	2752
1	64	31	344	61	736	91	1448	121	2816
2	72	32	352	62	752	92	1480	122	2880
3	80	33	360	63	768	93	1504	123	2944
4	88	34	368	64	776	94	1536	124	3008
5	96	35	376	65	800	95	1560	125	3072
6	104	36	384	66	824	96	1600	126	3200
7	120	37	400	67	848	97	1640	127	3264
8	128	38	416	68	872	98	1672	128	3328
9	136	39	432	69	888	99	1712	129	3392
10	144	40	440	70	912	100	1752	130	3456
11	152	41	456	71	936	101	1784	131	3520
12	160	42	472	72	960	102	1824	132	3648
13	176	43	480	73	984	103	1864	133	3712
14	184	44	496	74	1000	104	1896	134	3776
15	192	45	512	75	1024	105	1920	135	3840
16	200	46	528	76	1048	106	1952	136	3904
17	208	47	544	77	1072	107	2000	137	3968
18	216	48	552	78	1096	108	2048	138	4096

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Table 701—FEC block size table for downlink and uplink data channels

Index	NFB	Index	NFB	Index	NFB	Index	NFB	Index	NFB
19	232	49	568	79	1112	109	2096	139	4160
20	240	50	584	80	1136	110	2144	140	4224
21	248	51	600	81	1160	111	2192	141	4288
22	256	52	608	82	1184	112	2232	142	4352
23	264	53	624	83	1216	113	2280	143	4416
24	272	54	640	84	1248	114	2328	144	4544
25	288	55	656	85	1280	115	2368	145	4608
26	296	56	664	86	1312	116	2432	146	4672
27	304	57	680	87	1336	117	2496	147	4736
28	312	58	696	88	1368	118	2560	148	4800
29	320	59	712	89	1392	119	2624		

The burst size N_{DB} including burst CRC and FEC block CRC is defined by Equation (241):

$$N_{DB} = \sum_{k=0}^{K_{FB-1}} N_{FB,k} \tag{241}$$

The payload size excluding burst CRC and FEC block CRC is defined by Equation (242):

$$N_{PL} = N_{DB} - N_{DB-CRC} - I_{MFB} \cdot K_{FB} \cdot N_{FB-CRC} \tag{242}$$

where:

   I_{MFB} equals 0 when $K_{FB} = 1$, 1 when $K_{FB} > 1$

   N_{FB-CRC} equals 16, which is the size of the FEC block CRC

   N_{DB-CRC} equals 16, which is the size of the burst CRC.

The burst partition block generates K_{FB} FEC blocks, with each FEC block processed by the FEC block CRC encoding block as described in 15.3.12.1.4.

15.3.12.1.4 FEC block CRC encoding

The burst partition procedure generates K_{FB} FEC blocks for each burst. If $K_{FB} > 1$, the FEC block CRC generator appends a 16-bit FEC block CRC for each FEC block. The cyclic generator for FEC block CRC encoding is shown in Equation (243):

$$g_{FB-CRC}(D) = D^{16} + D^{15} + D^2 + 1 \tag{243}$$

Denote the bits of the k-th input FEC block by with d1 being the MSB and NFB, k being the size of the k-th input FEC block, including the 16-bit FEC block CRC. Denote the parity bits produced by the burst CRC generator by . The burst CRC encoding is performed in a systematic form, which means that in GF(2), the polynomial in Equation (244):

$$d_1 D^{N_{FB,k}-1} + d_2 D^{N_{FB-k}-2} + \ldots + d_{N_{FB,k}-16} D^{16} + p_1 D^{15} + p_2 D^{14} + \ldots + p_{15} D^1 + p_{16} \tag{244}$$

yields a remainder equal to 0 when divided by $g_{FB-CRC}(D)$.

15.3.12.1.5 FEC encoding

Each FEC block shall be encoded using the convolutional turbo codes specified in section 15.3.12.1.5.1.

15.3.12.1.5.1 Convolutional turbo codes

CTC encoder

The CTC encoder, including its constituent encoder, is depicted in Figure 459.

It uses a double binary CRSC (Circular Recursive Systematic Convolutional) code.

The bits of the data to be encoded are alternatively fed to A and B, starting with the MSB of the first byte being fed to A, followed by the next bit being fed to B. The encoder is fed by blocks of N_{EP} bits ($N_{FB} = 2N$ bits).

The polynomials defining the connections are described in octal and symbol notations as follows:

For the feedback branch: 15, equivalently $1 + D + D^3$ (in symbolic notation)

For the Y parity bit: 13, equivalently $1 + D^2 + D^3$

For the W parity bit: 11, equivalently $1 + D^3$

Figure 459—CTC encoder

First, the encoder (after initialization by the circulation state S_{C_2}, see <<15.13.1.6.1.3>>) is fed the sequence in the natural order (switch 1 in Figure 459) with incremental address $i = 1, 2, ..., N$. This first encoding is called C_1 encoding.

Next, the encoder (after initialization by the circulation state S_{C_2}, see <<15.13.1.6.1.3>>) is fed by the interleaved sequence (switch 2 in FFigure 459) with incremental address $i = 1, 2, ..., N$. This second encoding is called C_2 encoding.

The order in which the encoded bits shall be fed into the bit separation block <<(15.x.1.6.1.4)>> is:

$$A, B, Y_1, Y_2, W_1, W_2 =$$
$$A_0, A_1, A_2...,A_{N-1}, B_0, B_1, B_2, B_{N-1}, Y_{1,0}, Y_{1,1}, Y_{1,2}, ...Y_{1,N-1},$$
$$Y_{2,0}, Y_{2,1}, Y_{2,2}, ...Y_{2,N-1}, W_{1,0}, W_{1,1}, W_{1,2}, ...W_{1,N-1}, W_{2,0}, W_{2,1}, W_{2,2}, ...W_{2,N-1}.$$

CTC interleaver

The CTC interleaver requires the parameters $P0$, $P1$, $P2$, and $P3$ shown in Table 702 of which N_{EP} set corresponds to that in Table 701.

The detailed interleaver structures except table for interleaver parameters correspond to <<8.4.9.2.3.2>>.

Table 702—Interleaver Parameters

Index	NEP	P0	P1	P2	P3	Index	NEP	P0	P1	P2	P3	Index	NEP	P0	P1	P2	P3
0	48	5	0	0	0	50	584	21	74	20	214	100	1752	31	314	656	666
1	64	11	12	0	12	51	600	31	12	272	28	101	1784	33	886	888	518
2	72	11	18	0	18	52	608	23	288	244	140	102	1824	41	774	548	898
3	80	7	4	32	36	53	624	23	286	220	70	103	1864	33	504	444	664
4	88	13	36	36	32	54	640	23	84	296	236	104	1896	35	936	940	832
5	96	13	24	0	24	55	656	23	24	300	52	105	1920	43	318	556	778
6	104	7	4	8	48	56	664	23	272	220	60	106	1952	35	94	144	686
7	120	11	30	0	34	57	680	19	48	240	144	107	2000	37	290	692	638
8	128	13	46	44	30	58	696	31	252	216	48	108	2048	31	2	332	622
9	136	13	58	4	58	59	712	25	214	180	286	109	2096	39	400	688	68
10	144	11	6	0	6	60	720	23	130	156	238	110	2144	29	298	252	610
11	152	11	38	12	74	61	736	29	126	208	270	111	2192	39	1074	148	710
12	160	13	68	76	64	62	752	23	26	24	230	112	2232	29	240	496	1100
13	176	17	52	68	32	63	768	29	252	0	88	113	2280	41	474	376	814
14	184	13	2	0	2	64	776	29	100	196	140	114	2328	41	254	884	1054
15	192	7	58	48	10	65	800	23	150	216	150	115	2368	47	228	440	724
16	200	11	76	0	24	66	824	29	130	332	42	116	2432	43	452	888	96
17	208	11	10	32	42	67	848	29	234	388	82	117	2496	43	0	208	528
18	216	11	54	56	2	68	872	29	408	300	316	118	2560	53	264	488	824
19	232	11	70	60	58	69	888	25	414	84	414	119	2624	47	378	1092	1250

Table 702—Interleaver Parameters

Index	NEP	P0	P1	P2	P3	Index	NEP	P0	P1	P2	P3	Index	NEP	P0	P1	P2	P3
20	240	13	60	0	60	70	912	29	14	264	94	120	2752	37	430	880	970
21	248	13	6	84	46	71	936	25	272	168	400	121	2816	31	624	704	400
22	256	11	64	8	8	72	960	53	62	12	2	122	2880	43	720	360	540
23	264	13	72	68	8	73	984	31	142	40	342	123	2944	41	338	660	646
24	272	13	82	44	38	74	1000	29	290	148	446	124	3008	43	916	1136	912
25	288	17	74	72	2	75	1024	29	320	236	324	125	3072	53	184	824	1368
26	296	13	0	84	64	76	1048	27	424	212	416	126	3200	43	1382	632	1086
27	304	13	130	112	46	77	1072	35	290	228	390	127	3264	49	142	828	1354
28	312	11	32	124	108	78	1096	23	178	392	430	128	3328	37	258	28	1522
29	320	17	84	108	132	79	1112	33	38	244	550	129	3392	51	460	56	1608
30	328	17	148	160	76	80	1136	37	170	276	134	130	3456	43	170	920	1518
31	344	17	160	116	52	81	1160	31	314	348	222	131	3520	57	776	1232	1012
32	352	17	106	56	50	82	1184	31	2	568	94	132	3648	49	132	720	276
33	360	17	40	132	128	83	1216	31	368	584	524	133	3712	41	1328	772	1036
34	368	19	88	0	172	84	1248	31	88	404	608	134	3776	53	772	256	408
35	376	13	110	92	14	85	1280	29	152	8	24	135	3840	53	92	1124	476
36	384	11	96	48	144	86	1312	31	214	160	506	136	3904	51	664	200	64
37	400	19	142	0	142	87	1336	39	2	168	646	137	3968	57	1296	760	1360
38	416	17	102	132	178	88	1368	29	570	348	574	138	4096	55	148	808	308
39	432	17	126	92	74	89	1392	31	218	484	446	139	4160	79	214	308	262
40	440	19	48	20	144	90	1424	31	676	124	184	140	4224	59	14	668	1474
41	456	17	184	0	48	91	1448	33	254	372	158	141	4288	57	662	1516	42
42	472	19	40	104	28	92	1480	31	32	716	736	142	4352	59	2052	712	1804
43	480	13	120	60	180	93	1504	31	254	416	474	143	4416	59	1342	1968	1562
44	496	17	194	0	58	94	1536	31	34	564	710	144	4544	65	1380	1068	1036
45	512	19	64	52	124	95	1560	29	300	248	568	145	4608	67	954	1140	1566
46	528	17	36	196	100	96	1600	31	454	216	234	146	4672	67	410	1020	114
47	544	19	222	248	134	97	1640	33	164	432	748	147	4736	59	2	956	458
48	552	13	198	180	190	98	1672	35	164	368	700	148	4800	53	66	24	2
49	568	19	102	140	226	99	1712	41	4	848	332						

Determination of CTC cirulation states

Correspond to <<8.4.9.2.3.3>>.

Bit separation

Correspond to <<8.4.9.2.3.4.1>>.

Subblock interleaving

The subblock interleaver requires the parameters *m* and *J* shown in Table 703 of which N_{EP} set corresponds to that in Table 701.

The detailed subblock interleaver structures except table for subblock interleaver parameters correspond to <<8.4.9.2.3.4.2>>.

The subblock interleaver requires the parameters *m* and *J* shown in Table Table 703 of which N_{EP} set corresponds to that in Table 701.

The detailed subblock interleaver structures except table for subblock interleaver parameters correspond to <<8.4.9.2.3.4.2>>.

Table 703—Parameters for the subblock interleavers

Index	NEP	m	J	Index	NEP	m	J	Index	NEP	m	J	Index	NEP	m	J	Index	NEP	m	J
0	48	3	3	30	328	6	3	60	720	7	3	90	1424	8	3	120	2752	9	3
1	64	4	2	31	344	6	3	61	736	7	3	91	1448	8	3	121	2816	9	3
2	72	4	3	32	352	6	3	62	752	7	3	92	1480	8	3	122	2880	9	3
3	80	4	3	33	360	6	3	63	768	7	3	93	1504	8	3	123	2944	9	3
4	88	4	3	34	368	6	3	64	776	7	4	94	1536	8	3	124	3008	9	3
5	96	4	3	35	376	6	3	65	800	7	4	95	1560	8	4	125	3072	9	3
6	104	4	4	36	384	6	3	66	824	7	4	96	1600	8	4	126	3200	9	4
7	120	5	2	37	400	6	4	67	848	7	4	97	1640	8	4	127	3264	9	4
8	128	5	2	38	416	6	4	68	872	7	4	98	1672	8	4	128	3328	9	4
9	136	5	3	39	432	6	4	69	888	7	4	99	1712	8	4	129	3392	9	4
10	144	5	3	40	440	6	4	70	912	8	2	100	1752	8	4	130	3456	9	4
11	152	5	3	41	456	7	2	71	936	8	2	101	1784	8	4	131	3520	9	4
12	160	5	3	42	472	7	2	72	960	8	2	102	1824	9	2	132	3648	10	2
13	176	5	3	43	480	7	2	73	984	8	2	103	1864	9	2	133	3712	10	2
14	184	5	3	44	496	7	2	74	1000	8	2	104	1896	9	2	134	3776	10	2
15	192	5	3	45	512	7	2	75	1024	8	2	105	1920	9	2	135	3840	10	2
16	200	5	4	46	528	7	3	76	1048	8	3	106	1952	9	2	136	3904	10	2
17	208	5	4	47	544	7	3	77	1072	8	3	107	2000	9	2	137	3968	10	2
18	216	5	4	48	552	7	3	78	1096	8	3	108	2048	9	2	138	4096	10	2
19	232	6	2	49	568	7	3	79	1112	8	3	109	2096	9	3	139	4160	10	3
20	240	6	2	50	584	7	3	80	1136	8	3	110	2144	9	3	140	4224	10	3
21	248	6	2	51	600	7	3	81	1160	8	3	111	2192	9	3	141	4288	10	3
22	256	6	2	52	608	7	3	82	1184	8	3	112	2232	9	3	142	4352	10	3
23	264	6	3	53	624	7	3	83	1216	8	3	113	2280	9	3	143	4416	10	3
24	272	6	3	54	640	7	3	84	1248	8	3	114	2328	9	3	144	4544	10	3
25	288	6	3	55	656	7	3	85	1280	8	3	115	2368	9	3	145	4608	10	3
26	296	6	3	56	664	7	3	86	1312	8	3	116	2432	9	3	146	4672	10	3

Table 703—Parameters for the subblock interleavers

Index	NEP	m	J	Index	NEP	m	J	Index	NEP	m	J	Index	NEP	m	J	Index	NEP	m	J
27	304	6	3	57	680	7	3	87	1336	8	3	117	2496	9	3	147	4736	10	3
28	312	6	3	58	696	7	3	88	1368	8	3	118	2560	9	3	148	4800	10	3
29	320	6	3	59	712	7	3	89	1392	8	3	119	2624	9	3				

Bit grouping

Corresponding to section <<8.4.9.2.3.4.3>>.

Resource segmentation

If $K_{FB} > 1$, the N_{RE} data resource elements allocated for the subpacket are segmented into K_{FB} blocks, one for each FEC block. The number of data resource elements for the kth FEC block is defined by Equation (245).

$$N_{RE,k} = 2 \cdot \left\lfloor \frac{\frac{N_{RE}}{2} + (K_{FB} - k - 1)}{K_{FB}} \right\rfloor, 0 \le k \le K_{FB} \tag{245}$$

Bit selection and repetition

Bit selection and repetition are performed to generate the subpacket.

Let $N_{CTC,k}$ be the number of coded bits that shall be transmitted for the kth FEC block. The value of $N_{CTC,k}$ is calculated by Equation (246):

$$N_{CTC,k} = N_{RE,k} \cdot N_{SM} \cdot N_{mod} \tag{246}$$

The index in the HARQ buffer for the jth bit transmitted for the kth FEC block shall be:

$u_{k,j} = (P_{i,k} + j) \bmod N_{FB\_Buffer,k}$, for $k = 0, \ldots, K_{FB} - 1$, and $j = 0, 1, ..., N_{CTC,k} - 1$, where i is the subpacket ID of the subpacket (SPID = i), $P_{i,k}$ is the starting position for subpacket i of the k_{th} FEC block as specified in 15.3.12.2.1, and is the buffer size for the kth FEC block.

Bit collection

The selected bits from each FEC block are collected in the order of FEC block for the HARQ transmission.

Modulation

Correspond to <<8.4.9.4.2>>.

15.3.12.2 HARQ

15.3.12.2.1 IR HARQ

HARQ IR is performed by changing the starting position, $P_{i,k}$, of the bit selection for HARQ retransmissions.

For downlink HARQ, the starting point for the bit selection algorithm as described in section 15.3.12.1.5.1 is determined as a function of SPID using Table 704.

Table 704—Starting position determination for downlink HARQ

SPID	Starting position
0	$P_{0,k} = 0$
1	$P_{1,k} = (-N_{CTC,k}) \bmod N_{FB\_Buffer,k}$
2	TBD
3	TBD

For uplink HARQ, the starting position for the bit selection algorithm as described in section 15.3.12.1.5.1 is determined as a function of SPID for Equation (247).

$$P_{i,k} = (i \cdot N_{CTC,k}) \bmod N_{FB\_Buffer,k} \tag{247}$$

For uplink HARQ, subpackets shall be transmitted in sequential order. In other words, for the tth transmission, the subpacket ID shall be set to SPID = $t \bmod 4$.

15.3.12.2.1.1 Constellation rearrangement

Two constellation re-arrangement versions shall be supported. Costellation rearrangement only applies to 16QAM and 64QAM. In case of QPSK, it is transparent.

In one HARQ process, all transmissions/retransmissions use the same constellation rearrangement scheme. In this particular constellation rearrangement scheme, two constellation rearrangement versions are exploited for 16QAM and 64 QAM modulation respectively.