Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>	
Title	**PHY Structure text for the IEEE 802.16m Amendment**	
Date Submitted	**2008-12-19**	
Source(s)	Mark Cudak TGm Drafting Group Chair HanGyu Cho, Jong-Kae (JK) Fwu, Taeyoung Kim, Richard Li, Xin Qi, Guan Yanfeng TGm Drafting Group	Voice: +1 847 632 3160 E-mail: mark.cudak@motorola.com
Re:	Consolidation of contributions submitted in response to call IEEE 802.16m-08/042, “Call for Contributions on Project 802.16m Draft Amendment Content” providing text for the topic of “Downlink Physical Structure”	
Abstract	The contribution provide PHY structure text for the IEEE 802.16m amendment. Highlighted text is not agreed and will not be included in the draft.	
Purpose	To be incorporated into the initial IEEE 802.16 amendment as directed in Session 58	
Notice	*This document does not represent the agreed views of the IEEE 802.16 Working Group or any of its subgroups*. It represents only the views of the participants listed in the “Source(s)” field above. It is offered as a basis for discussion. It is not binding on the contributor(s), who reserve(s) the right to add, amend or withdraw material contained herein.	
Release	The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE’s name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE’s sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.	
Patent Policy	The contributor is familiar with the IEEE-SA Patent Policy and Procedures: <http://standards.ieee.org/guides/bylaws/sect6-7.html#6> and <http://standards.ieee.org/guides/opman/sect6.html#6.3>. Further information is located at <http://standards.ieee.org/board/pat/pat-material.html> and <http://standards.ieee.org/board/pat>.	

PHY Structure text for the IEEE 802.16m Amendment

Mark Cudak, HanGyu Cho, Jong-Kae (JK) Fwu, *Taeyoung Kim, Richard Li, Xin Qi, Guan Yanfeng*
TGm Drafting Group

1. Introduction

This contribution is the output of the TGm drafting group that has worked to consolidate contributions that have provided detailed Stage 3 text on DL PHY Structure and UL PHY Structure.

2. Outline

The following is the high level outline of the DL PHY structure:

```
15.3.5. Downlink physical structure
15.3.5.1 Physical and Logical Resource Unit
15.3.5.1.1 Distributed Resource Unit
15.3.5.1.2 Contiguous Resource Unit
15.3.5.2 Multi-cell Resource Mapping
15.3.5.2.1. Subband partitioning
15.3.5.2.2. Miniband permutation
15.3.5.2.3. Frequency partitioning
15.3.5.3 Cell-Specific Resource Mapping
15.3.5.3.1. CRU/DRU allocation
15.3.5.3.2. Secondary permutation
15.3.5.3.3. Subcarrier permutation
```

3. Contribution List

The following contributions were identified as containing detailed DL PHY Structure text:

Section 5 Source Document Authors	Section 5 Source Document Reference
Mark Cudak, et. al.	IEEE C802.16m-08/1441
J. K. Fwu, et. al.	IEEE C802.16m-08/1443r2
Guan Yanfeng, et. al.,	IEEE C802.16m-08/1448r1
Lai-Huei Wang, et. al.	IEEE C802.16m-08/1449r1
Xin Qi, et. al.	IEEE C802.16m-08/1450r1
Taeyoung Kim, et. al.	IEEE C802.16m-08/1464r3
HanGyu Cho, et. al	IEEE C80216m-07/1466r1

Text proposal for inclusion in the 802.16m amendment

------------------------------- Text Start ---

Insert a new section 15:

15. Advanced Air Interface

15.3. Physical layer

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 15.3.5.1 illustrates the downlink physical structure in the example of two frequency partitions with frequency partition 2 including both contiguous and distributed resource allocations.

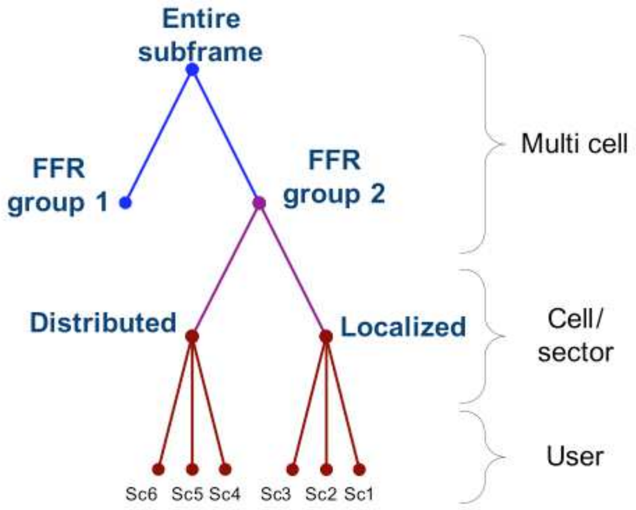


Figure 1 – Example of downlink physical structure

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 $P_{sc} \bullet N_{sym}$ subcarriers for type-1 subframes and type-2 subframes. The LRU includes the pilots in 15.3.5.3 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., Psc subcarriers by Nsym OFDMA symbols. The minimum unit for forming the DRU is equal to a pair of subcarriers, called tone-pair, as defined in 15.3.5.2.3.1.

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., Psc subcarriers by Nsym 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 [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 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 $L_{SB} = N_1 * K_{SB}$. 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 $L_{MB} = N_2 * K_{MB}$. The total number of PRUs is denoted as N_{PRU} where $N_{PRU} = L_{SB} + L_{MB}$. [The mapping of the BCH is FFS and may be incorporated in the partitioning process.]

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 1 defines the mapping of PRUs to PRU_{SB}s. Equation 2 defines the mapping of PRUs to PRU_{MB}s. Figure 2 illustrates the PRU to PRU_{SB} and PRU_{MB} mapping for a 5 MHz bandwidth with SAC equal to 3.

$$PRU_{SB}[j] = PRU[i], \qquad j = 0,1,\ldots,L_{SB}-1, \text{ .... Eqn. (1)}$$

[Editor's note: following option is proposed in 1441]

$$\text{where } i = \begin{cases} k + \left\lceil \dfrac{L_{MB}}{4} \right\rceil & for \quad k < 4\left\lfloor \dfrac{SAC}{3} \right\rfloor \\ k + \dfrac{L_{MB}}{2} & for \quad 4\left\lfloor \dfrac{SAC}{3} \right\rfloor \le k < 4\left(SAC - \left\lfloor \dfrac{SAC}{3} \right\rfloor \right) \\ k + \left(L_{MB} - \left\lceil \dfrac{L_{MB}}{4} \right\rceil \right) & for \quad k \ge 4\left(SAC - \left\lfloor \dfrac{SAC}{3} \right\rfloor \right) \end{cases}$$

[Editor's note: following option is proposed in 1443r2…]

In Option 1:

Let N_{sub} be the maximum number of subbands that can be formed and $N_{sub} = N_{PRU} / N_1$.

$$i = PermUniform\left(N_{sub}, K_{SB} \;; \lfloor j / N_1 \rfloor\right) \; N_1 + \{j\} \bmod N_1 , \; ,$$

where $PermUniform(L, K; \;\cdot)$ is a permutation function whose K elements are chosen evenly among all L elements:

$$PermUniform(L, K; \; i) = \begin{cases} \left\{ i \left\lceil \frac{L}{K} \right\rceil + \left\lfloor \frac{i}{L} GCD\left(L, \lceil L / K \rceil \right) \right\rfloor \right\} \bmod(L) & K > 0 \\ i & K = 0 \end{cases} , \; .$$

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

In Option 2:

$$i = \begin{cases} \lfloor j / N_1 \rfloor N_2 \lceil N_{PRU} /(N_2 * K_{SB}) \rceil + \{j\} \bmod(N_1) & for \quad j < (\{N_{PRU} / N_2\} \mathrm{m} \\ \lfloor j / N_1 \rfloor N_2 \lfloor N_{PRU} /(N_2 * K_{SB}) \rfloor + \{j\} \bmod N_1 + (\{N_{PRU} / N_2\} \bmod(K_{SB})) N_2 & for \quad j \geq (\{N_{PRU} / N_2\} \mathrm{m} \end{cases}$$

[Editor's note: following option is proposed in 1464r3…]

$$i = N_1 \cdot N_{dist} \cdot \left(\left\lfloor \frac{j}{N_1} \right\rfloor \bmod \frac{N_{sub}}{N_{dist}} \right) + N_1 \cdot \left\lfloor \frac{N_{dist}}{N_{sub}} \cdot \frac{j}{N_1} \right\rfloor + \left(j \bmod N_1 \right) , \qquad \text{(Eq. 2)}$$

where

where

$$N_{dist} = \begin{cases} 2, & \left\lfloor \frac{N_{sub}}{N_{res}} \right\rfloor == 1 \\ \left\lfloor \frac{N_{sub}}{N_{res}} \right\rfloor, & otherwise \end{cases} .$$

and $N_{res} = \begin{cases} 4, & K_{SB} < 4 \\ K_{SB}, & otherwise \end{cases}$.

[Editor's note: following option is proposed in 1466r1]

where

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

where .

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

[Editor’s note: following option is proposed in 1448r1]

$$i = N_1 \cdot \left(n \cdot \left(\left\lfloor \frac{j}{N_1} \right\rfloor \bmod m \right) + \left\lfloor \frac{\left\lfloor \frac{j}{N_1} \right\rfloor}{m} \right\rfloor \right) + \left(j \bmod N_1 \right), \quad j = 0, 1, \ldots, L_{SB} - 1$$

where $N_{sub} = \left\lfloor \frac{N_{PRU}}{N_1} \right\rfloor, n = \left\lceil \frac{N_{Sub}}{K_{SB}} \right\rceil, m = \left\lceil \frac{N_{Sub}}{n} \right\rceil, \ \lfloor x \rfloor = floor(x), \ \lceil x \rceil = ceil(x)$

$$PRU_{MB}[k] = PRU[i], \qquad k = 0, 1, \ldots, L_{MB} - 1, \ \ldots\ldots\ldots\ldots\ldots\ldots \text{ Eqn. (2)}$$

[Editor’s note: following option is proposed in 1441]

where $$i = \begin{cases} j & for \quad j < \left\lceil \frac{L_{MB}}{4} \right\rceil \\ j + 4\left\lfloor \frac{SAC}{3} \right\rfloor & for \quad \left\lceil \frac{L_{MB}}{4} \right\rceil \le j < \frac{L_{MB}}{2} \\ j + 4\left(SAC - \left\lfloor \frac{SAC}{3} \right\rfloor \right) & for \quad \frac{L_{MB}}{2} \le j < L_{MB} - \left\lceil \frac{L_{MB}}{4} \right\rceil \\ j + 4SAC & for \quad j \ge L_{MB} - \left\lceil \frac{L_{MB}}{4} \right\rceil \end{cases}$$

[Editor’s note: following option is proposed in 1443r2…]

where

In Option 1:

$$i = PermUniform\left(N_{sub}, K_{SB};\ \ K_{SB} + \lfloor k / N_1 \rfloor\right)\ \ N_1 + \{k\} \bmod N_1$$

In Option 2:

After PRU_{SB} are selected, the remaining PRUs are renumbered and assigned as PRU_{MB} without reordering.

[Editor's note: following option is proposed in 1448r1…]

$$i = \begin{cases} N_1 \cdot \left(n \cdot \left(\left\lfloor \dfrac{k + L_{SB}}{N_1} \right\rfloor \bmod m \right) + \left\lfloor \dfrac{\left\lfloor \dfrac{k + L_{SB}}{N_1} \right\rfloor}{m} \right\rfloor \right) + \left((k + L_{SB}) \bmod N_1 \right), & k = 0, 1, \ldots, L_{MB} - (N_{PRU} \bmod N_1) - 1 \\ k + L_{SB}\ , & k = L_{MB} - (N_{PRU} \bmod N_1), \ldots, L_{MB} - 1, (N_{PRU} \bmod N_1) > 0 \end{cases}$$

where $N_{sub} = \left\lfloor \dfrac{N_{PRU}}{N_1} \right\rfloor, n = \left\lceil \dfrac{N_{Sub}}{K_{SB}} \right\rceil, m = \left\lceil \dfrac{N_{Sub}}{n} \right\rceil\ ,\ \lfloor x \rfloor = floor(x),\ \lceil x \rceil = ceil(x)$

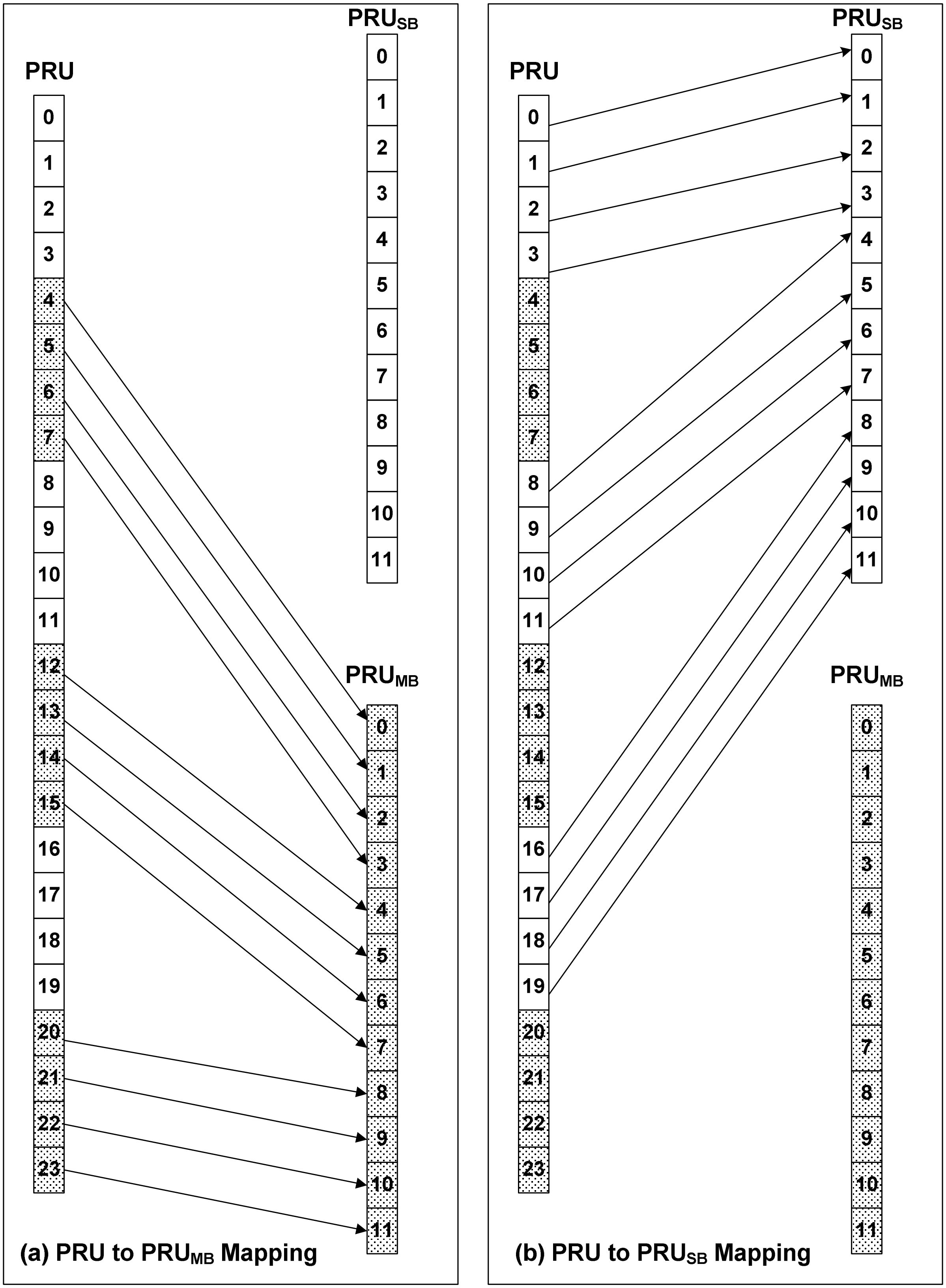
[Editor's note: following option is proposed in 1464r3…]

where the relationship equation between *i* and *k* is same as the equation (1) except for $j = k + L_{SB}$.

[Editor's note: following option is proposed in 1466r1]

where

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



(a) PRU to PRU$_{MB}$ Mapping

(b) PRU to PRU$_{SB}$ Mapping

Figure 2 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 (3) provides a mapping from PRU_{MB} to $PPRU_{MB}$s

$$PPRU_{MB}[j] = PRU_{MB}[i], \qquad j = 0,1,\ldots,L_{MB}-1 \qquad \text{Eqn} \quad 3$$

[Editor's note: following option is proposed in 1441]

where $i = (j \bmod 4)\dfrac{L_{MB}}{4} + \left\lfloor \dfrac{j}{4} \right\rfloor \quad for \quad j < L_{MB}$

[Editor's note: following option is proposed in 1443r2…]

where

$$i = PermSeq(\lfloor j/N_2 \rfloor)\ \ N_2 + \{j\} \bmod N_2$$

and $PermSeq$ (k) is the k-th elelment of the S-Random permutation sequence of length L_{MB} from Table 15.3.5.1. Sequences of different length are tabulated in Table 15.3.5.1

[Editor's note: following option is proposed in 1448r1…]

$$i = \begin{cases} n \cdot (j \bmod m) + \left\lfloor \dfrac{j}{m} \right\rfloor, & j = 0,1,\ldots,L_{MB} - (L_{MB} \bmod N_2) - 1 \\ j, & j = L_{MB} - (L_{MB} \bmod N_2),\ldots,L_{MB} - 1 \end{cases}$$

where $n = \dfrac{L_{MB} - (L_{MB} \bmod N_2)}{N_2 \cdot m}$

[Editor's note: following option is proposed in 1449r1…]

where

$$i = (q(j) \bmod D) \cdot (FFRC + 1) + \left\lfloor \frac{q(j)}{D} \right\rfloor, \quad j = 0,1,...,L_{MB} - 1$$

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

$$r(j) = \max(j - (L_{MB} \bmod (FFRC+1)) \cdot D, 0),$$

$$D = \left\lfloor \frac{L_{MB}}{FFRC+1} + 1 \right\rfloor$$

[Editor's note: following option is proposed in 1464r3…]

where $i = \frac{N_1}{N_2}\times\left(\left\lfloor\frac{j}{N_2}\right\rfloor \bmod K_{MB}\right) + \mathrm{BRO}_{\log_2(\frac{N_1}{N_2})}\left(\left\lfloor\frac{\lfloor j/N_2\rfloor}{K_{MB}}\right\rfloor\right)$

where $\mathrm{BRO}_k(y)$ indicates the bit-reversed k-bit value of y (i.e., $\mathrm{BRO}_3(6)=3$).

[Editor's note: following option is proposed in 1466r1…]

where

$$i = N_2\cdot\{FPCT\cdot\left\lfloor\frac{j}{N_2}\right\rfloor + \left\lfloor\left\lfloor\frac{j}{N_2}\right\rfloor\cdot\frac{GCD(K_{MB},FPCT)}{K_{MB}}\right\rfloor\}\bmod K_{MB} + j \bmod N_2.$$

where *FPCT* denotes the number of frequency partitions.

Figure 3 depicts the mapping from PRUs to PRU_{SB} and PPRU_{MB}.

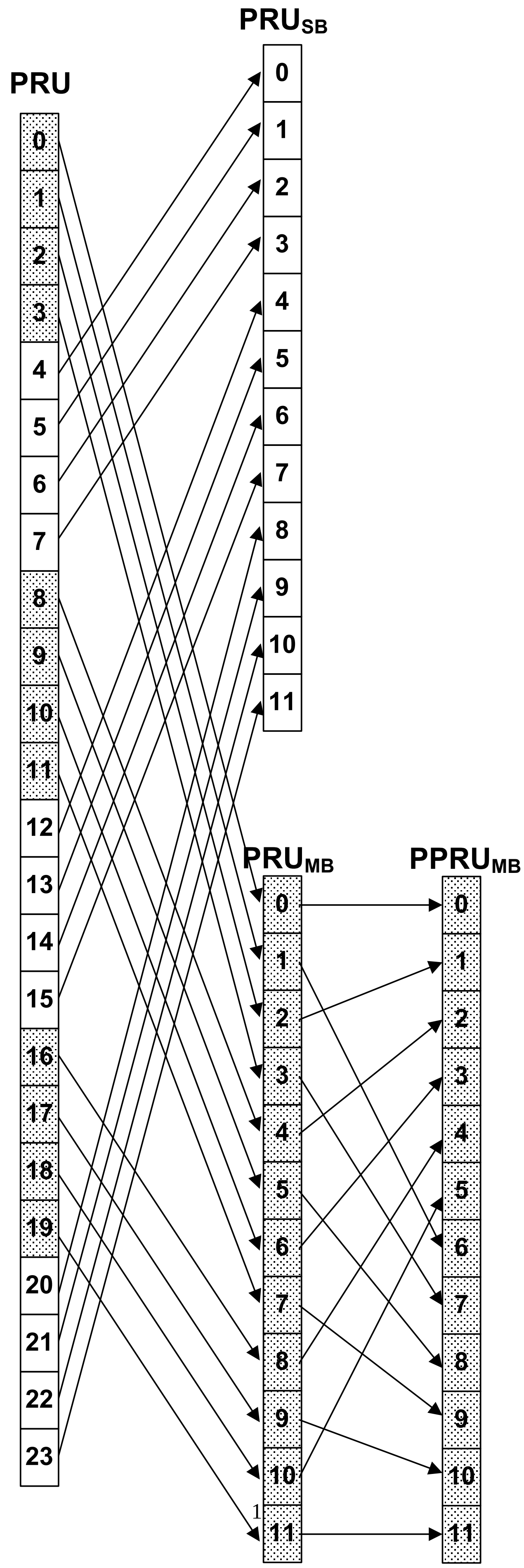

PRU
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
PRU_SB
0
1
2
3
4
5
6
7
8
9
10
11
PRU_MB
0
1
2
3
4
5
6
7
8
9
10
11
PPRU_MB
0
1
2
3
4
5
6
7
8
9
10
11

Figure 3 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 FPi, i>0 in the number of minibands (N2). The remaining 4 bits carry FPSC that define the number of subbands allocated to FPi, 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 $L_{SB,FPi} = N_1 * K_{SB,FPi}$. The number of miniband PRUs in each frequency partition is denoted by $L_{MB,FPi}$, which is given by $L_{MB,FPi} = N_2 * K_{MB,FPi}$.

$$\mathrm{K}_{\mathrm{SB,FPi}} = \begin{cases} SAC - (FPCT - 1) \cdot FPSC & i = 0 \\ FPSC & i > 0 \end{cases}$$

$$\mathrm{K}_{\mathrm{MB,FPi}} = \begin{cases} K_{MB} - (FPCT - 1) \cdot (FPS - \dfrac{FPSC \cdot N1}{N2}) & i = 0 \\ FPS - \dfrac{FPSC \cdot N1}{N2} & i > 0 \end{cases}$$

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

$$PRU_{FPi}(j) = \begin{cases} PRU_{SB}(k_1) & \text{for } 0 \le j < L_{SB,FPi} \\ PPRU_{MB}(k_2) & \text{for } L_{SB,FPi} \le j < (L_{SB,FPi} + L_{MB,FPi}) \end{cases} \qquad \textbf{\textit{(Eq 6)}}$$

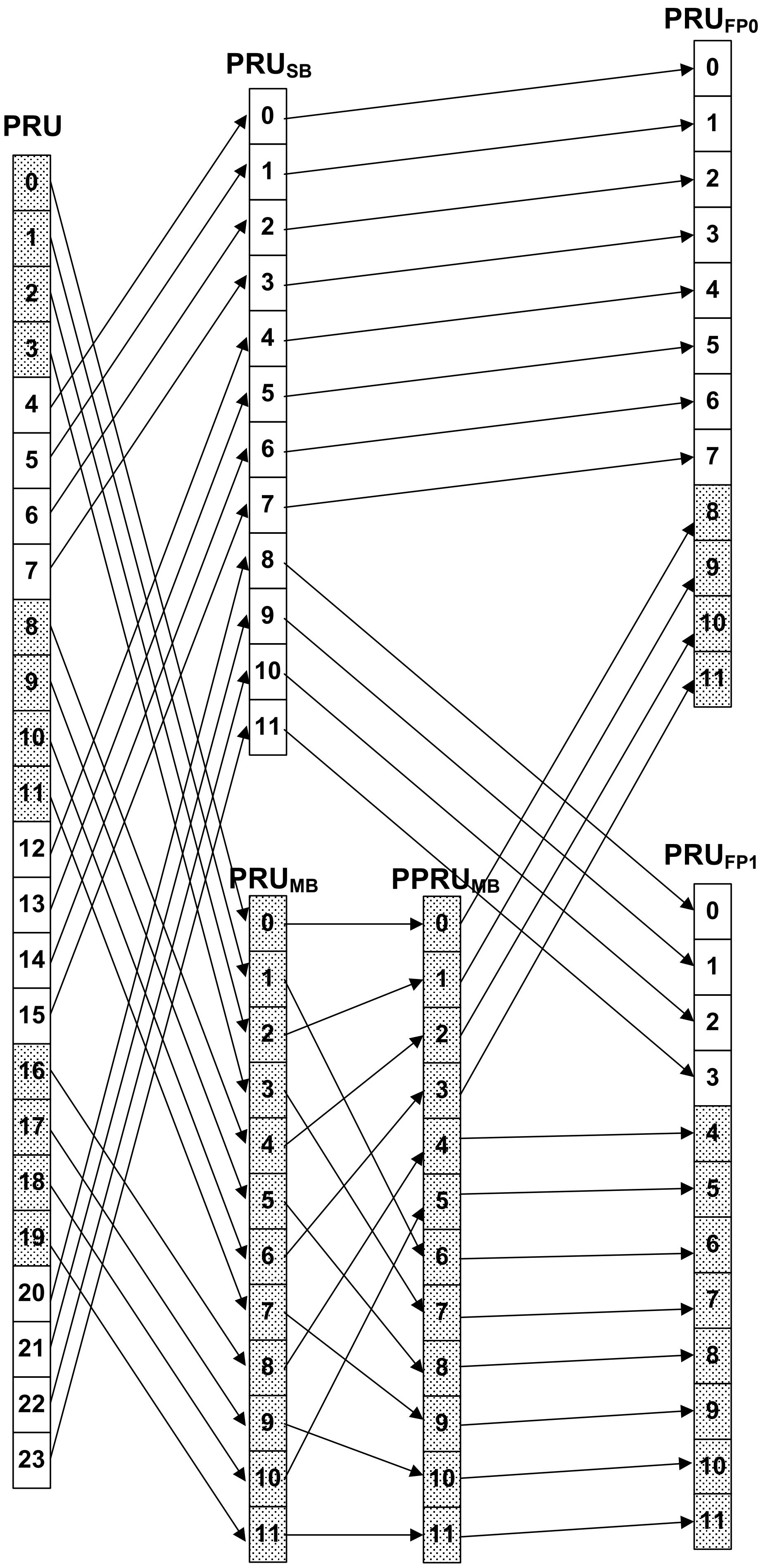
where

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

and

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

Figure 4 depicts the frequency partitioning BW=5 MHz, SAC=3, FPCT=2, FPS=12 and FPSC=1.


PRU
PRU$_{SB}$
PRU$_{FP0}$
PRU$_{MB}$
PPRU$_{MB}$
PRU$_{FP1}$
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

1

Figure 4 Frequency partitioning

15.3.5.3. Cell-specific resource mapping

PRU_{FPi}s will be mapped to LRUs. All further PRU and subcarrier permutation will be constrained to the PRUs

15.3.5.3.1. CRU/DRU allocation

The partition between CRUs and DRUs is done on a sector specific basis. DRU allocation is signaled in two step process.

There are four possible pre-configured allocations signaled in two bits:

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

When explicit mapping is indicated, additional 4-bit (TBD) CRU allocation size (CAS) field is sent in the BCH for each allocated frequency partition. CASi indicated the number of allocated CRUs for partition FPi in a unit of subband size.

The number of **C**RUs in each frequency partition is denoted by $L_{CRU,FPi.}$, where

$$L_{CRU,FPi} = CAS_i * N1 \text{ for } 0 \le i < FPCT$$

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

$$L_{DRU,FPi} = FPS_i * N2 - CAS_i * N1 \text{ for } 0 \le i < FPCT$$

The mapping of PRU_{FPi} to

$$CRU_{FPi}[j] = PRU_{FPi}[j], \; for \quad 0 \le i < FPCT, \quad and \quad 0 \le j < L_{CRU,FPi}$$

$$DRU_{FPi}[j] = PRU_{FPi}[j + L_{CRU,FPi}], \; for \quad 0 \le i < FPCT, \quad and \quad 0 \le j < L_{DRU,FPi}$$

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 the following equation:

TBD (eq X)

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 tones.

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

Let $L_{pair,l}$ denote the number of tone-pairs in *l*-th OFDMA symbol within a PRU, i.e., $L_{pair,l} = (Psc - n_l)/2$, where n_l denotes the number of pilot tones in the *l*-th OFDMA symbol within a PRU. A permutation sequence *PermSeq( )* is defined by [a lookup table][a sequence generation algorithm] 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 PRU as described in section (TBD)

2. Renumber the remaining $L_{DRU, FP,i} *(Psc - n_l)$ data subcarriers in order, from 0 to $L_{DRU, FPi} (Psc - n_l) -1$. Group these contiguous and logically renumbered subcarriers into $L_{DRU, FPi} * L_{pair,l}$ pairs and renumber them from 0 to $L_{DRU, FP,i} *L_{pair,l}$-1. . The renumbered tone pairs in the *l*-th OFDMA symbol are denoted by $RTP_{FPi,l}$.

3. Apply the subcarrier permutation formula (eqn. subcarrier_perm) to form the permuted tone-pairs 0 to $L_{DRU, FP,i} *L_{pair,l}$-1.

4. Map logically contiguous tone-pairs $[i* L_{pair,l},\ (i+1)*L_{pair,l}-1]$ into the *i*-th distributed LRUs, $i=0,1,\ldots, L_{DRU, FPi} -1$.

For the *s*-th distributed LRU of the *t*-th subframe, the subcarrier permutation formula is given by

$$pair(s,m,l,t)= L_{DRU, FP,i} *f(m,s)+g(PermSeq(),s,m,l,t),\ l = 0, 1,\ldots, N_{sym} \qquad Eqn(\text{subcarrier\_perm})$$

where *pair(s,m,l,t)* is the tone-pair index of the *m*-th tone-pair ($(0<=m< L_{pair,l})$) 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 ($0<=s < L_{DRU, FP,i}$), *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 $[0, L_{pair,l} -1]$

The following is proposed by proposed in 1443r2

$$f(m,s) = \{m + 13s\} \bmod L_{pair,l}$$

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

where PermSeq is the sequence of length $L_{DRU,\ FPi}$ specified in Table 15.3.5.1. and *DL_PermBase* is an integer ranging from 0 to 31 (TBD), which is set to preamble IDCell or specified by the SBCH.

Table 15.3.5.1 Permutation sequences (*PermSeq*) of different lengths

Size (N)	Permutation Sequence (*PermSeq*)
4	3 1 4 2
5	1 4 2 5 3
6	1 3 5 2 4 6
7	1 3 5 2 7 4 6
8	1 6 3 7 2 5 8 4
9	7 4 1 8 5 2 9 6 3
10	1 4 7 10 3 6 9 2 5 8
11	1 9 6 3 11 8 5 2 10 7 4
12	1 7 4 11 8 5 2 12 9 3 6 10
13	1 11 8 3 13 6 10 2 5 9 12 4 7
14	1 13 7 4 14 8 11 3 6 10 2 5 12 9
15	1 7 4 12 8 15 3 11 6 14 9 5 2 10 13
16	13 9 5 1 14 10 6 2 15 11 7 3 16 12 8 4
17	5 1 9 13 17 4 8 12 16 3 7 11 15 2 6 10 14
18	1 18 14 10 6 2 15 11 7 3 16 12 8 4 17 13 9 5
19	1 16 12 8 4 17 13 9 5 18 14 10 2 6 19 11 15 7 3
20	1 7 12 16 20 5 10 14 18 3 9 13 17 2 6 11 19 15 4 8
21	1 7 11 15 19 4 8 12 16 20 5 9 13 17 2 6 21 10 14 3 18
22	1 6 15 19 11 7 3 16 12 8 20 2 14 10 21 5 17 9 13 22 18 4
23	1 10 5 21 17 9 13 4 23 19 11 15 7 2 20 16 12 6 22 18 14 3 8

24	1 6 17 12 21 8 3 15 19 7 11 23 2 16 10 20 24 5 13 18 22 9 14 4
25	21 16 11 6 1 22 17 12 7 2 23 18 13 8 3 24 19 14 9 4 25 20 15 10 5
26	6 1 11 16 21 26 5 10 15 20 25 4 9 14 19 24 3 8 13 18 23 2 7 12 17 22
27	6 1 11 16 21 26 5 10 15 20 25 2 7 12 17 22 27 4 9 14 19 24 3 8 13 18 23
28	6 11 1 16 21 26 8 3 13 18 23 28 7 2 12 17 22 27 5 10 15 20 25 4 9 14 19 24
29	1 6 11 16 21 26 5 10 15 20 25 4 9 14 19 24 29 2 12 7 18 23 28 13 3 8 22 27 17
30	1 6 19 24 29 12 7 17 22 2 27 11 16 21 5 26 10 15 20 4 25 30 13 18 8 23 3 28 14 9
31	1 30 19 14 8 24 29 3 17 12 22 27 2 7 13 18 23 28 6 11 16 21 26 5 10 31 15 20 25 9 4
32	1 11 6 16 21 26 31 2 12 17 22 32 5 27 15 10 20 4 25 30 9 19 14 24 29 8 3 18 23 13 28 7
33	1 6 11 16 21 26 31 5 10 15 25 30 20 3 14 9 33 28 23 4 18 13 32 27 8 22 17 2 29 12 7 19 24
34	1 28 18 23 8 33 13 3 22 27 32 14 9 19 24 4 34 29 12 17 2 7 31 26 21 16 11 6 30 25 20 15 5 10
35	1 28 21 15 34 10 5 20 26 31 14 8 3 25 19 32 12 2 7 27 17 33 22 9 4 16 29 35 24 11 18 30 6 23 13
36	1 8 13 23 18 35 30 3 25 20 36 14 31 26 5 21 15 10 33 28 4 17 9 22 32 27 16 11 6 34 29 19 12 2 24 7
37	32 26 20 14 8 2 33 27 21 15 9 3 34 28 22 16 10 4 35 29 23 17 11 5 37 31 25 19 13 7 1 36 30 24 18 12 6
38	8 2 14 20 26 32 38 5 11 17 23 29 35 1 7 13 19 25 31 37 6 12 18 24 30 36 4 10 16 22 28 34 3 9 15 21 27 33
39	21 30 36 3 9 15 22 28 34 2 8 14 20 27 33 39 6 12 18 25 31 37 4 10 16 23 29 35 1 7 13 19 26 32 38 5 11 17 24
40	9 2 36 30 24 18 12 6 40 34 28 22 16 10 3 39 33 27 21 15 8 1 35 29 23 17 11 5 37 31 25 19 13 7 38

	32 26 20 14 4
41	5 37 31 13 25 19 7 39 1 33 27 21 15 40 9 34 28 22 3 16 10 35 41 29 23 17 11 4 36 30 24 18 12 6 38 32 26 20 14 2 8
42	1 8 40 34 28 22 16 10 4 39 33 27 21 15 9 2 38 32 26 20 14 7 41 35 29 23 17 3 11 37 31 25 19 5 13 42 36 30 24 6 12 18
43	5 19 25 39 31 13 7 1 21 41 33 27 12 6 18 42 36 24 30 10 16 43 37 4 29 23 11 17 38 2 32 26 8 14 20 40 34 28 3 9 22 15 35
44	6 32 18 12 38 24 4 44 30 17 11 36 5 42 28 22 16 34 10 40 3 26 20 33 13 39 1 7 23 29 14 41 35 8 21 27 2 15 43 37 9 31 25 19
45	32 13 38 7 1 25 19 31 43 37 10 3 16 22 28 42 34 9 15 21 27 44 36 5 11 17 23 29 35 41 8 14 2 26 20 33 45 39 6 12 24 30 18 40 4
46	1 7 14 32 26 20 41 5 11 35 29 23 17 45 9 38 31 25 19 44 13 37 6 30 24 43 18 12 3 36 28 42 22 16 8 2 34 40 27 15 46 21 33 39 4 10
47	9 1 15 31 43 37 7 25 13 19 47 41 5 34 27 14 21 40 46 8 30 2 24 18 39 45 33 12 6 26 20 44 32 38 3 11 17 23 29 36 4 10 16 22 28 42 35
48	25 8 1 17 42 36 24 11 30 4 18 44 38 12 32 6 22 47 41 16 28 34 10 2 48 40 26 20 14 33 7 46 39 27 19 13 5 45 35 29 23 15 3 43 9 31 21 37

[Editor's note: following option is proposed in 1449r1…]

$$f(m,s) = \{m + 13s\} \bmod L_{pair,l}$$

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

where

PermSeq(k,r) is is the series obtained by rotating basic permutation sequence *PermSeq(k,0)* cyclically to the left r times. The basic permutation sequence is defined as

PermSeq(k,0) = k, 0<=k<$L_{DRU,FPi}$

and *DL_PermBase* is an integer ranging from 0 to 31 (TBD), which is set to preamble IDCell or specified by the BCH.

[Editor's note: following option is proposed in 1450r1…]

Denote the number of LRUs (PRUs) of frequency partition *i* as $L_{LRU,FPi}$ PRUs, $L_{LRU,FPi} = FPSi * N2$. The subcarrier permutation is performed in two steps. Step 1 permutes the whole frequency partition into $L_{LRU,FPi}$ virtual distributed LRUs. Note that the number of virtual distributed LRUs equals the number of PRUs in the frequency partition. Step 2 further forms $L_{DRU,FPi}$ distributed LRUs based the $L_{LRU,FPi}$ virtual distributed LRUs.

- Step 1: For each *l*-th OFDMA symbol in the subframe,

1. Allocate the n_l pilots within each PRU in the frequency partition as described in section (TBD)

2. Renumber the remaining $L_{LRU,FPi}$ *(Psc - n_l) data subcarriers in order, from 0 to $L_{LRU,FPi}$ (Psc - n_l) -1. Group these contiguous and logically renumbered subcarriers into $L_{LRU,FPi}$ * $L_{pair,l}$ pairs and renumber them from 0 to $L_{LRU,FPi}$ *$L_{pair,l}$-1. . The renumbered tone pairs in the *l*-th OFDMA symbol are denoted by $RTP_{FPi,l}$.

3. Apply the subcarrier permutation formula to form the permuted tone-pairs 0 to $L_{LRU,FPi}$ *$L_{pair,l}$-1.

4. Map logically contiguous tone-pairs [i* $L_{pair,l}$, ($i+1$)*$L_{pair,l}$-1] into the *i*-th virtual distributed LRUs, i=0,1,…, $L_{LRU,FPi}$ -1.

For the *s*-th virtual distributed LRU of the *t*-th subframe, the subcarrier permutation formula is given by

$$
\begin{aligned}
&pair(s,m,l) = L_{LRU,FPi} \cdot f(m,s) + g\left(perm\_seq(\ ),s,m,l\right)\\
&f(m,s) = L_{LRU,FPi} \cdot \operatorname{mod}\left(m+23s, L_{pair,l}\right) \qquad (1)\\
&g\left(perm\_seq(\ ),s,m,l\right) = \begin{cases} \left[s+P_{1,c_1}(k')+P_{2,c_2}(k')\right], 0<c_1,c_2<L_{LRU,FPi} \\ \left[s+P_{1,c_1}(k')\right], c_1 \neq 0, c_2 = 0 \\ \left[s+P_{2,c_2}(k')\right], c_1 = 0, c_2 \neq 0 \\ s, c_1 = 0, c_2 = 0 \end{cases}
\end{aligned}
$$

where k' is mod(mod(m+s×23, $L_{pair,l}$)+l, $L_{LRU,FPi}$ -1); $pair(s,m,l)$ is the tone-pair index of the *m*-th tone-pair ((0<=m< $L_{pair,l}$)) in the *l*-th OFDMA symbol in the *s*-th virtual LDRU; *m* is the tone-pair index in the *l*-th OFDMA symbol in the *s*-th virtual distributed LRU; *s* is the virtual LDRU (0<=s < $L_{LRU, FP,i}$); $P_{1,c_1}(j)$ is the *j*-th element of the sequence obtained by rotating basic permutation sequence P_1 cyclically to the left c_1 times; $P_{2,c_2}(j)$ is the *j*-th element of the sequence obtained by rotating basic permutation sequence P_2 cyclically to the left c_2 times; $c_1 = \operatorname{mod}\left(\text{DL\_PermBase}, L_{LRU,FPi}\right)$; $c_2 = \operatorname{floor}\left(\text{DL\_PermBase}/L_{LRU,FPi}\right)$. The operation in [ ] is over GF($L_{LRU,FPi}$). Specifically, in GF(2^n), addition is binary XOR operation. The basic permutation sequences are given in Table 1.

Table 1 – Basic permutation sequences

N_s	Basic permutation sequences		
2	GF(2)	P_1	1
		P_2	1
4	GF(2^2)	P_1	1, 2, 3
		P_2	1, 3, 2
8	GF(2^3)	P_1	1, 2, 4, 3, 6, 7, 5
		P_2	1, 4, 6, 5, 2, 3, 7
16	GF(2^4)	P_1	1, 2, 4, 8, 3, 6, 12, 11, 5, 10, 7, 14, 15, 13, 9
		P_2	1, 4, 3, 12, 5, 7, 15, 9, 2, 8, 6, 11, 10, 14, 13
32	GF(2^5)	P_1	1, 2, 4, 8, 16, 5, 10, 20, 13, 26, 17, 7, 14, 28, 29, 31, 27, 19, 3, 6, 12, 24, 21, 15, 30, 25, 23, 11, 22, 9, 18
		P_2	1, 4, 16, 10, 13, 17, 14, 29, 27, 3, 12, 21, 30, 23, 22, 18, 2, 8, 5, 20, 26, 7, 28, 31, 19, 6, 24, 15, 25, 11, 9
64	GF(2^6)	P_1	1, 2, 4, 8, 16, 32, 3, 6, 12, 24, 48, 35, 5, 10, 20, 40, 19, 38, 15, 30, 60, 59, 53, 41, 17, 34, 7, 14, 28, 56, 51, 37, 9, 18, 36, 11, 22, 44, 27, 54, 47, 29, 58, 55, 45, 25, 50, 39, 13, 26, 52, 43, 21, 42, 23, 46, 31, 62, 63, 61, 57, 49, 33
		P_2	1, 4, 16, 3, 12, 48, 5, 20, 19, 15, 60, 53, 17, 7, 28, 51, 9, 36, 22, 27, 47, 58, 45, 50, 13, 52, 21, 23, 31, 63, 57, 33, 2, 8, 32, 6, 24, 35, 10, 40, 38, 30, 59, 41, 34, 14, 56, 37, 18, 11, 44, 54, 29, 55, 25, 39, 26, 43, 42, 46, 62, 61, 49

- Step 2: In the virtual distributed LRUs, data tone-pairs from the CRUs are for localized resource. In this step, the localized resources (i.e. the $L_{CRU,FPi}$ PRUs) are "punctured" from the virtual distributed LRUs.
    1. Initiate j=0.
    2. $N'= L_{LRU, FP,i} - j$. All the virtual distributed LRUs are numbered 0 to N'-1. Take out all the data tone-pairs of $\mathrm{CRU}_{\mathrm{FPi}}[j]$ from the virtual distributed LRUs. Then, in the l-th OFDMA symbol, there are $L_{pair,l}$ data tone-pairs punctured from the virtual distributed LRUs.
    3. For each l-th OFDMA symbol, l=0,1,…, N_{sym}-1,
        - Sequentially, take the tone-pairs from the (N'-1)-th virtual distributed LRUs (Note that "virtual distributed LRUs with index N'-1" is the virtual distributed LRUs with the highest index in all the virtual distributed LRUs) one-by-one and fill them into the $L_{pair,l}$ punctured tone-pairs (or $L_{pair,l}-q$ "punctured tone-pairs" if q tone-pairs of the (N'-1)th virtual distributed LRU belong to $\mathrm{CRU}_{\mathrm{FPi}}[j]$). During the filling process, the largest possible frequency diversity is ensured by the following method:
            - Assume an integer variable x = 0,1,…, $L_{pair,l}-q-1$. For each x, take the x-th tone-pair from the (N'-1)-th virtual distributed LRU, and denote the tone-pair as s_x. Assume that there are V virtual distributed LRUs that have 1 or more data tone-pair punctured. Denote these V virtual distributed LRUs as c_v, v=0,1,…,V-1. For each c_v, check how many data subcarriers in c_v are from the PRU which s_x belongs to, and denote the number as t_v.
                - Find the 1st virtual distributed LRU with the smallest t_v among all the V virtual distributed

LRUs. Fill tone-pair s_x in it.

4. N' new virtual distributed LRUs are formed. If $j< N_{CRU}$ -1, $j=j+1$, go to b); If $j= N_{CRU}$ -1, the subchannelization for distributed resources are done. The resulted virtual distributed LRUs are $L_{DRU, FP,i}$ distributed LRUs for distributed resource allocation, which are renumbered from 0 to $L_{DRU, FP,i}$ -1.

[Editor's note: following option is proposed in 1464r3…]

$$f(m,s) = (m + 13 \cdot s) \bmod L_{pair,l}$$

$$g(PermSeq,s,m,l,t) = PermSeq\left[\left(f(m,s) + 107 \cdot l + s\right) \bmod L_{DRU,FPi}\right]$$

where *PermSeq* is the sequence of length $L_{DRU,FPi}$ and is determined by SEED = {(*IDcell*+1024**t*)*1357351} mod 2^{20}. The *IDcell* is the cell identification. The specific permutation sequence generation algorithm with 20-bit SEED (S_{n-20}, S_{n-19}, … , S_{n-1}) and a permutation size of *M* is defined as below.

The permutation sequence generation algorithm 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 20-bit seed, SEED.
        - i. Set $d_1 = \left\lfloor \frac{\text{SEED}}{2^{10}} \right\rfloor + 1$.
        - ii. Set $d_2 = \text{SEED} \bmod 2^{10}$.
    - B. Initialize the maximum iteration number, *N*=8 (TBD)
    - 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,
        - i. Increment *x* by 1.
        - ii. Calculate the output variable of the first order polynomial, $y = \{(d_1 \times x + d_2) \bmod 1048583\} \bmod M$.
        - iii. Increment *j* by 1.
        - iv. Repeat the above steps (i.~ iii.), if $y \geq i$ and $j < N$.

C. If $y > i$, set $y = y \bmod i$.

D. Swap the i-th and the y-th elements in the array (i.e. perform the steps Temp= $\mathbf{A}[i]$, $\mathbf{A}[i]$= $\mathbf{A}[y]$, $\mathbf{A}[y]$=Temp).

E. Decrement i by 1.

F. The permuted sequence is represented by $PermSeq(i) = \mathbf{A}[i]$.

[Editor's note: following option is proposed in 1466r1…]

$$f(m,s) = (5m + 7s) \bmod L_{pair,l}$$

$$g(PermSeq(), s, m, l, t) = PermSeq(f(m,s) + s + O_{IP} \cdot l)$$

Where

$$PermSeq(i) = \{D_{IP} \cdot i + O_{IP} + \left\lfloor i \cdot \frac{GCD(L_{DRU,FPi}, D_{IP})}{L_{DRU,FPi}} \right\rfloor\} \bmod L_{DRU,FPi}, \quad i = 0,1,\ldots, L_{DRU,FPi} - 1$$

where

$$D_{IP} = (\text{Cell ID} + 1) \bmod L_{DRU,FPi}$$

$$O_{IP} = \left\lfloor \frac{\text{Cell ID}}{(L_{DRU,FPi} - 1)} \right\rfloor$$

[Editor's note: following option is proposed in 1448…]

$pair(s,m,l,t) = L_{DRU,\ FP,i} * f(m,s) + g(PermSeq(),s,m,l,t),\ l = 0, 1, \ldots, N_{sym}$

where $f(m,s) = (m + 17s) \bmod L_{pair,l}$

$$g(PermSeq, s, m, l, t) = \\ \left\{\left(PermSeq\left(f(m,s) + s + t + l\right) \bmod L_{DRU,FPi}\right) + DL\_PermBase\right\} \bmod L_{DRU,FPi}$$

PermSeq is generated by the following steps:

a) Let p is the minimal prime that bigger than $L_{DRU,FPi}$,

b) Let $f(k) = \left((k+1)^{p-2} \bmod p\right) - 1$,

c) Generate a list: $\left\{ f\left(p-2\right), f\left(1\right), f\left(2\right), \ldots, f\left(p-3\right), f\left(0\right) \right\}$,

d) For each $f\left(j\right)$, $j = 0,1,2,\ldots,p-2$, if $f\left(j\right) \geq L_{DRU,FPi}$, then delete $f\left(j\right)$,

e) The remaining list is the PermSeq.

------------------------------- Text End ---