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| Project | **IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16> |
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| Re: | IEEE 802.16m-08/042, "Call for Contributions on Project 802.16m Draft Amendment Content". Topic: "Uplink Physical Structure". |
| Abstract | The contribution proposes the text for the UL PHY Structure. |
| Purpose | To be discussed and adopted by TGm for the 802.16m amendment. |
| Notice |  |
| Release |  |
| Patent Policy |  |

# Proposed Text of UL PHY Structure for the IEEE 802.16m Amendment

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## 1. Introduction

This contribution addresses the "Downlink Physical Structured" as resquested in IEEE 802.16m-08/042, "Call for Contributions on Project 802.16m Draft Amendment Content". The contribution attempts to address the competing requirements set forth in System Description Document regarding uplink physical structure and interference mitigation fractional frequency re-use technique..

The authors have made attempts to harmonize the SDD text with other 16m members. We would like to acknowledge the work of Jeongho Park and his colleagues of whom we share some common text.

## 2. Considerations for UL Physical Structure

The text proposed in this document is in accordance with the agreements in SDD subclause 11.6. The subclause defines a complex structure that is governed by many objectives whose parameterization must be considered as part of the permutation structure. The parameters are as follows:

- **Frequency Selectivity/Diversity –** The SDD supports both frequency selective allocations by using localized or contiguous resource units and frequency diversity allocations through distributed resource units. To this purpose, the SDD defines both a N1=4 and N2=1 outer permutation scheme[1]. The ratio of N1 and N2 blocks must be known prior to the permutation of those blocks and is intrinsically linked to the partitioning of FFR zones. The amount of broadcast information required to communicate this information must be accounted for in the proposal and hopefully minimized.
- **Fraction Frequency Reuse –** The FFR partitions provide a means for multiplexing different re-use schemes similar to the PUSC permutation in 16e. The outer permutation maps frequency diverse blocks into the FFR partitions. In order to be effective, the FFR partitions must be coordinated across all sectors within a cell and potentially across multiple cells. Effectively, this suggests that outer permutation is identical across a region if not the whole network. Therefore, it is assumed that the outer permutation is common to all 16m cells and is only governed by the partition between N1 and N2. However, it is clear that number of blocks allocated to N2 is related to the number of FFR partitions and cell configuration. Depending on the desired effective re-use pattern (e.g. 1x1x1, 1x3x1, 1x3x3, 1x4x2, 1x4x4 or 1x4x1) anywhere from 1 to 7 FFR partitions are envisioned. At a minimum, each FFR partition should contain at least two PRUs in order to support frequency diverse allocations. Therefore, if 7 FFR partitions are desired (e.g. SDD Figure 45), at least 14 PRUs need to be set aside for N2 outer permutation.

[1] It is acknowledged that N1=4 and N2=1 are TBD in the SDD. The authors choose to support these values as part of the Stage 3 text proposal. It is impossible to capture all potential configurations in one cohesive structure. Other Stage 3 proposals may elect different values for N1 and N2.

# 3. Text proposal for inclusion in the 802.16m amendment

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## 3. Definitions

***Insert the following at the end of section 3.1:***

xx. PRU : 18x6 (consecutive subcarriers) which include the resource unit before the outer permutation.

xx. DRU: This has still 18x6 PRU structure, which is going to be permuted by DL/UL inner permutation

xx. CRU: This has still 18x6 RU structure, which will pass-through inner permutation (i.e. is not going to be inner permuted). CRU has two types - subband-based CRU and PRU-based CRU, depending on system parameters.

xx. LRU : Basic logical unit for distributed and localized resource allocations.

xx. Distributed-LRU: the LRU which is obtained from distributed allocation after inner permutation

xx. Contiguous-LRU: the LRU obtained from contiguous allocation via. pass-through inner permutation

Insert a new section 15:

# 15. Advanced Air Interface

## 15.3. Physical layer

### 15.3.6. Uplink physical structure

Each UL subframe is divided into a number of frequency partitions, where 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 1 illustrates the uplink physical structure in the example of two FFR groups with FFR group 2 including both localized and distributed resource allocations.

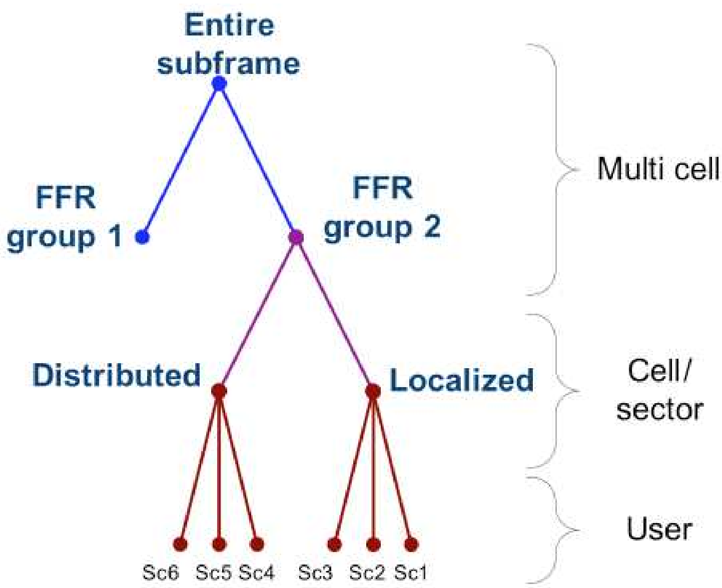


Figure 1 - Example of uplink physical structure

#### 15.3.6.1. 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 the number of OFDMA symbols depending on the subframe type. PRU structure in case of 6 symbol-subframe is shown in Figure 2. A logical resource unit (LRU) is the basic logical unit for distributed and localized resource allocations. The size of LRU for data transmission is $P_{sc}$* $N_{sym}$. Each LRU for data transmission can have different number of tones which are available for data allocation according to the number of pilots.

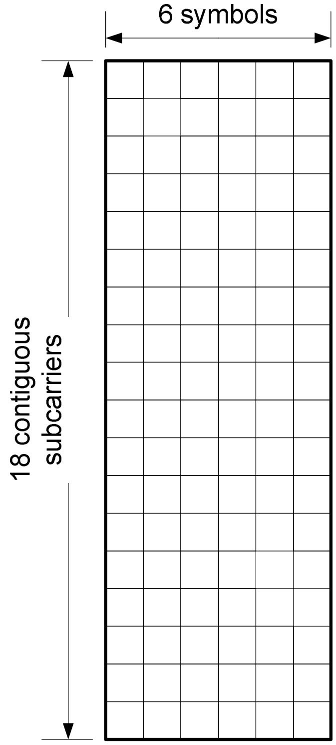


Figure 2 – A PRU structure for uplink physical structure

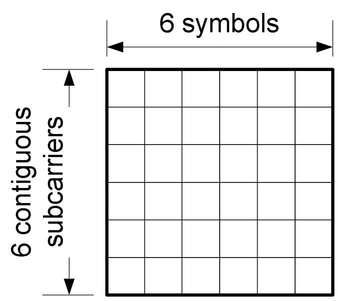


Figure 3 – A tile structure for distributed-LRU

#### 15.3.6.1.1. Distributed logical resource unit

The distributed logical resource unit (distributed-LRU) is used to achieve frequency diversity gain. The distributed-LRU contains a group of tiles which are spread across the distributed resource allocations. A tile is the minimum unit for forming the distributed-LRU and is defined as 6 consecutive subcarriers by $N_{sym}$. Figure 3 shows a tile structure for distributed-LRU in case of 6 symbol-subframe.

#### 15.3.6.1.2. Contiguous logical resource unit

The contiguous logical resource unit (contiguous-LRU) is used to achieve frequency-selective scheduling gain. A contiguous-LRU contains a group of subcarriers which are contiguous. The size of a localized-LRU equals the size of $P_{sc}$ subcarriers by $N_{sym}$ OFDMA symbols.

### 15.3.6.2. Subchannelization and resource mapping

#### 15.3.6.2.1. Basic symbol structure

The subcarriers of an OFDMA symbol 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 PRUs. Each PRU contains pilot and data subcarriers. The number of used pilot and data subcarriers depends on MIMO mode, rank and number of multiplexed MS and the type of resource allocation, i.e., distributed or localized resource allocations as well as the type of the subframe, i.e., type-1 or type-2.

Table 1 – Subcarrier partitioning

| FFT size, $N_{FFT}$ | 512 | 1024 | 2048 |
|---|---|---|---|
| Number of DC Subcarriers ($N_{dc}$) | 1 (Index 256, counting from 0) | 1 (Index 512, counting from 0) | 1 (Index 1024, counting from 0) |
| Number of Guard Subcarriers, Left ($N_{g,left}$) | 40 | 80 | 160 |
| Number of Guard Subcarriers, Right ($N_{g,right}$) | 39 | 79 | 159 |
| Number of Used Subcarriers ($N_{used}$) (including all possible allocated pilots and the DC subcarrier) | 433 | 865 | 1729 |
| Number of Physical Resource Units ($N_{PRU}$) | 24 | 48 | 96 |

#### 15.3.6.2.2. Uplink subcarrier to resource unit mapping overview

The main features of resource mapping include:

1. Support of contiguous resource unit (contiguous-LRU) and distributed resource unit (distributed-LRU) in an FDM manner.

2. Distributed-LRUs comprise multiple tiles which are spread across the distributed resource allocations to get diversity gain.

3. FFR can be applied in UL.

Based on the main design concepts above, the UL subcarriers to resource unit mapping process is defined as follows and illustrated in Figure 4:

1. First-level or outer permutation is applied to the PRUs in the units of N1 and N2 PRUs, where N1=4 and N2=1. Direct mapping of outer permutation can be supported.

2. Distributing the reordered PRUs into frequency partitions.

3. The frequency partition is divided into contiguous and/or distributed resource allocations. Using sector specific permutation can be supported; directly mapping of the resources can be supported for contiguous resource. The sizes of the distributed/contiguous resources are flexibly configured per sector. Adjacent sectors do not need to have same configuration of contiguous and diversity resources.

4. The contiguous and distributed groups resources are further mapped into LRUs. For the contiguous resources, the mapping is direct. For the distributed resources, a tile permutation is carried out for permuting or hopping the tiles of the distributed groups.

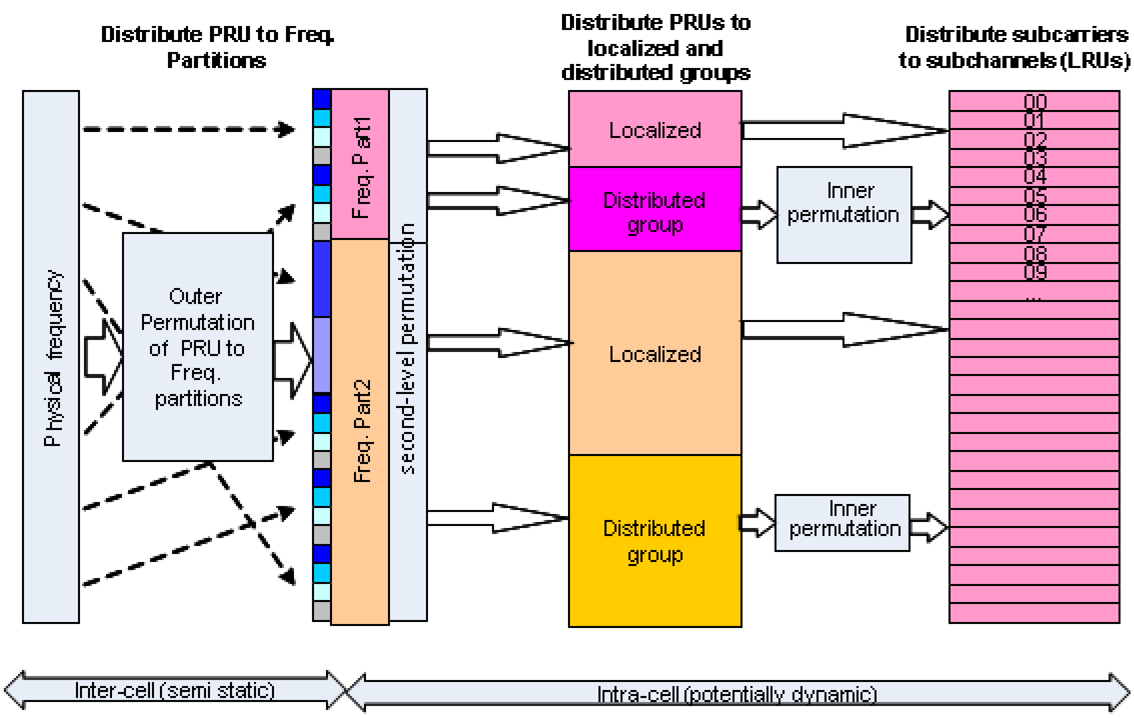


Figure 4 – Illustration of the uplink subcarrier to resource unit mapping

### 15.3.6.2.3. Uplink subcarrier to partition mapping

This subclause describes how the PRUs are re-ordered and mapped on the uplink.

#### 15.3.6.2.3.1. Segment Partitioning

The physical PRUs are subdivided into N1=4 & N2=1 segments based on a system-wide N2 ratio signaled in PBCH. N1 segments, called Contiguous Segments, are suitable for frequency selective allocations as they provide a contiguous allocation of PRUs in frequency. N2 segments, called Distributed Segments, are suitable for frequency diverse allocation and are subject to an outer permutation. Contiguous Segments are not subject to an outer permutation and may not be used for DRUs

A 5-bit field Contiguous Segment Count (CSC) field determines how many segments are allocated to Contiguous Segments.. The number of PRUs allocated to Contiguous Segments is $N_{CS.,}$ where $N_{CS.}$ = 4*CSC. The remainder of the PRUs are allocated to Distributed Segments. The number of PRUs allocated to Distributed Segments is $N_{DS.,}$ where $N_{DS.} = N_{PRU.} - N_{CS}$.

PRUs are segmented and reordered into two groups distributed segment PRUs and contiguous segment PRUs, called DS-PRUs and CS-PRUs, respectively. The set of PRUs is number *0* to ($N_{PRU}$-*1*). The set of DS-PRUs are numbered *0* to ($N_{DS} - 1$). The set of DS-PRUs are numbered *0* to ($N_{CS} - 1$).

DS-PRUs are drawn from the set of PRUs to provide 4th order frequency diversity while maximizing the number of frequency contiguous CS-PRUs. The mapping of PRUs to DS-PRUs and CS-PRUs is shown in Figure 2(a) and (b), respectively. The mapping of PRUs to DS-PRUs and CS-PRUs are defined by the following formula.

$$DS\text{-}PRU_j = PRU_i \qquad \text{(Eq 1)}$$

where

$$i = \begin{cases} j & \text{for} \quad j < \left\lceil \frac{N_{DS}}{4} \right\rceil \\ j + 4\left\lfloor \frac{CSC}{3} \right\rfloor & \text{for} \quad \left\lceil \frac{N_{DS}}{4} \right\rceil \le j < \frac{N_{DS}}{2} \\ j + 4\left( CSC - \left\lfloor \frac{CSC}{3} \right\rfloor \right) & \text{for} \quad \frac{N_{DS}}{2} \le j < N_{DS} - \left\lceil \frac{N_{DS}}{4} \right\rceil \\ j + 4CSC & \text{for} \quad j \ge N_{DS} - \left\lceil \frac{N_{DS}}{4} \right\rceil \end{cases}$$

$$CS\text{-}PRU_k = PRU_i \qquad \text{(Eq 2)}$$

where

$$i = \begin{cases} k + \left\lceil \frac{N_{DS}}{4} \right\rceil & \text{for} \quad k < 4\left\lfloor \frac{CSC}{3} \right\rfloor \\ k + \frac{N_{DS}}{2} & \text{for} \quad 4\left\lfloor \frac{CSC}{3} \right\rfloor \le k < 4\left( CSC - \left\lfloor \frac{CSC}{3} \right\rfloor \right) \\ k + \left( N_{DS} - \left\lceil \frac{N_{DS}}{4} \right\rceil \right) & \text{for} \quad k \ge 4\left( CSC - \left\lfloor \frac{CSC}{3} \right\rfloor \right) \end{cases}$$

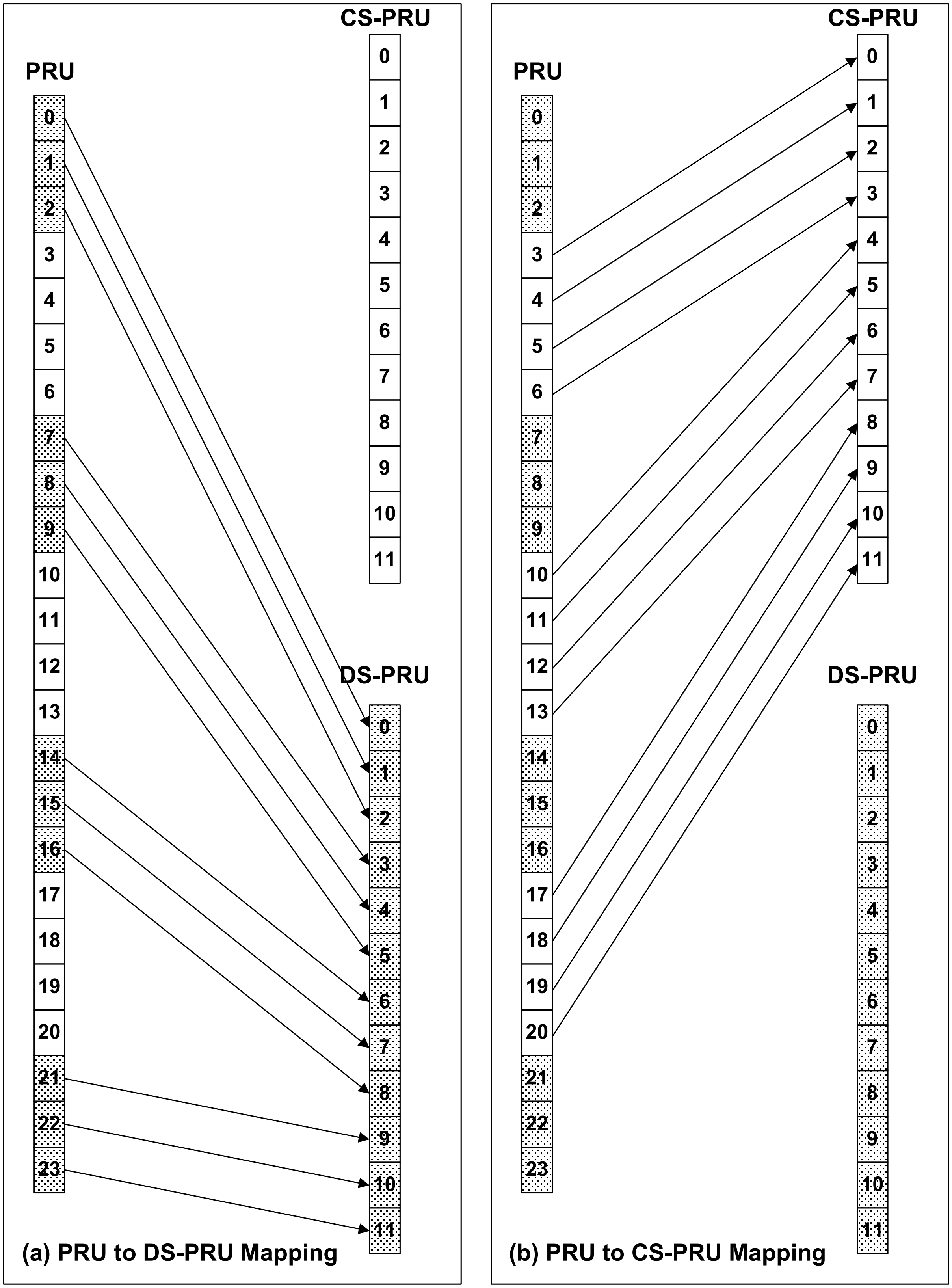


Figure 2 PRU to DS-PRU and CS-PRU mapping for BW=5 MHz, CSC=3

**15.3.6.2.3.2. Outer permutation**

The outer permutation maps the DS-PRU to Permuted DS-PRUs (P-DS-PRUs) to insure frequency diverse PRUs are allocated to each FFR partition. Equation (3) provides a mapping from PRUs to DS-PRUs which guarantees every 4 consecutive PRUs provide 4th order frequency diversity.

$$P\text{-}DS\text{-}PRU_j = DS\text{-}PRU_i \qquad \text{(Eq 3)}$$

$$\text{where} \quad i = (j \bmod 4)\frac{N_{DS}}{4} + \left\lfloor \frac{j}{4} \right\rfloor \quad for \quad j < N_{DS}$$

Other functions for the outer permutation are for further study.

Following the outer permutation of the DS-PRUs, P-DS-PRUs are concatenated with the CS-PRUs to form the Re-ordered PRUs (R-PRUs). The concatenation is captured in the following equation.

$$R \cdot PRU = \begin{cases} CS \cdot PRU_j & for \quad j < N_{CS} \\ P \cdot DS \cdot PRU_{j-N_{CS}} & for \quad j \geq N_{CS} \end{cases} \qquad \text{(Eq 4)}$$

Figure 3 depicts the concatenation of CS-PRUs with P-DS-PRUs to form R-PRUs.

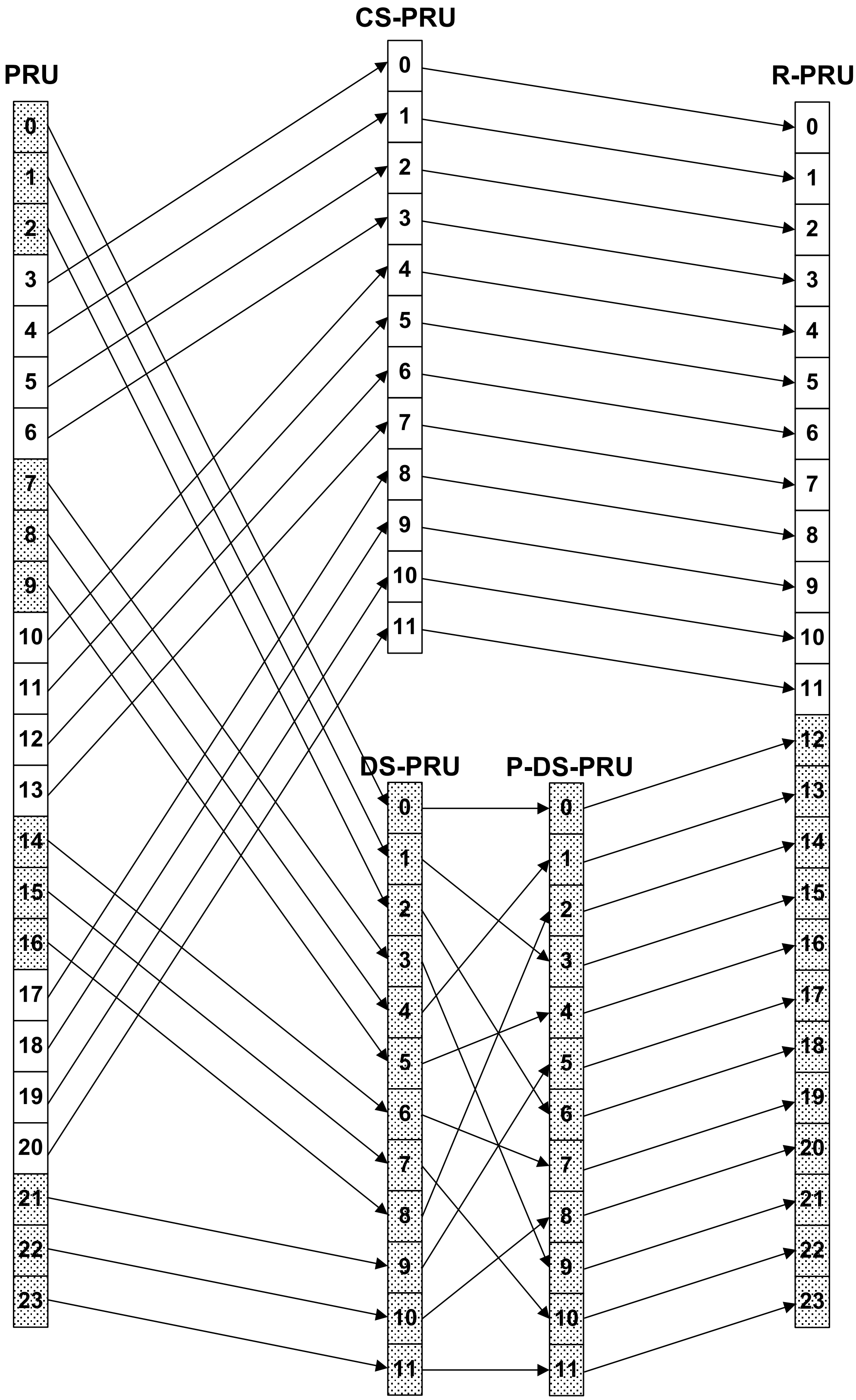


Figure 3 Mapping from PRUs to R-PRUs for BW=5 MHz, CSC=3

**15.3.6.2.3.3. FFR partitioning**

The P-PRUs are allocated to one or more FFR partitions. By default, only one partition is present. This is called the primary partition or *$FFR_0$*. Optionally, S-BCH may define one or more secondary FFR partitions. Up to 6 secondary partitions may be defined. All secondary partitions are of equal size. When present, the secondary partitions are defined by a 9-bit field transmitted in the S-BCH called the FFR Configuration. The first three bits carry a field called FFR Count (FFRC) that defines the number of secondary FFR partitions. The remaining 6 bits carry a field called FFR Size (FFRS) that defines the size of all secondary FFR partitions.

The mapping of *R-PRUs to the primary FFR permutation is governed by the following equation:*

$$FFR_i\text{-}PRU_j = R\text{-}PRU_k \text{ for } i \le FFRC$$

$$\text{where } k = \begin{cases} j & \text{for } \quad i = 0 \quad \text{and } \quad j < (N_{PRU} - FFRC \cdot FFRS) \\ j + (i-1) \cdot FFRS + (N_{PRU} - FFRC \cdot FFRS) & \text{for } \quad 0 < i \le FFRC \quad \text{and } \quad j < FFRS \end{cases}$$

Figure 4 depicts the FFR partitioning for FFRC=3, FFRS=3, BW=5 MHz and CSC=3.

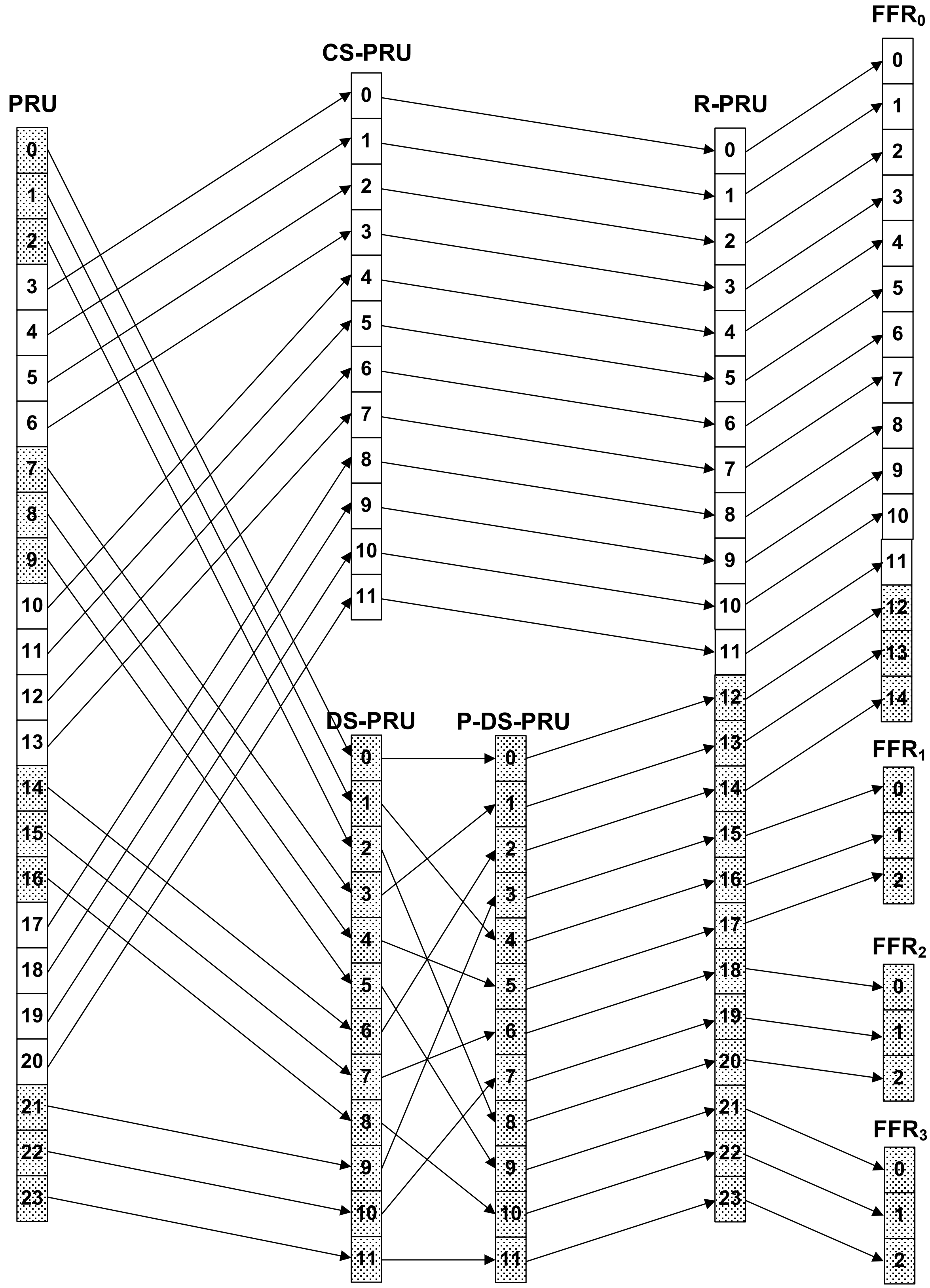


Figure 4 FFR partitioning

### 15.3.6.2.4. Partition subchannelization

$FFR_i$-PRUs will be mapped to logical LRUs. All further PRU and subcarrier permutation will be constrained to the PRUs within the FFR partition.

#### 15.3.6.2.4.1. Secondary permutation

The $FFR_i$-PRUs may be permuted on a sector specific basis. The primary FFR partition, $FFR_0$, is never permuted by a secondary permutation. Permutation of the secondary permutation will be signaled by a 1-bit secondary permutation field in the S-BCH.

The secondary permutation of $FFR_i$-PRUs will be governed by the following equation:

$$P\text{-}FFR_i\text{-}PRU_j = FFR_i\text{-}PRU_k \text{ for } 0<i \leq FFRC$$

*where k =f(Cell ID)*

The PRU permutation function, *f(x)*, is FFS.

#### 15.3.6.2.4.2. CRU/DRU allocation

The partition between CRUs and DRUs is done on a sector specific basis. By default, all P-FFR-PRUs are allocated to CRUs. DRU allocation is signaled in two step process. A 1-bit field Tile-Based Permutation Enabled bit in the P-BCH signals that DRU tile-based permutations are enabled. A 12-bit DRU allocation field in the S-BCH signals the allocation of PRUs in the primary and all secondary permutations. The DRU allocation field is sub-divided into a Primary DRU allocation field and a secondary DRU allocation field. The primary DRU allocation field, $DRU_{primary}$, is 6 bits long and signals how many DRUs are allocated in the primary FFR partition. The secondary DRU allocation field, $DRU_{secondary}$, is also 6 bits long and signal how many DRUs are in the secondary FFR partition.

The following equations map the P-FFR-PRUs to FFR-DRUs and FFR-CRUs when DRU tone-based PRUs are enabled.:

$$FFR_i \bullet CRU_j = \begin{cases} P \cdot FFR_0 \cdot PRU_j & \text{for} \quad i = 0 \quad \text{and} \quad j < N_{PRU} - FFRC \cdot FFRS - DRU_{primary} \\ P \cdot FFR_i \cdot PRU_j & \text{for} \quad 0 < i < FFRC \quad \text{and} \quad j < FFRS - DRU_{secondary} \end{cases}$$

$$FFR_i \cdot DRU_j = P \cdot FFR_i \cdot PRU_k$$

where

$$k = \begin{cases} j + \left(N_{PRU} - FFRC \cdot FFRS - DRU_{primary}\right) & \text{for} \quad i = 0 \quad \text{and} \quad 0 \leq j < DRU_{primary} \\ j + \left(FFRS - DRU_{secondary}\right) & \text{for} \quad 0 < i \leq FFRC \quad \text{and} \quad 0 \leq j < DRU_{secondary} \end{cases}$$

#### 15.3.6.2.4.3. DRU inner permutation

The inner permutation defined for the DL distributed resource allocations within a frequency partition spreads the subcarrriers of the LRU across the whole distributed resource allocations. The granularity of the inner permutation is equal to a pair of tones.

After mapping all pilots, the remainders of the used subcarriers are used to define the data subchannel. To allocate the data subchannels, the remaining subcarriers are paired into contiguous tone-pairs. Each subchannel consists of a group of tone-pairs. The exact partitioning of tone-pairs into subchannels is FFS.

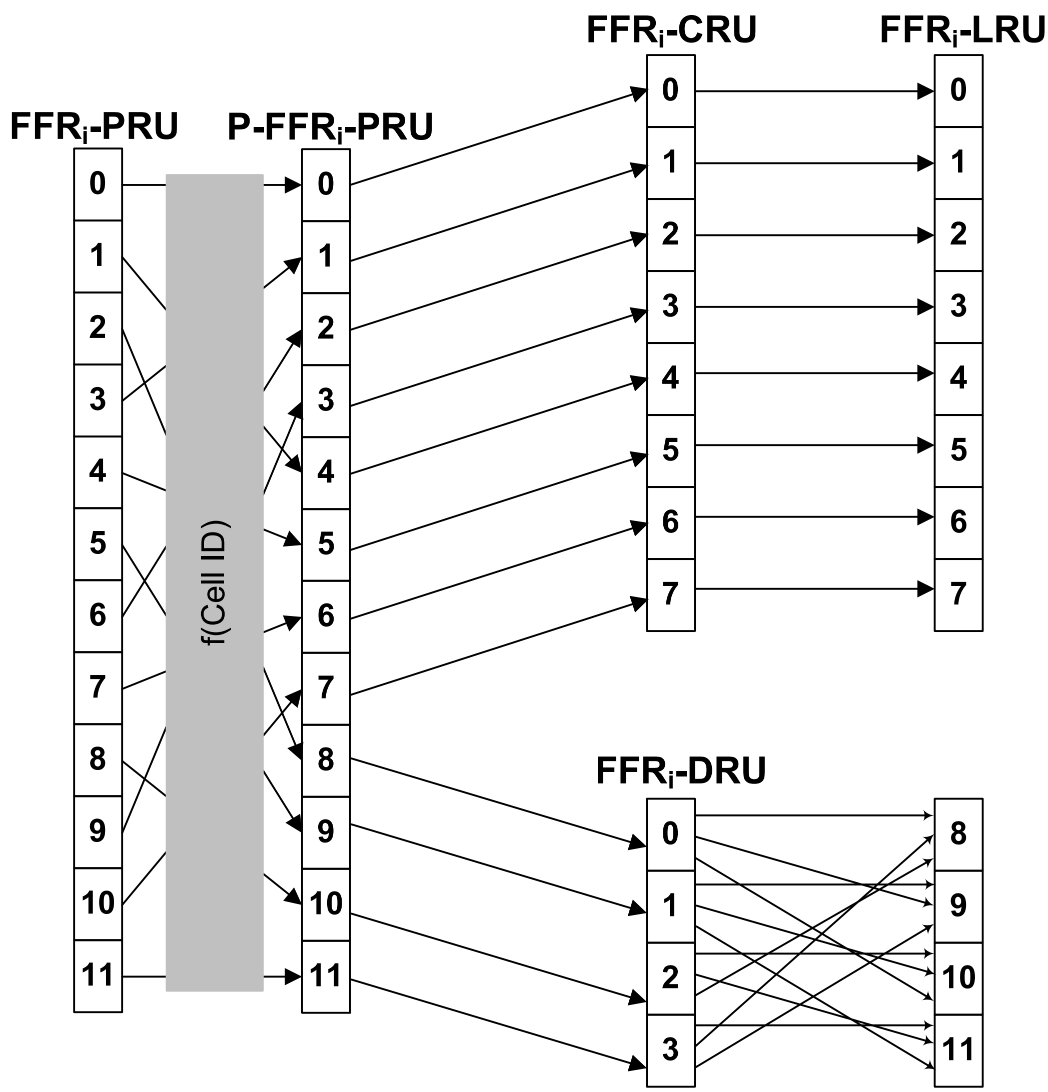


Figure 5 Partition subchannelization

### 15.3.6.3. Pilot Structure

The transmission of pilot subcarriers in the uplink is necessary for enabling channel estimation, measurements of SINR, frequency and time offset estimation, etc. 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.

Pilot structure for each tile structure used for distributed LRUs and for contiguous LRUs are shown in from Figure 5 to Figure 6. Figure 5 shows the pilot structure for contiguous LRU when the number of stream is one, two and four. Note that the pilot pattern for UL contiguous LRUs are same to the downlink case. Figure 6 is used for distributed LRUs when the number of stream is one and two.

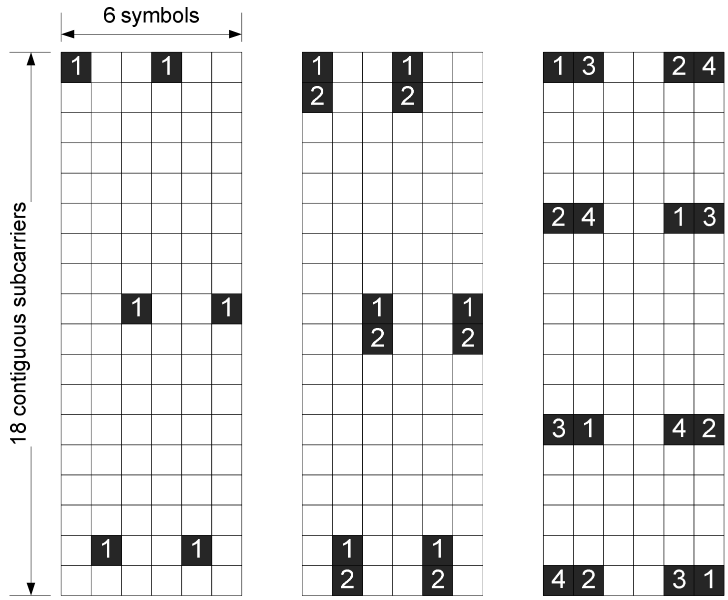


Figure 5 – Pilot patterns for localized-LRUs in case of 1 Tx, 2 Tx and 4 Tx

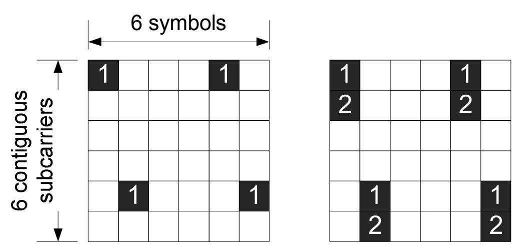


Figure 6 – Pilot patterns for distributed-LRUs in case of 1 Tx and 2 Tx

### 15.3.6.4. 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 [1], a new symbol structure and subchannelization defined in this section are used.

#### 15.3.6.4.1. 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 $N_{basic}$ used subcarriers. The DC subcarrier is not loaded. The $N_{basic}$ subcarriers are divided into multiple PUSC tiles.

In particular case, the subcarriers once reserved for guard band can be used for the data transmission. The number of data subcarriers used in data region symbol is $N_{used}=N_{basic}+n_1+n_2$ where $N_{basic}$ is the number of data subcarriers without using the guard band subcarriers and, $n_1$ and $n_2$ are additional available subcarriers used in left and right guard band respectively, which are given by [DL broadcasting control message] in *z.z.z*. MS shall perform UL PUSC permutation for $N_{basic}$ data subcarriers first and then consider $n_1$, $n_2$ additionally. Basic symbol structures for various bandwidths are shown in from Table 1 to Table 3.

Table 1 – 512 FFT OFDMA UL subcarrier allocations for DRU in PUSC-compatible zone

| Parameters | Value | Comments |
|---|---|---|
| Number of DC subcarriers | 1 | Subcarrier index 204 |
| Guard subcarrier: $N_{g,left}$, $N_{g,right}$ | 52, 51 | |
| Number of total used subcarriers ($N_{used}$) | 409 | Number of all subcarriers used in WirelessMAN-OFDMA PUSC zone within a symbol, including DC carrier |

Table 2 – 1024 FFT OFDMA UL subcarrier allocations for DRU in PUSC-compatible zone

| Parameters | Value | Comments |
|---|---|---|
| Number of DC subcarriers | 1 | Subcarrier index 420 |
| Guard subcarrier: $N_{g,left}$, $N_{g,right}$ | 92, 91 | |
| Number of total used subcarriers ($N_{used}$) | 841 | Number of all subcarriers used in WirelessMAN-OFDMA PUSC zone within a symbol, including DC carrier |

Table 3 – 2048 FFT FFT OFDMA UL subcarrier allocations for PUSC-compatible zone

| Parameters | Value | Comments |
|---|---|---|
| Number of DC subcarriers | 1 | Subcarrier index 840 |
| Guard subcarrier: $N_{g,left}$, $N_{g,right}$ | 160, 159 | |
| Number of total used subcarriers ($N_{used}$) | 1681 | Number of all subcarriers used in WirelessMAN-OFDMA PUSC zone within a symbol, including DC carrier |

#### 15.3.6.4.2. Resource unit structure for FDM based UL PUSC zone support

When supporting FDM based UL PUSC zone, a tile consists of 4 consecutive subcarriers and $N_{sym}$ OFDMA symbols depending on the subframe type. A tile structure and pilot pattern for 6 symbol-subframe is shown in Figure 7.

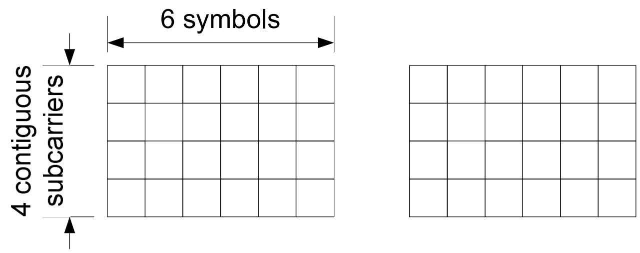


Figure 7 – Tile structure and pilot pattern for FDM based UL PUSC zone Support

(Pilot pattern is TBD)

### 15.3.6.4.3. Subchannelization for FDM based UL PUSC Zone Support

The subchannelization for the FDM based UL PUSC 16m tiles is FFS.

### 15.3.6.4.4. Frame Structure for FDM based UL Band AMC Zone Support

In supporting WirelessMAN-OFDMA UL band AMC, 802.16m adopts same numerology of OFDMA subcarrier allocation as the WirelessMAN-OFDMA UL band AMC. The numerology includes total number of used subcarriers, left and right guard subcarriers.

In Fig. 9, the portion of WirelessMAN-OFDMA UL band AMC contains one or several WirelessMAN-OFDMA bands. The portion of 16m UL contains one or several distributed LRUs, localized LRUs, or a mixture of them.

In supporting the legacy system, the first UL subframe is concatenated with the second UL subframe. The first portion (3 OFDM symbols) of the first UL subframe is allocated for WirelessMAN-OFDMA UL control channels with PUSC subchannelization. The remaining portion (3 OFDM symbols) of the first UL subframe and the second UL subframe are concatenated to form a UL subframe with 9 OFDM symbols. This concatenated subframe is for FDM the 802.16m and the WirelessMAN-OFDMA UL Band AMC.

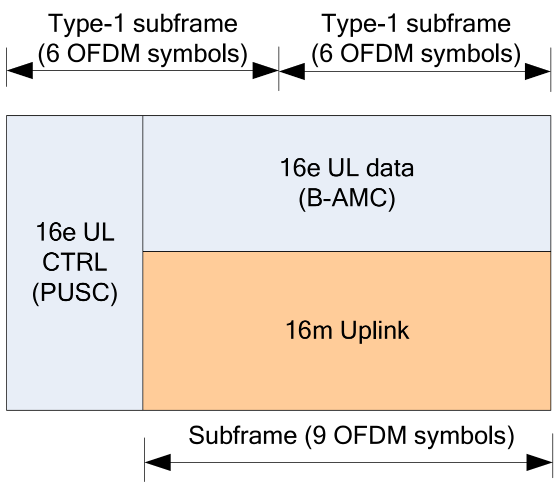

Figure 9 – Frame Structure for FDM based coexistence of 802.16m and WirelessMAN-OFDMA UL Band AMC

### 15.3.6.4.5. Subchannelization for FDM based UL AMC Zone Support

The subchannelization for the FDM based UL AMC 16m tiles is FFS.

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