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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)

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3. Definitions

[Insert the following definitions:]

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

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: More than 1 OFDMA carrier is used to exchange data between BS and MSs.

3.98 primary carrier: 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: 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 multicarrier 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 6 consecutive symbols (in a same subframe) defined before any permutation.

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.

4. Abbreviations and acronyms

[Insert the following abbreviations:]

CRU	contiguous resource unit
DRU	distributed resource unit
LRU	logical resource unit
PRU	physical resource unit
SFH	superframe header

[Insert the following clause:]

15. Advanced Air Interface

15.1 Introduction

15.2 Medium access control

15.2.1 Security

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 387 illustrates this structure.

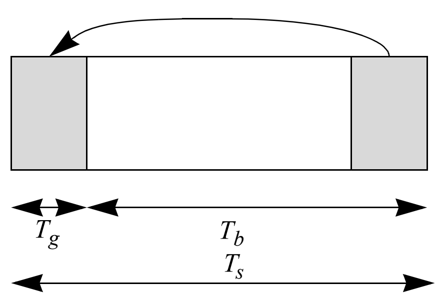


Figure 387—OFDMA symbol time structure

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 N_{used} determines the subcarrier spacing and the useful symbol time. This value is set as follows: for channel bandwidths that are a multiple of 1.75 MHz, $n = 8/7$, for channel bandwidths that are a multiple of 1.25 MHz, $n = 28/25$.
- 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

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	91.4	128	102.4	91.4	91.4

Table 647—OFDMA parameters

CP ratio, G, = 1/8	OFDMA symbol time, Ts, (μ s)	102.82	144	115.2	102.82	102.82
	Number of OFDMA symbols per 5ms frame	48	34	43	48	48
	Idle time (μ s)	62.86	104	46.40	62.86	62.86
CP ratio, G, = 1/16	OFDMA symbol time, Ts, (μ s)	97.143	[TBD]	[TBD]	97.143	97.143
	Number of OFDMA symbols per 5ms frame	51	[TBD]	[TBD]	51	51
	Idle time (μ s)	45.71	[TBD]	[TBD]	45.71	45.71
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		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.

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

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

T_s is the OFDMA symbol duration, including guard time

Δf is the subcarrier frequency spacing

15.3.2.6 Definition of basic terms on the transmission chain

The basic terms related with the transmission chain shall be defined as illustrated in Figure 388.

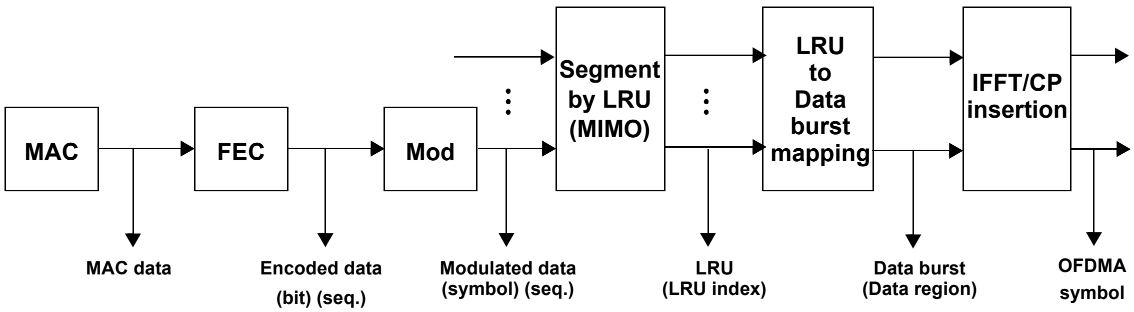


Figure 388—Definition of basic terms on the transmission chain

15.3.3 Frame structure

15.3.3.1 Basic frame structure

The advanced air interface basic frame structure is illustrated in Figure 389. 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 two types of subframes depending on the size of cyclic prefix:

1) the type-1 subframe consists of six OFDMA symbols, and
2) the type-2 subframe consists of seven OFDMA symbols. In both subframe types, some of symbols may be idle symbols.

The basic frame structure is applied to FDD and TDD duplexing schemes, including H-FDD MS operation. The default 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. Depending on the application, additional number of switching points (up to 4) may be considered.

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.

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.

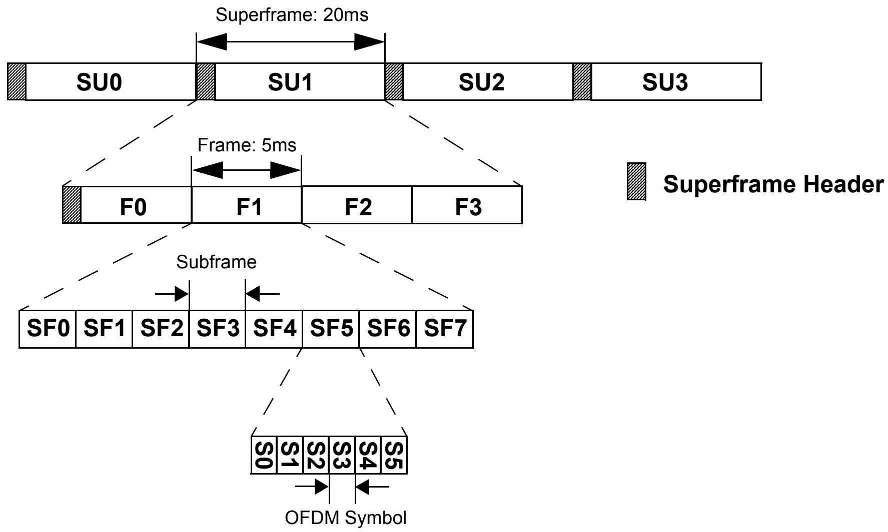


Figure 389—Basic frame structure for 5, 10 and 20 MHz channel bandwidths

15.3.3.2 Frame structure for CP = 1/8 T_b

15.3.3.2.1 FDD frame structure

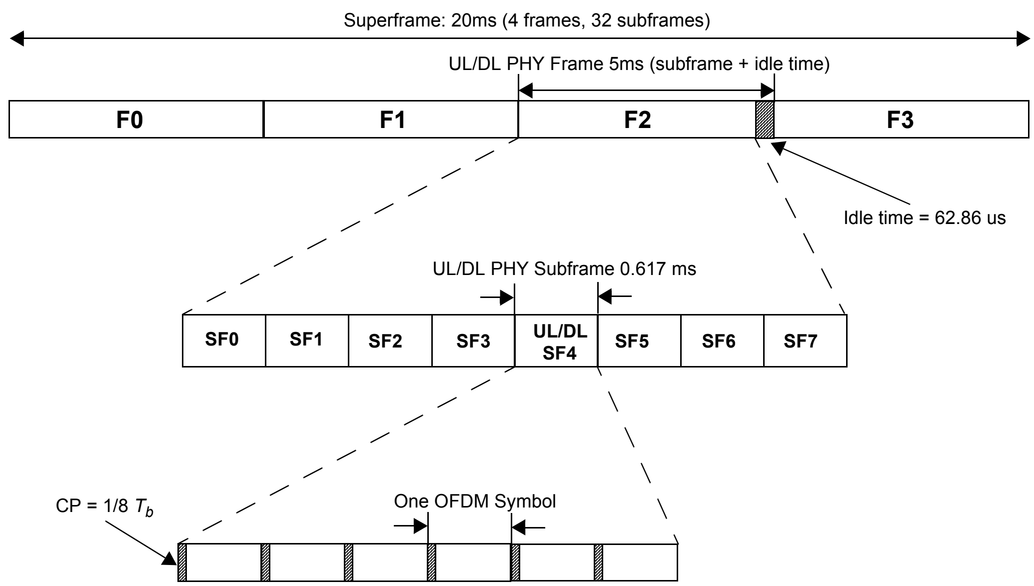
A BS supporting FDD mode shall be able to simultaneously support half duplex and full duplex MSs operating on the same RF carrier. The MS supporting FDD mode shall use either H-FDD or FDD.

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, only one of transmission and reception 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 Table 390.

Figure 390 illustrates an example FDD frame structure, which is applicable to the nominal channel bandwidth of 5, 10, and 20 MHz with $G = 1/8$.



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

Figure 390—Frame structure with Type-1 FDD subframe

15.3.3.2.1.1 H-FDD frame structure

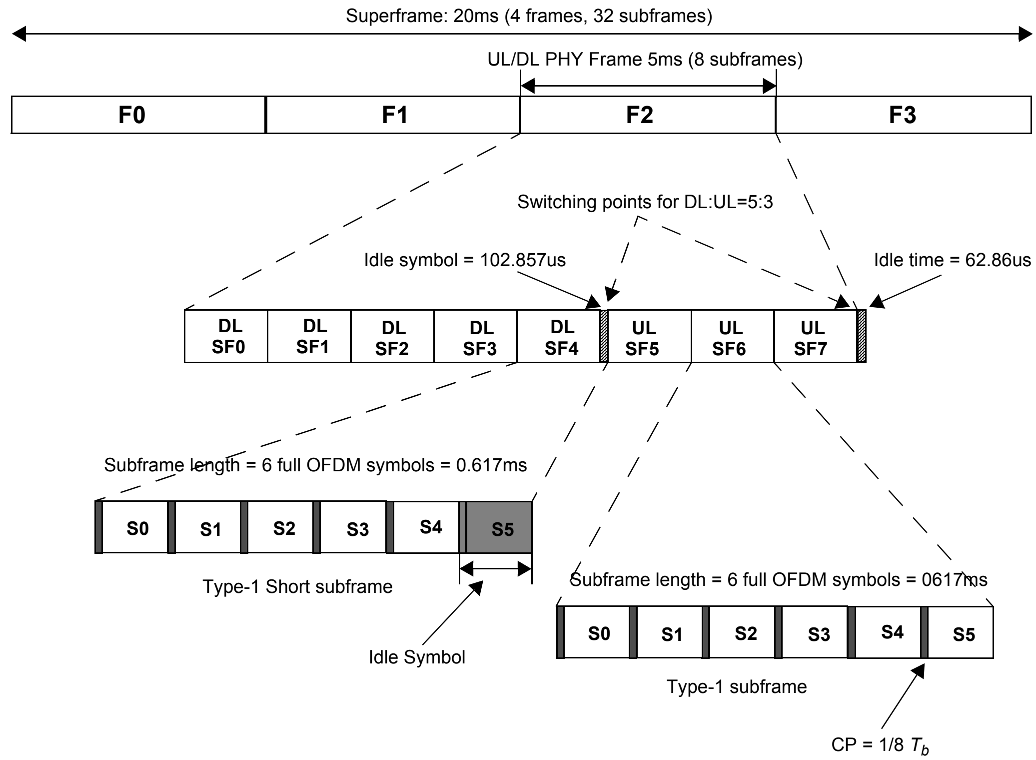
15.3.3.2.2 TDD frame structure

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. The ratio of D:U for 5, 10 and 20 MHz channel bandwidths shall be selected from one of the following values: 8:0, 6:2, 5:3, 4:4, or 3:5.

In each frame, the TTG and RTG shall be inserted between the DL and UL and at the end of each frame, respectively.

Figure 391 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.



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

Figure 391—Frame structure with Type-1 TDD subframe

15.3.3.3 Frame structure for CP = 1/16 T_b

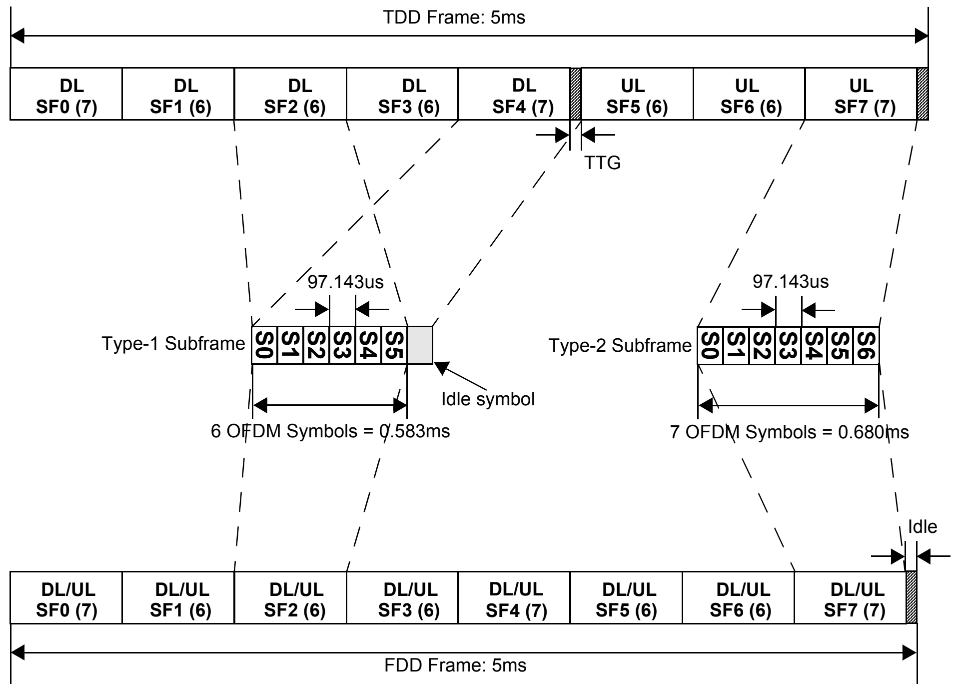
The frame structure for a CP length of 1/16 T_b shall consist of type-1 and type-2 subframes.

For channel bandwidths of 5, 10, and 20 MHz, a frame shall have five type-1 subframes and three type-2 subframes.

In the TDD frame, the first and last subframes within each frame shall be type-2 subframes. The last OFDMA symbol in a type-2 subframe preceding a DL to UL switching point shall be an idle symbol, which is used to accommodate the gap required to switch from DL to UL.

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

Figure 392 illustrates an example of TDD and FDD frame structure 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.



TDD and FDD frame structure with a CP of 1/16 T_b (DL to UL ratio of 5:3) for 5, 10, and 20 MHz channel bandwidths.

Figure 392—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 393 and Figure 394. The maximum value of parameter K is equal to the number of DL subframes minus one, since the Advanced Air Interface frame shall contain at least one DL subframe. In the case where Advanced Air Interface BSs coexist with Wireless-MAN-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 393 illustrates an example frame configuration for supporting the WirelessMAN-OFDMA operation when FDM mode is used.

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.

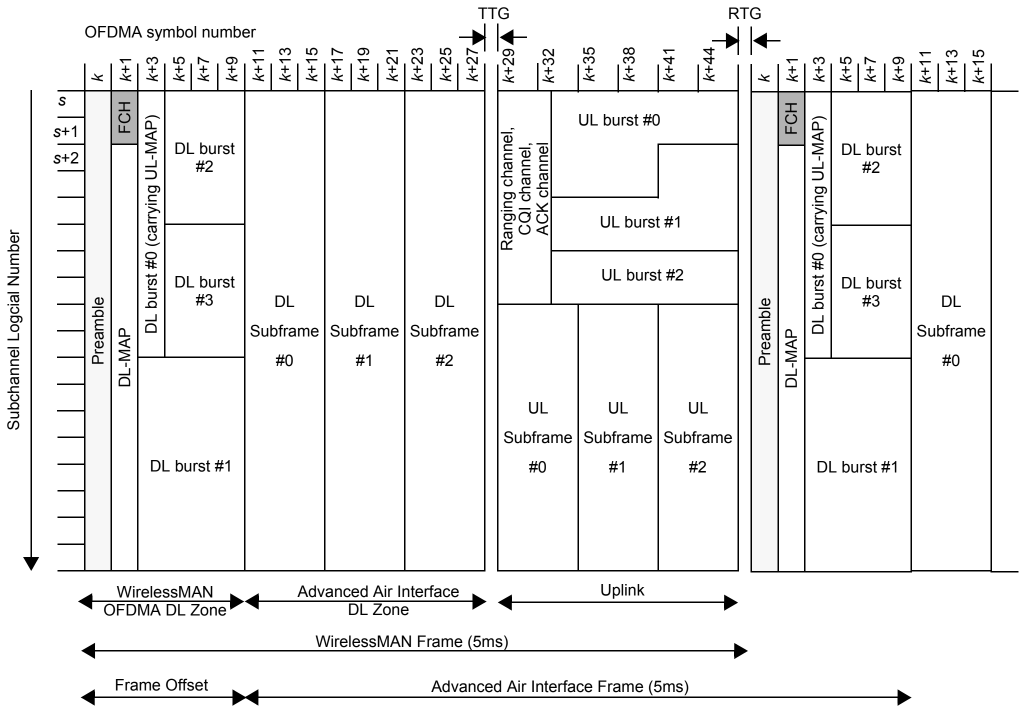


Figure 393—TDD frame configuration for supporting the WirelessMAN-OFDMA operation with UL FDM

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 394 illustrates an example frame configuration for supporting the WirelessMAN-OFDMA operation when TDM mode is used.

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.

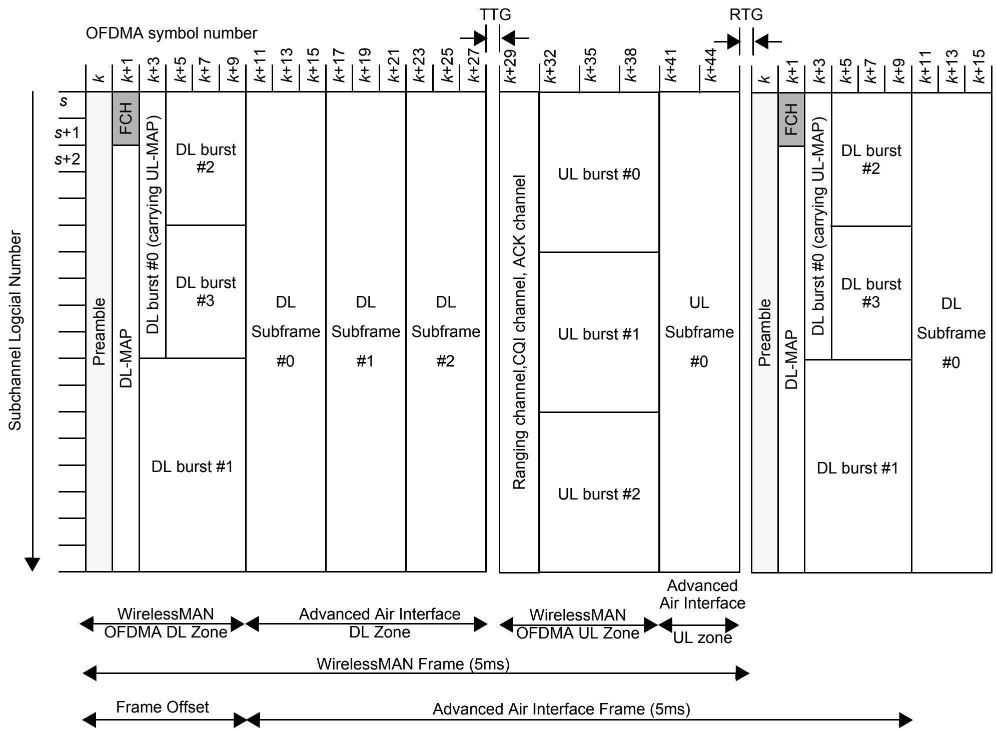


Figure 394—TDD frame configuration for supporting the WirelessMAN-OFDMA operation with UL TDM

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 multicarrier mode operation. Each carrier may have its own superframe header. Some carriers may have only part of superframe header. Figure 395 illustrates the example of the frame structure to support multi-carrier operation. For FDD UL, the preamble and superframe header is replaced with traffic OFDMA symbols.

The multiple carriers involved in multicarrier 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 a 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).

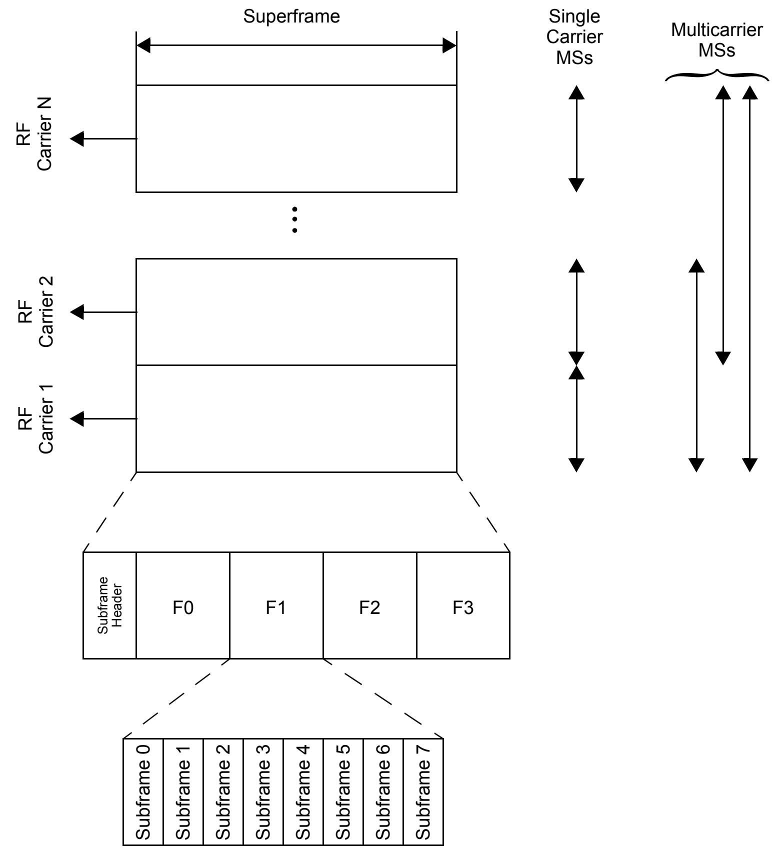


Figure 395—Example of the frame structure to support multi-carrier operation

15.3.3.5.1 Frame structure supporting multicarrier operation in WirelessMAN-OFDMA support mode

In the multicarrier 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). 396 illustrates an example of the frame structure in the multicarrier mode supporting WirelessMAN-OFDMA. In the carrier to support WirelessMAN-OFDMA, uplink can be also configured in TDM as defined 15.3.3.3.

The multicarrier operation (ref. TBD) is only performed between subframes where the Advanced Air Interface frame is defined. No multicarrier operation is defined between the Advanced Air Interface frames and WirelessMAN-OFDMA frames.

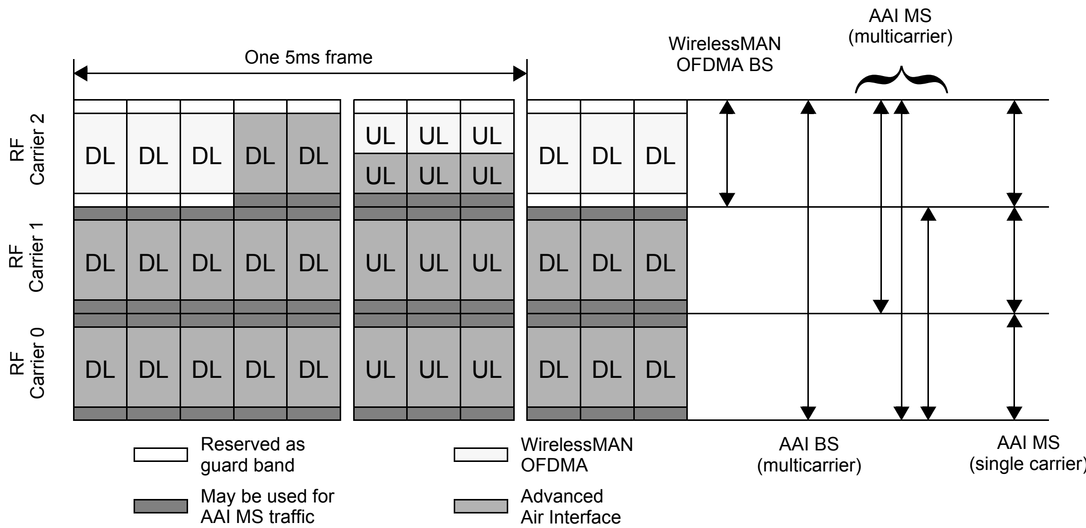


Figure 396—Example of the frame structure to support multi-carrier operation in WirelessMAN-OFDMA support mode

15.3.3.5.2 Subcarrier alignment for multi-carrier operation

When contiguous carriers are involved in multicarrier 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 ($\Delta f'$) will be applied over the original center frequency. The basic principle is shown by the example in Figure 397.

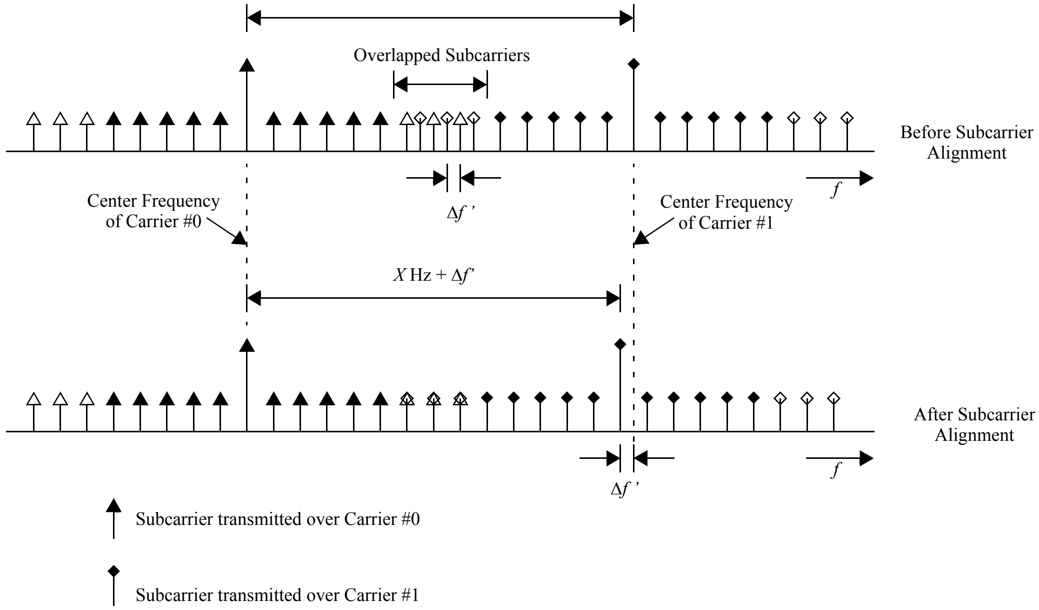


Figure 397—Example of subcarrier alignment of adjacent carriers

During the network entry procedure defined in [TBD], the ABS will notify the frequency offset to be applied over each carrier for sub-carrier to the AMS.

15.3.3.5.3 Data Transmission over guard subcarriers in multi-carrier operation

When contiguous carriers are involved in multicarrier 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 398 illustrates the downlink physical structure in the example of two frequency partitions with frequency partition 2 including both contiguous and distributed resource allocations.

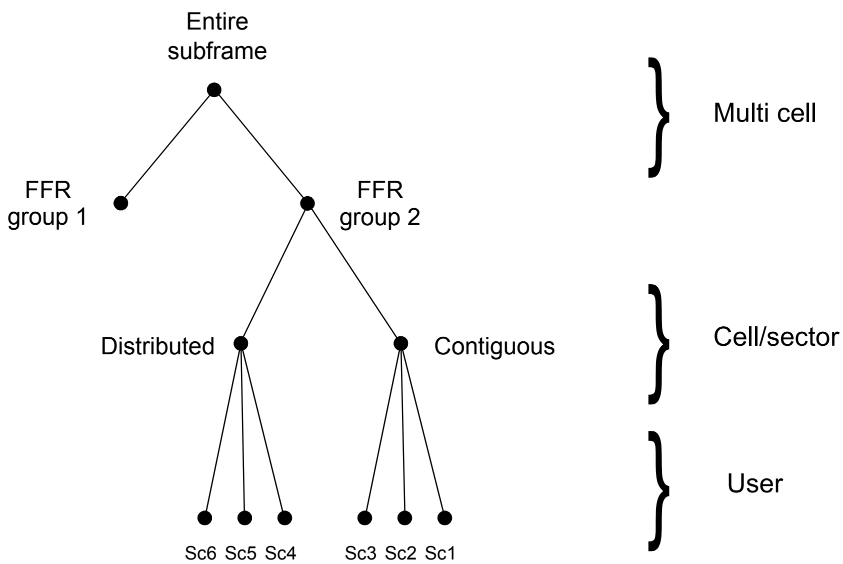


Figure 398—Example of downlink physical structure

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, and N_{sym} is 7 OFDM symbols for type-2 sub frames. A logical resource unit (LRU) is the basic logical unit for distributed and localized resource allocations. A LRU is $P_{sc} \cdot N_{sym}$ subcarriers for type-1 subframes and type-2 subframes. The LRU includes the pilots in (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).

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 physical 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 $L_{SB} = N_1 \cdot K_{SB}$. A 5-bit (TBD) field called Subband Allocation Count (SAC) field determines the value of K_{SB}. The SAC is transmitted in the BCH. 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 $N_{PRU} = L_{SB} + L_{MB}$.

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 399 illustrates the PRU to PRU_{SB} and PRU_{MB} mapping for a 5 MHz bandwidth with SAC equal to 3.

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

where:

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

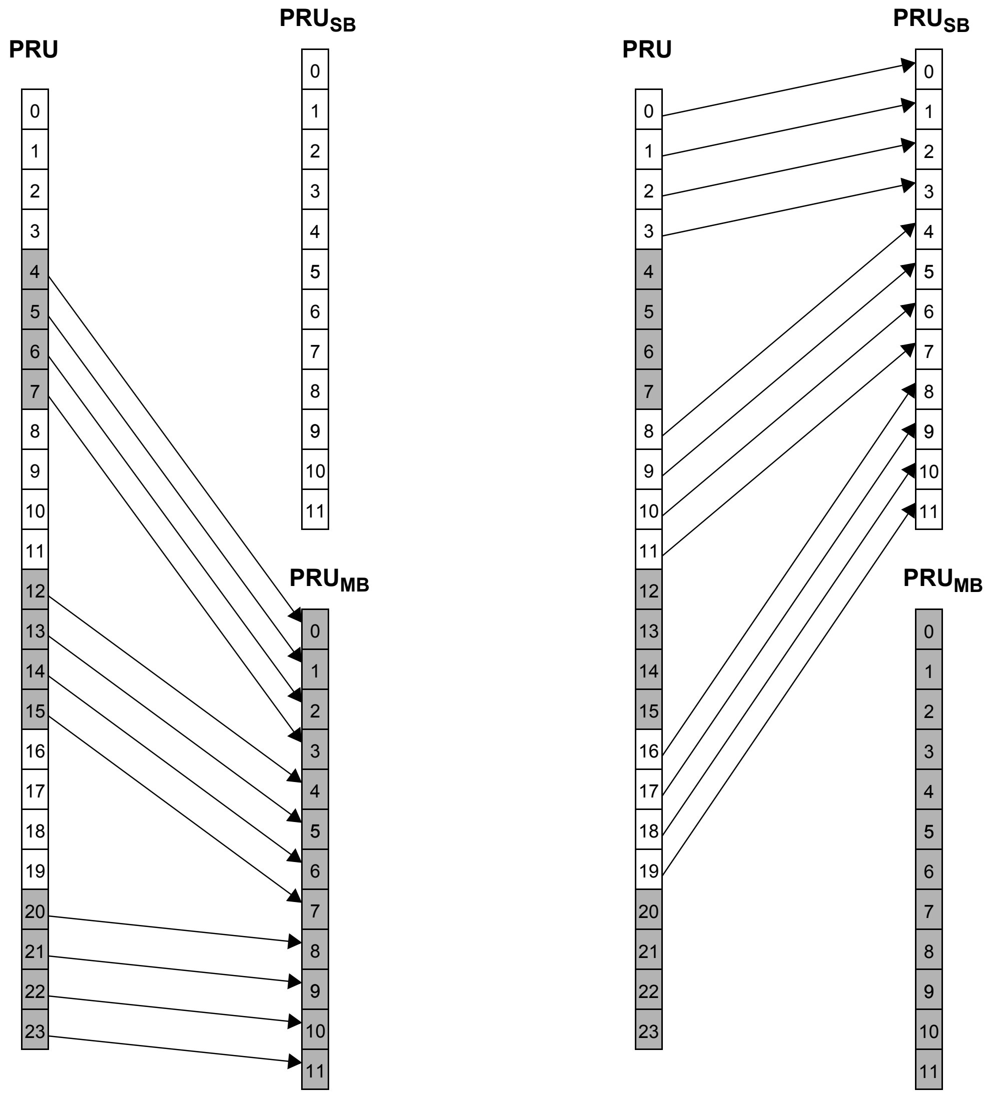
where $GCD(x,y)$ is the greatest common divisor of x and y.

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

where:

$$k = N_1 \cdot \left\{ \left\lceil \frac{N_{sub}}{K_{SB}} \right\rceil \cdot \left\lfloor \frac{k + L_{SB}}{N_1} \right\rfloor + \left\lfloor \left\lfloor \frac{k + L_{SB}}{N_1} \right\rfloor \cdot \frac{GCD(N_{sub}, \lceil N_{sub}/K_{SB} \rceil)}{N_{sub}} \right\rfloor \right\} \mathrm{mod}(N_{sub}) + j \cdot \mathrm{mod}(N_1) \tag{177}$$

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



(a) PRU to PRU_{MB} mapping (b) PRU to PRU_{SB} mapping

Figure 399—PRU to PRU_{SB} and PRU_{MB} mapping for BW=5 MHz, SAC=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:

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

Figure 400 depicts the mapping from PRUs to PRU_{SB} and PRU_{MB}.

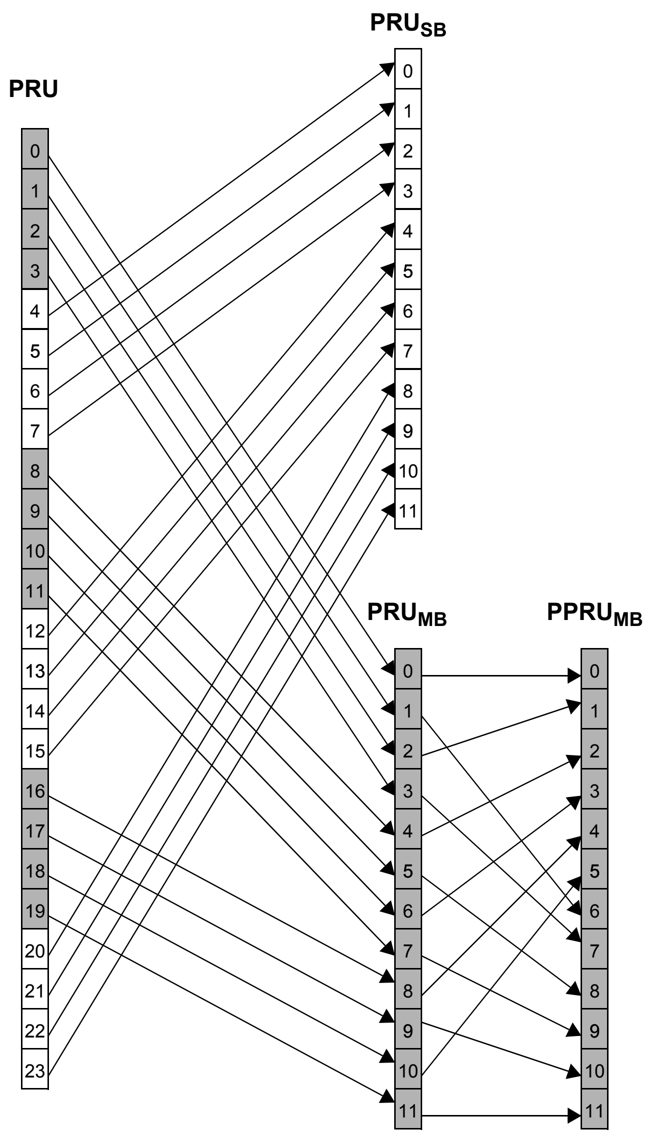


Figure 400—Mapping from PRUs to PRU_{SB} and $PPRU_{MB}$ for BW=5 MHz, SAC=3

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 BCH in a 12-bit called the Frequency Partition Configuration (FPC).

The FPC consists of a Frequency Partition Count (FPCT), Frequency Partition Size (FPS) and Frequency Partition Subband Count (FPSC). The first two bits carry the FPCT that defines the number of frequency partitions (1 to 4). The following 6 bits carry the FPS that defines the number of PRUs allocated to FP_i, i>0 in the number of minibands (N_2). The remaining 4 bits carry FPSC that define the number of subbands allocated to FP_i, i>0.

The number of subbands in i-th frequency partition are denoted by $K_{SB,FPi}$. The number of minibands is denoted by $K_{MB,FPi}$, which are 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 $L_{SB,FPi} = N_1 \cdot K_{SB,FPi}$. The number of miniband PRUs in each frequency partition is denoted by $L_{MB,FPi}$, which is given by $L_{MB,FPi} = N_2 \cdot K_{MB,FPi}$.

$$K_{SB,FP_i} = \begin{cases} SAC - (FPCT - 1) \cdot FPSC & i = 0 \\ FPSC & i > 0 \end{cases} \quad (179)$$

$$K_{MB,FP_i} = \begin{cases} K_{MB} - (FPCT - 1) \cdot \left(FPS - \dfrac{FPSC \cdot N_1}{N_2}\right) & i = 0 \\ FPS - \dfrac{FPSC \cdot N_1}{N_2} & i > 0 \end{cases} \quad (180)$$

The mapping of subband PRUs and miniband PRUs to the frequency partition is given by Equation (181):

$$PRU_{FP_i}(j) = \begin{cases} PRU_{SB}(k_1) & \text{for } 0 \le j < L_{SB,FP_i} \\ PPRU_{MB}(k_2) & \text{for } L_{SB,FP_i} \le j < (L_{SB,FP_i} + L_{MB,FP_i}) \end{cases} \quad (181)$$

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 401 depicts the frequency partitioning BW=5 MHz, SAC=3, FPCT=2, FPS=12, and FPSC=1.

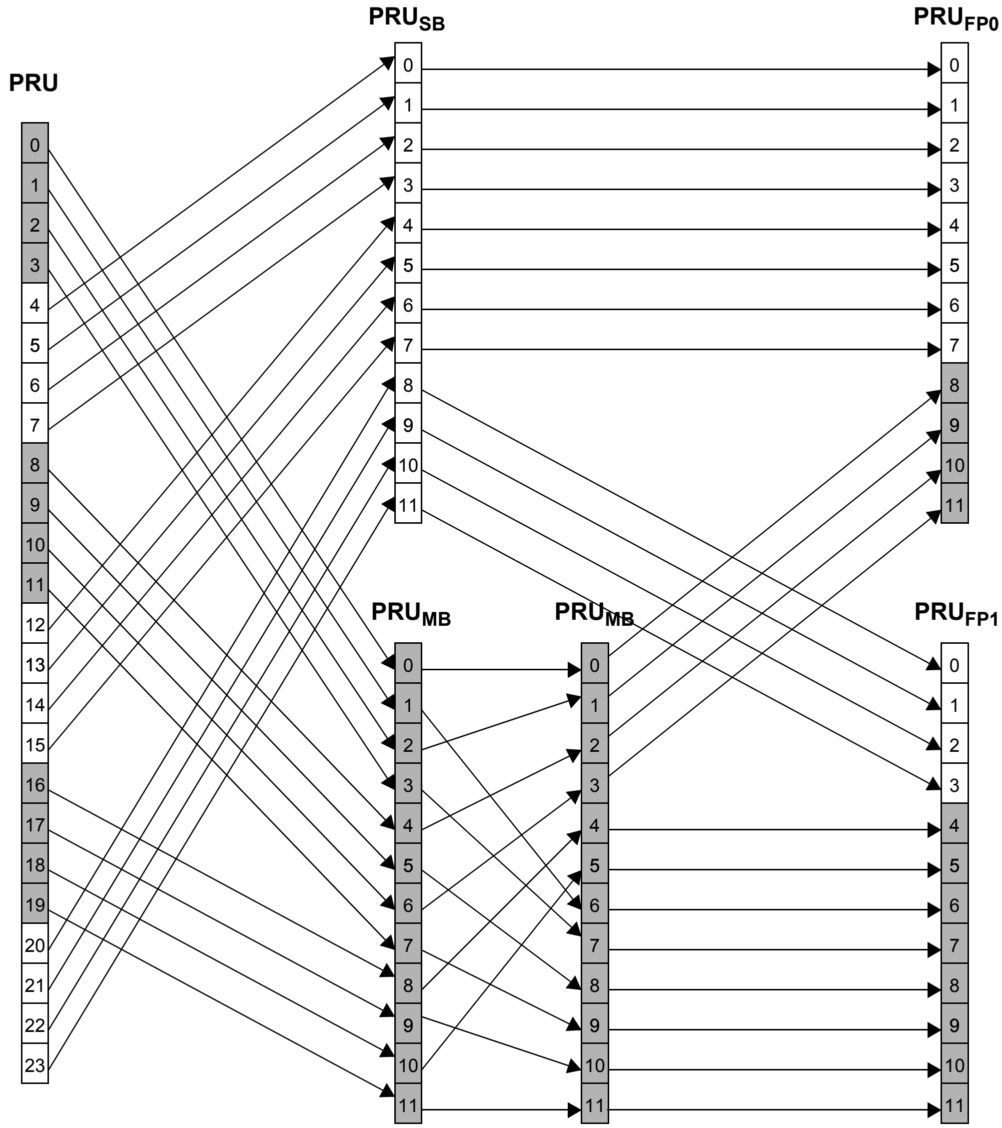


Figure 401—Frequency partitioning

15.3.5.3 Cell-specific resource mapping

PRU_{FPi}s are mapped to LRUs. All further PRU and subcarrier permutation will be 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 BCH for each allocated frequency partition. CAS_{SBi} indicated the number 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 BCH 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

$$L_{CRU,FP_i} = \begin{cases} CAS_{SB,i} \cdot N_1 + CAS_{MB} & i=0 \\ CAS_{SB,i} \cdot N_1 & 0 \le i < FPCT \end{cases} \quad (182)$$

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 $0 \le i < FPCT$

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

$$CRU_{FPi}[j] = \begin{cases} PRU_{FPi}[j], & 0 \le j < CAS_{SB,i} \cdot N_1 \\ PRU_{FPi}[k + CAS_{SB,i} \cdot N_1], & CAS_{SB,i} \cdot N_1 \le j < L_{CRU,FPi} \end{cases} \quad 0 \le i < FPCT \quad (183)$$

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

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

$$DRU_{FP_i}[j] = PRU_{FP_i}[k + CAS_{SB,i} \cdot N_1],\ 0 \le j < L_{DRU,FP_i} \quad (184)$$

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 Secondary permutation

The miniband CRUs may be permuted on a sector specific basis by a secondary permutation. Permutation of the secondary permutation will be signaled by a 1-bit secondary permutation field in the BCH.

The secondary permutation will be governed by Equation (185):

$$TBD \quad (185)$$

15.3.5.3.3 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 dta subcarrier-pairs in the l^{th} 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 l^{th} OFDMA symbol as $SC_{DRUi,LFPi}$, $0 \le j < L_{DRU,FPi}$, 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 $\mathrm{RSP}_{l,FPi}$.

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

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

3) Apply the subcarrier permutation formula Equation (186) to the $R_{SPl,FPi}$ 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 s^{th} distributed LRUs $s = 0,1,..., L_{DRU,FPi} - 1$. The subcarrier permutation formula is given by

$$SC_{LRUs,\,l,\,FPi}[m] = RSP_{l,\,FPi}[k] \qquad 0 \le m \le L_{SP,\,l} \tag{186}$$

where

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

$SC_{LRUs,l,FPi}[m]$ is the m^{th} subcarrier pair ($0 <= m < L_{SP,l}$) in the l^{th} OFDMA symbol ($0 <= l < N_{sym}$) in the s^{th} distributed LRU of the t^{th} subframe; t is the subframe index with respect to the frame, s is the distributed LRU index ($0 <= s < L_{DRU,FPi}$). *PermSeq*() is the permutation sequence generated by a function or by a lookup table; $g(PermSeq(),s,m,l,t)$ is a function (TBD) with value from the set $[0, L_{DRU,FPi} - 1]$; $f(m,s)$ is a function (TBD) with value from the set $[0, L_{SP,l} - 1]$.

pair(s,m,l,t) is the tone-pair index of the m-th tone-pair ($0<=m< L_{pair,1}$) in the l-th OFDMA symbol ($0<=l<N_{sym}$) in the s-th distributed LRU of the t-th subframe; t is the subframe index with respect to the frame, s is the distributed LRU index ($0<=s < L_{DRU,\ FP,i}$), m is the tone-pair index within the l-th OFDMA symbol. *PermSeq()* is the permutation sequence generated by a function or by a lookup table; *g(PermSeq(),s,m,l,t)* is a function (TBD) with value from the set $[0, L_{DRU,\ FP,i}-1]$; *f(m,s)* is a function (TBD) with value from the set $[0, L_{pair,1} -1]$

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.

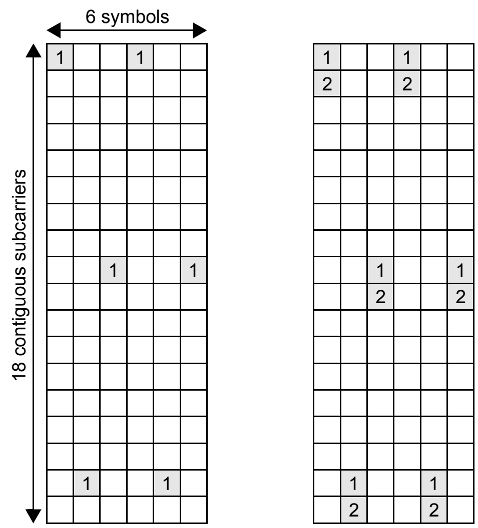


Figure 402—Pilot patterns used for 1 and 2 DL data streams

Base pilot patterns used for one and two DL data streams in dedicated and common pilot scenarios are shown in Figure 402 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. 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 patterns for one and two streams are shown in Figure 403 and Figure 404, respectively. Each BS chooses one of the three pilot pattern sets (pilot pattern set 0, 1, and 2) as shown in Figure 403 and Figure 404. 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:

$$p_k = mod(k, 3) \quad (187)$$

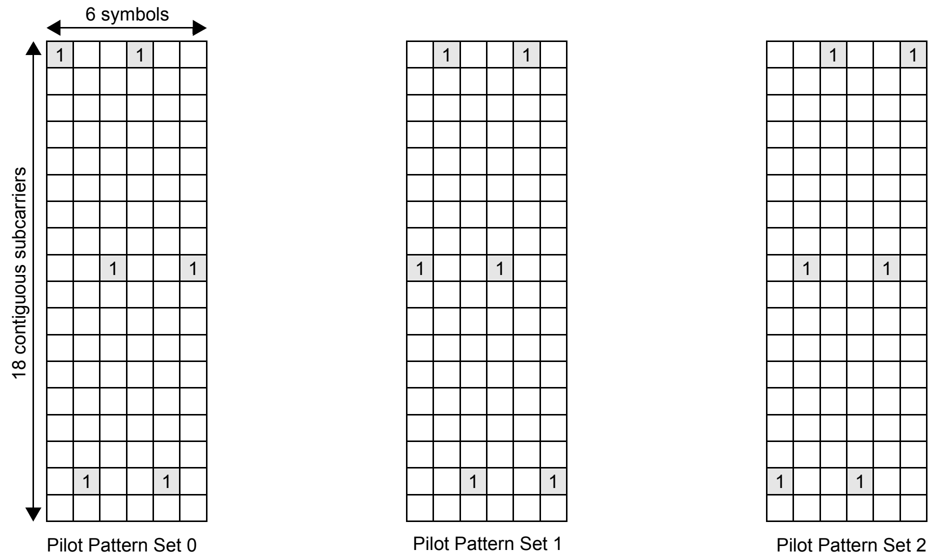


Figure 403—Interlaced pilot patterns for 1 pilot stream

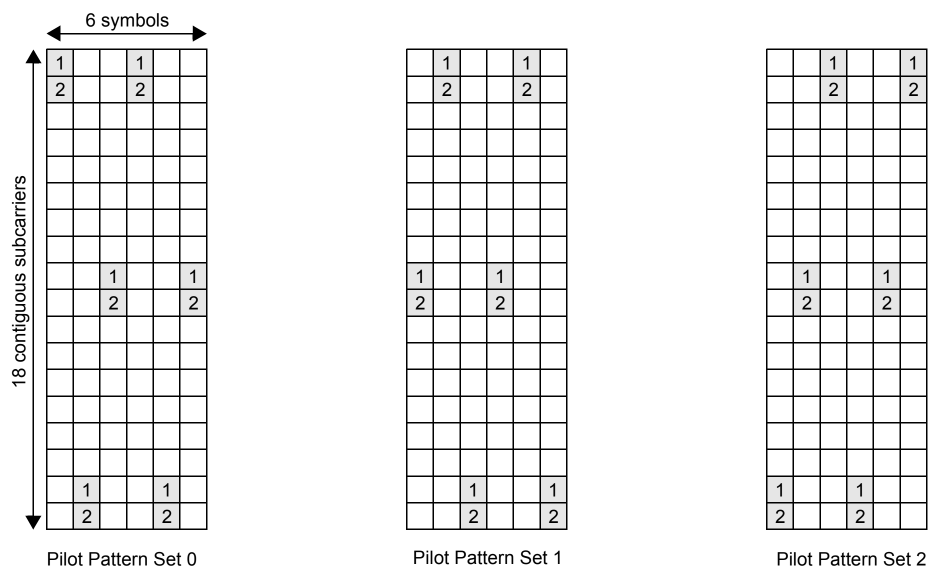


Figure 404—Interlaced pilot patterns for 2 pilot streams

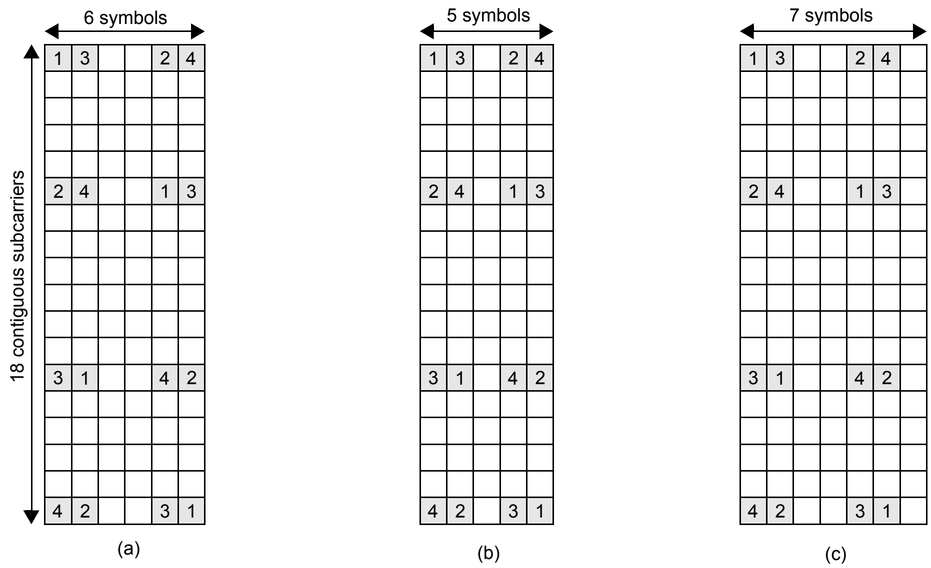


Figure 405—Pilot patterns for 4 pilot streams

The pilot patterns for four pilot streams are shown in Figure 405 with the subcarrier index increasing from top to bottom and the OFDM symbol index increasing from left to right. Subfigure (a) in Figure 405 shows the pilot pattern for four pilot streams in subframe with six OFDM symbols; Subfigure (b) in Figure 405 shows the pilot pattern for four pilot streams in subframe with five OFDM symbols; Subfigure (c) in Figure 405 shows the pilot pattern for four pilot streams in subframe with a seven OFDM symbols.

15.3.6 Downlink physical control

15.3.7 Downlink MIMO

15.3.8 Uplink physical structure

Each uplink 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). Figure 406 illustrates the uplink physical structure in the example of two frequency partitions with frequency partition 2 including both contiguous and distributed resource allocations.

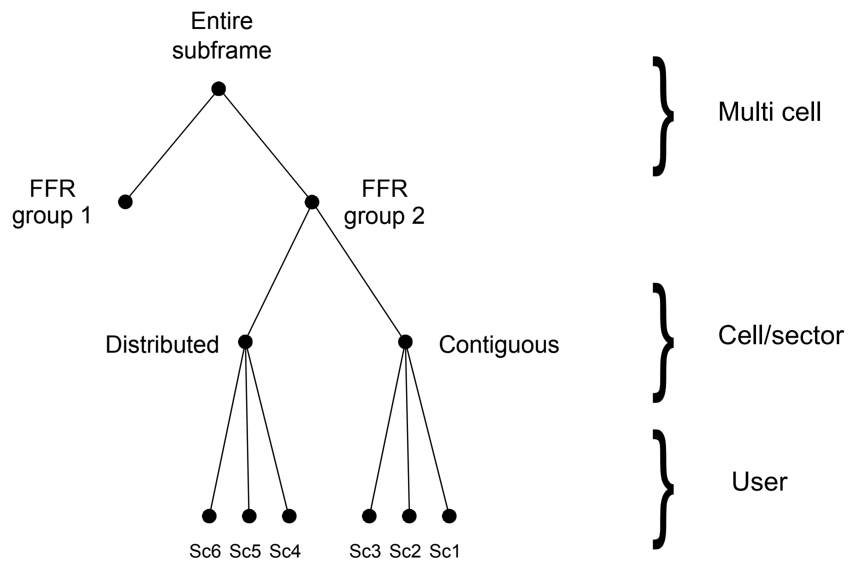


Figure 406—Example of uplink physical structure

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 and 7 for type-2 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 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 physical 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 [or 8 for the 2048 FFT] & N_2=1 [or 2 for the 2048 FFT]. 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 5-bit (TBD) field called *Uplink Subband Allocation Count* (USAC) determines the value of K_{SB}. The USAC is transmitted in the BCH. 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 $N_{PRU} = L_{SB} + L_{MB}$.

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).

Equation (188) defines the mapping of PRUs into PRU_{SB}s. Equation (189) defines the mapping of PRUs to PRU_{MB}s. Figure 407 illustrates the PRU to PRU_{SB}s and PRU_{MB}s mapping for a 5 MHz bandwidth with SAC equal to 3.

$$PRU_{SB}[j] = PRU[i]; \qquad 0 \le j \le L_{SB} - 1 \qquad (188)$$

$$PRU_{MB}[k] = PRU[i]; \quad k = 0, 1, \ldots, L_{MB} - 1 \qquad (189)$$

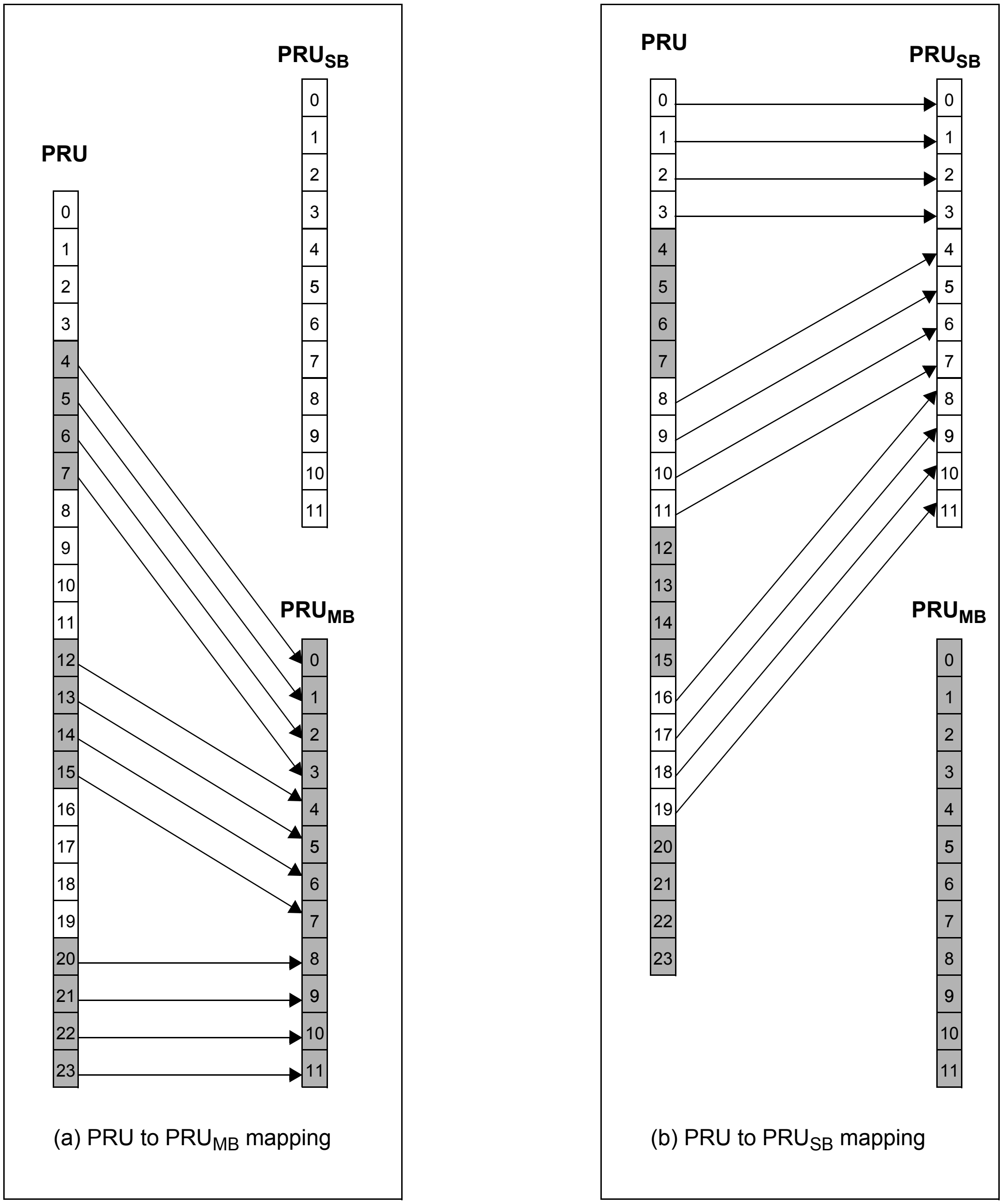


Figure 407—PRU to PRU_{SB} and PRU_{MB} mapping for BW of 5 MHz and USAC=3

15.3.8.2.2 Miniband permutation

The miniband permutation maps the PRU_{MS}s to permuted-PRU_{MS}s ($PPRU_{MS}$s) to insure allocation of frequency diverse PRUs to each frequency partition. Equation (190) provides a mapping from PRU_{MS}s to $PPRU_{MS}$s.

$$PPRU_{MB}[j] = PRU_{MB}[i]; \qquad 0 \le j \le L_{MB} - 1 \tag{190}$$

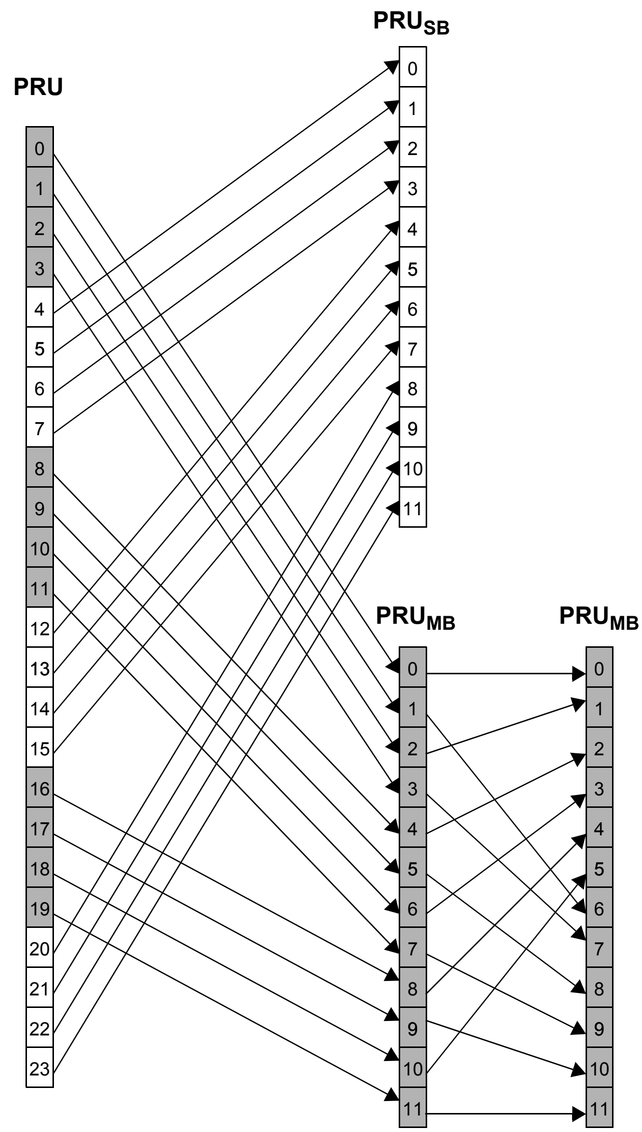


Figure 408—Mapping of PRUs to PRUSBs and PPRUMBs for BW of 5MHz and USAC=3

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 BCH in a 12-bit composite field called the *Uplink Frequency Partition Configuration* (UFPC).

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 (TBD). The FPS occupies the next 6 bits and defines the number of PRUs, in minibands (N_2) of PRUs, allocated to FP*i* for *i*>0. The FPSC occupies the remaining 4 bits and defines the number of subbands allocated to FP*i* for *i*>0.

The number of subbands and minibands in the i^{th} frequency partition are denoted by $K_{SB,FBi}$ and $K_{MB,FBi}$ respectively.

$$K_{SB,FPi} = \begin{cases} K_{SB} - (FPCT-1)\cdot FPSC & i = 0 \\ FPSC & i > 0 \end{cases} \tag{191}$$

$$K_{MB,FPi} = \begin{cases} K_{MB} - (FPCT-1)\cdot (FPS - FPSC\cdot N_1/N_2) & i = 0 \\ FPS - FPSC\cdot N_1/N_2 & i > 0 \end{cases} \tag{192}$$

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

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

$$PRU_{FPi}(j) = \begin{cases} PRU_{SB}(k_1) & 0 \le j < L_{SB,FPi} \\ PPRU_{MB}(k_2) & L_{SB,FPi} \le j < (L_{SB,FPi} + L_{MB,FPi}) \end{cases} \tag{193}$$

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

Figure 409 depicts the frequency partitioning for BW of 5 MHz, USAC = 3, FPCT = 2, FPS = 12, and FPSC = 1.

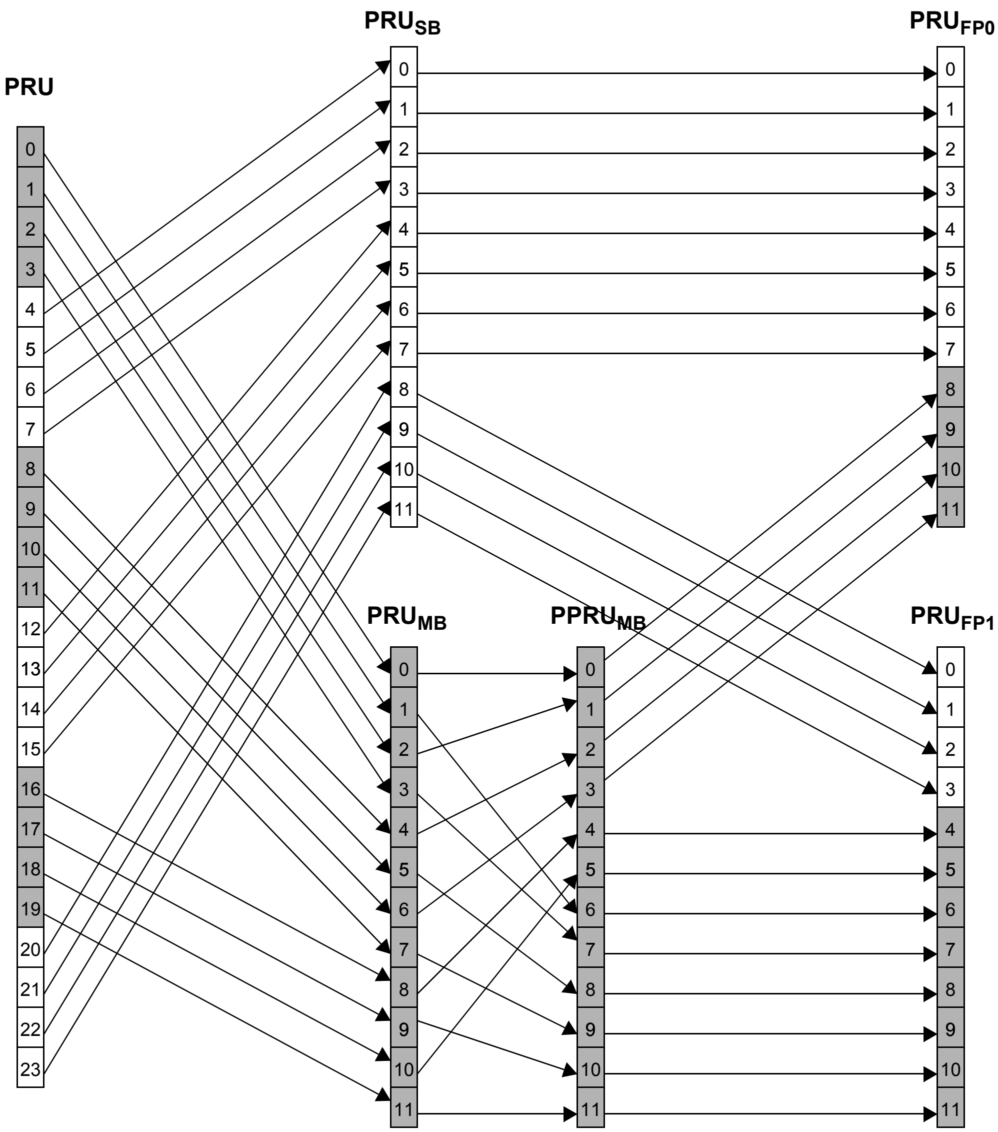


Figure 409—Frequency partitioning

15.3.8.3 Cell-specific resource mapping

PRU_{FPi}s will be mapped to LRUs. All further PRUs and tile permutations will be 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. DRU allocation is signaled in a two step process.

There are four possible uplink preconfigured allocations signaled in 2 bits:

Table 648—CRU/DRU Allocations

Value	Description
00	All PRU_{FPi}s are allocated to DRUs
01	All PRU_{FPi}s are alocated to CRUs
10	All subband PRUs are allocated to CRUs and all miniband PRUs to DRUs
11	The mapping is signaled explicitly

When explicit mapping is indicated, additional 4-bit (TBD) *Uplink CRU Allocation Size* (UCAS) field is sent in the BCH for each allocated frequency partition. $UCAS_i$ indicates the number of allocated CRUs for partition FP_i in units of subbands.

The number of CRUs in frequency partition i is denoted by:

$$L_{CRU,FPi} = UCAS_i \cdot N_1 \qquad 0 \le i < FPCT \tag{194}$$

The number of DRUs in frequency partition i is denoted by:

$$L_{DRU,FPi} = FPS_i - UCAS_i \cdot N_1 \qquad 0 \le i < FPCT \tag{195}$$

The mappings of PRU_{FPi}s to CRUs and DRUs are TBD.

15.3.8.3.2 Secondary permutation

Permutation of the secondary permutation will be signaled by a 1-bit secondary permutation field in the BCH.

The details of secondary permutation are FFS.

15.3.8.3.3 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 inner-permuted to obtain frequency-diversity across the allocated resources.

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

$$Tile(s, n, t) = TBD \tag{196}$$

where:

$Tiles(s,n,t)$ is the tile index of the n^{th} tile in the s^{th} distributed LRU of the t^{th} 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.

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 15.3.8.3.3 to form distributed LRUs.

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.

Pilot structures in 18-by-6 allocations used for contiguous LRUs and in 6-by-6 tiles for distributed LRUs are shown in Figures 1 and 2 respectively. Figure 410 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 411 shows the pilot structure for distributed LRUs where the number of streams is one or two.

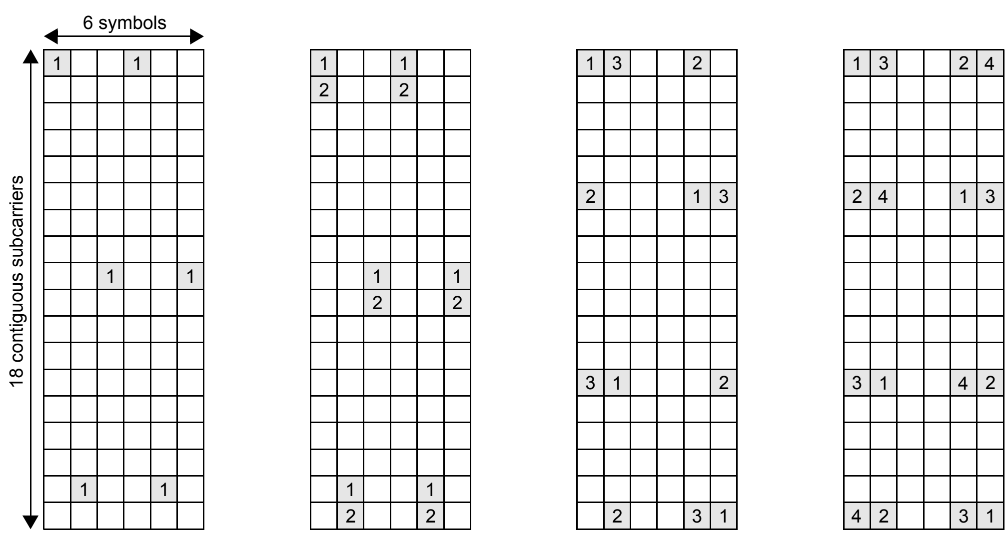


Figure 410—Pilot patterns for contiguous LRUs in cases of 1, 2, 3 or 4 Tx streams

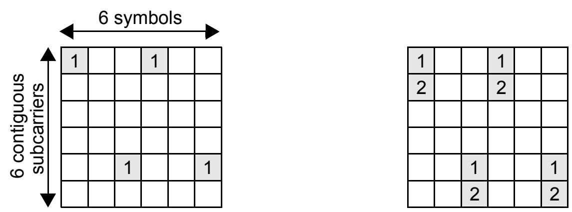


Figure 411—Pilot patterns for distributed LRUs in cases of 1 or 2 Tx streams

15.3.8.5 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 inner-permuted to frequency-diversify across the allocated resources.

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

$$Tile(s, n, t) = L_{DRU, FP_i} \cdot f(n, s) + g(PermSeq(\,), s, n, t, UL\_PermBase) \quad (197)$$

where

- $Tile(s,n,t)$ is the tile index of the n^{th} tile in the s^{th} distributed LRU of the t^{th} subframe.
- s is the distributed LRU index, 0 to $L_{DRU,\ FPi}$-1.
- n is the tile index, 0 to 2, in a distributed LRU.
- t is the subframe index with respect to the frame s.
- *PermSeq()* is the permutation sequence generated by a function or by a lookup table
- *UL_PermBase* is an integer value which is assigned by a management entity.
- *g(PermSeq(), s,n,t, UL_PermBase)* is a function of s, n, t, *UL_PermBase* and *PermSeq()*.
- *f(n,s)* is a function of n and/or s.

15.3.9 Uplink physical control

15.3.10 Uplink MIMO

15.3.11 Channel coding and HARQ