Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Proposed Text of UL Subchannelization Section for the IEEE 802.16m Amendment**
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Re	"IEEE 802.16m amendment text" IEEE 802.16m-08/042, "Call for Contributions on Project 802.16m Draft Amendment Content". Target topic: "Uplink Physical Structure (data plane only)"
Abstract	The contribution proposes the text of uplink physical structure section (11.6) to be included in the 802.16m amendment.
Purpose	To be discussed and adopted by TGm for the 802.16m amendment.
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Proposed Text of UL Subchannelization for the IEEE 802.16m Amendment

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1. Introduction

The contribution proposes the text of uplink subchannelization to be included in the 802.16m amendment. The proposed text is developed so that it can be readily combined with IEEE P802.16 Rev2/D7 [1], it is compliant to the 802.16m SRD [2] and the 802.16m SDD [3] , and it follows the style and format guidelines in [4].

2. Modifications to the SDD text

The text proposed in this contribution is based on the subclauses 11.6 in the IEEE 802.16m SDD [3]. The text proposed in this contribution is to provide the uplink subchannelization including outer permutation, second permutation and tile permutation in detail. The key proposal for uplink subchannelization is as follows:

- Details on the procedure of uplink subcarrier to resource unit mapping including outer permutation, second permutation and tile permutation are included.
- Guard carrier utilization for FDM Support of WirelessMAN-OFDMA UL PUSC zone is added.

3. References

[1] IEEE P802.16 Rev2 / D7, “Draft IEEE Standard for Local and Metropolitan Area Networks: Air Interface for Broadband Wireless Access,” Oct. 2008.

[2] IEEE 802.16m-07/002r6, “802.16m System Requirements”

[3] IEEE 802.16m-08/003r5, “The Draft IEEE 802.16m System Description Document”

[4] IEEE C802.16m-08/043, “Style guide for writing the IEEE 802.16m amendment”

[5] IEEE 802.16m-08/1464r2, “Proposed Text of DL Subchannelization Section for the IEEE 802.16m Amendment”

4. Text proposal for inclusion in the 802.16m amendment

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Insert a new section 15:

15. Advanced Air Interface

15.3. Physical layer

15.3.6.3. Subchannelization and Resource Mapping

15.3.6.3.1. Basic Symbol Structure

15.3.6.3.2. Permutation Sequence Generation

All permutations used for uplink subchannelization shall be generated using a permutation sequence generation algorithm which is described in 15.3.5.3.2 [5].

15.3.6.3.3. Uplink Subcarrier to Resource Unit Mapping

The uplink subcarrier to resource unit mapping process is defined as follows and illustrated in Figure 1:

1. First-level or outer permutation is applied to the PRUs in the units of N_1 and N_2 PRUs, where N_1=4 and N_2 =1 or 2 depending on system bandwidth. Direct mapping of outer permutation can be supported only for localized LRU.

2. Distributing the reordered PRUs into frequency partitions.

3. The frequency partition is divided into CRU and/or DRU for each resource group. Sector specific permutation can be supported and direct mapping of the resources can be supported for localized resources. The sizes of the distributed/localized resources are flexibly configured per sector. Adjacent sectors do not need to have same configuration of localized and distributed resources

4. The localized and distributed groups are further mapped into LRUs by direct mapping of CRU and by inner permutation on DRUs.

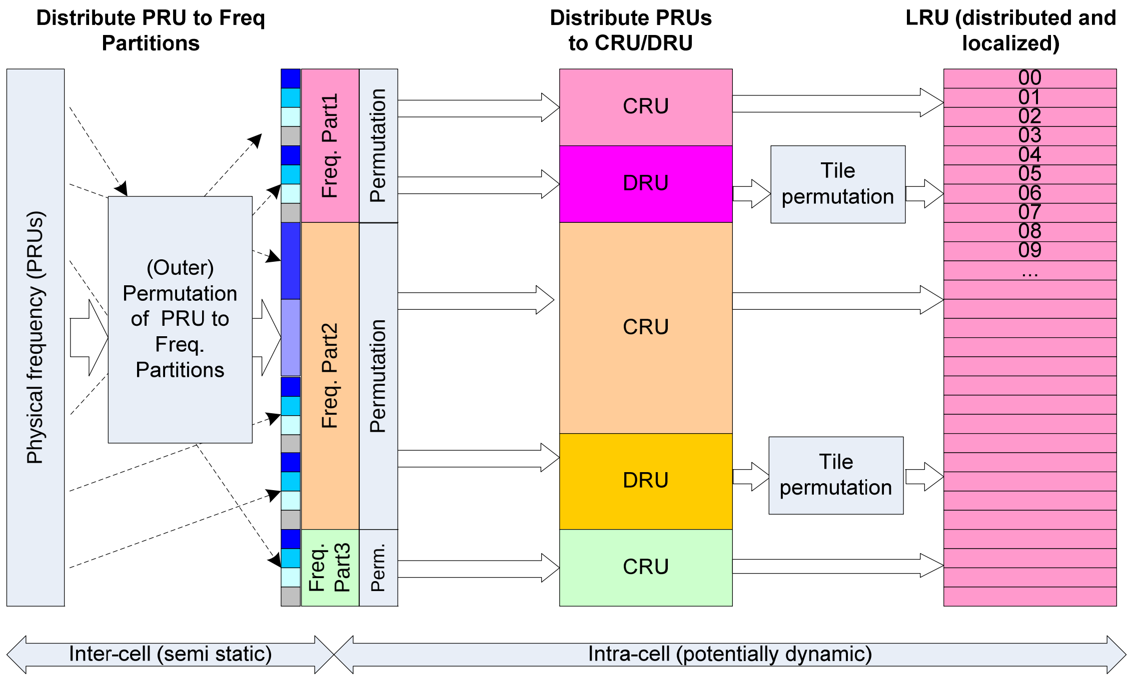

Figure 1 – Illustration of the uplink subcarrier to resource block mapping.

In Figure 2, an example of uplink subcarrier to resource block mapping is described in detail. In the figure, the size of bandwidth is 10MHz and the size of N_2 is equal to 1. The values of the parameters defined in the detailed procedure description in Section 15.3.6.3.3.1 are N_{tot_band}=12, N_{res_band}=3 and N_{band}=4.

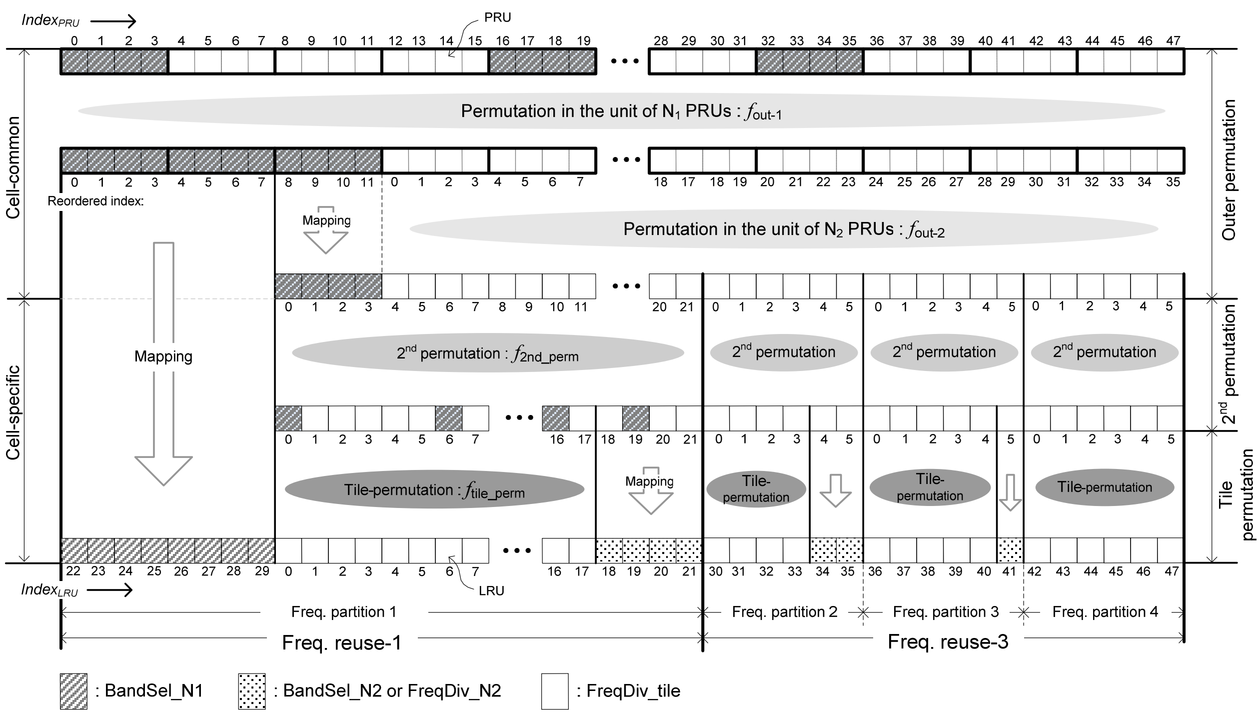

Figure 2 – An example of uplink subcarrier to resource block mapping (BW=10MHz, N_1=4, N_2=1)

15.3.6.3.3.1. Outer Permutation

Outer permutation has two stage procedures:

1) The first stage is to permute frequency resources in the unit of N_1 PRUs and to reserve specified bands according to the number of reserved bands, as shown in Figure 2. In the following description, the term "band" implies a set of N_1 PRUs contiguous in frequency domain.

- The permutation function in the unit of N_1 PRUs, $f_{out\text{-}1}$ is given as follow.

i. $$f_{out-1}(x) = \left\lfloor \frac{N_{tot\_band}}{N_{res\_band}} \right\rfloor \times N_{band} \times p(x) + N_{band} \times q(x) + h(x)$$

1. N_{tot_band}, N_{res_band} and N_{band} mean the total number of bands, the number of reserved bands and the number of PRUs per band, respectively. The number of reserved bands (N_{res_band}) is indicated by the SBCH [3]. The input to $f_{out\text{-}1}$, x, is from the set of contiguous indices [0,…,(N_{tot_band}*N_{band})-1]. The output of $f_{out\text{-}1}$ is the index of PRU as shown in Figure 2.

2. $$p(x) = \left\lfloor \frac{x}{N_{band}} \right\rfloor \bmod N_{res\_band}, \quad q(x) = \left\lfloor \frac{x}{N_{band} \times N_{res\_band}} \right\rfloor, h(x) = x \bmod N_{band}.$$

2) The second stage is for the permuted PRUs which are not reserved for N_{res_band} bands.

- Using the permutation in the unit of N_2 PRUs as shown in Figure 2, the PRUs except the reserved bands are permuted as described below:

i. $$f_{out-2}(x) = K \times p(x) + \mathrm{BRO}_{\log_2(K)}\left(q(x)\right)$$

1. K=N_{band} / N_2. $\mathrm{BRO}_k(y)$ indicates the bit-reversed k-bit value of y (i.e., $\mathrm{BRO}_3(6)=3$).

2. The input x is from the set of [0,…,(N_{tot_band}-N_{res_and})×N_{band} -1]. The output of $f_{out\text{-}2}$ is the reordered PRU index.

3. $$p = x \bmod (N_{tot\_band} - N_{res\_band}) \quad \text{and} \quad q = \left\lfloor \frac{x}{N_{tot\_band} - N_{res\_band}} \right\rfloor.$$

15.3.6.3.3.2. Second Permutation

Given the partition configuration such as FFR ratio of frequency reuse 1 region and frequency reuse N region, the reordered PRUs are split into frequency partitions. The partition configuration is indicated by SBCH [3].

Second permutation is performed within each partition for all partitions except the partition for band selection in the unit of N_1 PRUs.

- Reordered PRUs within a partition are once again permuted by *Perm*(M, SEED) where M is the number of PRUs within a specific partition. The algorithm of *Perm*(M, SEED) is described in Section 15.3.5.3.2.

- *Perm*(*M*, SEED) function generate the randomized sequence with length of *M*. For example, in case of A=*Perm*(*M*, SEED), A stands for sequence with length of *M*. A[*i*] means the *i*-th element of sequence A.

  i. SEED = (IDcell*1357351) mod 2^{20}, where IDcell is the cell identification.

For the second permutation in frequency reuse 1 region, the reordered PRUs as the input to the second permutation include the PRUs which are selected as the reserved bands in the outer permutation procedure, as shown in Figure 2. If the number of bands for band selection operation in units of N_1 PRUs (N_{BS_N1}) is smaller than the number of reserved bands (N_{res_band}), the PRUs within the remaining bands can be utilized for distributed resource. That is, the remaining PRUs which are not used for localized LRU in the unit of N_1 PRUs are also permuted by the second permutation in the frequency reuse 1 region. The value of N_{BS_N1} is indicated by PBCH [3]. If N_{BS_N1} is equal to N_{res_band}, there are no remaining PRUs for the second permutation in the frequency reuse 1 region. Therefore, each sector can have the different configuration of band selection and frequency diversity resource.

15.3.6.3.3.3. Tile Permutation

The tile permutation defined for the uplink distributed resource allocations within a frequency partition spreads the tiles of the distributed LRU across the whole distributed resource allocations. The granularity of the tile permutation is equal to the tile size for forming a distributed LRU according to section 11.6.1.1.

- All DRUs in every frequency partitions are split into tiles.
- Enumerate all tiles within a frequency partition for all partitions.
- All tiles within a partition is permuted by *Perm*(M, SEED) where M is the number of tiles within the partition. The algorithm of Perm(M, SEED) is described in 15.3.5.3.2.
- *Perm*(M, SEED) function generates the randomized sequence with length of M. For example, in case of A=*Perm*(M, SEED), A stands for sequence with length of M. A[x] means the x-th element of sequence A.

  i. Here, SEED = [(IDcell + 1024*m)*1357351] mod 2^{20}, where IDcell is the cell identification of each sector and m means the subframe index.

- Tile permutation function is defined as $(t,i) = f_{tile\ perm}(x,k)$, where t indicates the index of DRU, i indicates the index of tile for that DRU, x indicates the index of distributed LRU and k indicates the index of tile.

  i. $t = \lfloor tile(x,k)/3 \rfloor$ and $i = tile(x,k) \bmod 3$

  ii. Where $tile(x,k) = A[3x+k]$

15.3.6.3.4. Subchannelization for Uplink Distributed Resource

As shown in Figure 2, there are two different types of subchannelization for uplink distributed resource according to frequency reuse 1 or N region. Using the functions defined above section, the relationship between LRU index and PRU index is defined according to two different types of subchannelization for uplink distributed resource. For the simplicity to describe, the variable *x* and *y* as the input and output are substitute for the LRU and PRU index, respectively. The LRU indexing is performed for different resource types, as shown in Figure 4.

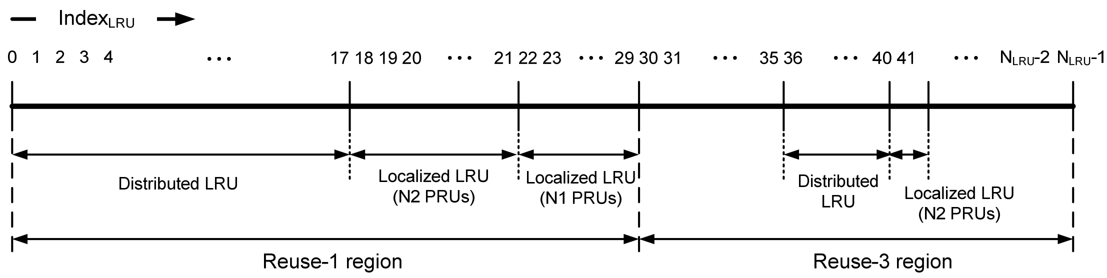

Figure 3 – LRU indexing for different resource types.

For the distributed LRU, there are several steps to make the relationship between *x* and *y*. For the simplicity, the intermediate indexes are defined as below.

- t : the reordered PRU index before the tile permutation, f_{tile_perm}.
- u : the reordered PRU index before the 2nd permutation, f_{2nd_perm}.
- z : the reordered PRU index before the permutation in the unit of N_2 PRUs in the outer permutation, f_{out-2}.

1) Subchannelization for the distributed LRU in frequency reuse 1 region

The relationship between LRU index as input *x* and PRU index as output *y* is derived as follows:

A. The tile permutation defined in Section 15.3.6.3.3.3 is applied to obtain the index of *t*.

- $(t, i) = f_{tile\_perm}(x, k)$
- (t, i) means the *t*-th reordered PRU index and the *i*-th tile index.

B. The second permutation defined in Section 15.3.6.3.3.2 is applied to obtain the index of *u*,

- $u = f_{2nd\_perm}(t)$.

C. The outer permutation (e.g. permutation in the unit of N_2 PRUs and direct mapping) defined in Section 15.3.6.3.3.1 is applied to obtain the index of *z*, depending on the value of *u*.

- $$z = \begin{cases} f_{out-2}(u - u_{offset\_2}), & u \geq u_{offset\_2} \\ u, & otherwise \end{cases}$$
- u_{offset_2} the number of PRUs in the remaining bands after reserving N_{res_band} bands, e.g. $u_{offset\_2} = (N_{res\_band} - N_{BS\_N1})* N_{band}$.

D. The outer permutation (e.g. permutation in the unit of N_1 PRUs) defined in Section 15.3.6.3.3.1 is applied to obtain the output *y*, depending on the value of *u*.

- $y = \begin{cases} f_{out-1}(z + u_{offset\_1} + u_{offset\_2}), & u \geq u_{offset\_2} \\ f_{out-1}(z + u_{offset\_1}), & otherwise \end{cases}$

- u_{offset_1} the number of PRUs in the reserved bands, e.g. $u_{offset\_1} = N_{res\_band} * N_{band}$.

2) Subchannelization for the distributed LRU in frequency reuse N region

The relationship between LRU index as input *x* and PRU index as output *y* is derived as follows:

A. The tile permutation defined in Section 15.3.6.3.3.3 is applied to obtain the index of *t*.

- $(t, i) = f_{tile\_perm}(x\text{-}L_2, k)$
- (t, i) means the *t*-th DRU index and the *i*-th tone pair.
- $L_2 = N_{FR1} + N_{FR3}/3 * IndexFP$, where N_{FR1} and N_{FR3} mean the number of PRUs for frequency reuse 1 and 3 region, respectively. The value of $Index_{FP}$ is the frequency partition order within frequency reuse 3 region, which can be inferred from the input *x*.

B. The second permutation defined in Section 15.3.6.3.3.2 is applied to obtain the index of *u*,

- $u = f_{2nd\_perm}(t)$.

C. The outer permutation (e.g. permutation in the unit of N_2 PRUs and direct mapping) defined in Section 15.3.6.3.3.1 is applied to obtain the index of *z*.

- $z = f_{out-2}(u + u_{offset\_3})$.
- $u_{offset\_3} = N_{FR1} – N_{res\_band} * N_{band} + N_{FR3}/3 * Index_{FP}$.

D. The outer permutation (e.g. permutation in the unit of N_1 PRUs) defined in Section 15.3.6.3.3.1 is applied to obtain the output *y*.

- $y = f_{out-1}(z + u_{offset\_1} + u_{offset\_2})$.

15.3.6.3.5. Subchannelization for Uplink Localized Resource

As shown in Figure 2, there are three different types of subchannelization for uplink localized resource according to frequency reuse 1 or N region. It includes the localized LRU in the unit of N_2 PRUs.

1) Subchannelization for the localized LRU in the unit of N_1 PRUs in frequency reuse 1 region

The relationship between LRU index as input *x* and PRU index as output *y* is derived as follows:

A. The direct mapping is applied to obtain the index of *t* and *u*.

- $u = t = x$

B. For the index of *z*,

- $z = u - L_1$, where L_1 is the number of PRUs assigned for the distributed LRU in the unit of tone pair and the localized LRU in the unit of N_2 PRUs in reuse=1 region.

C. The output *y* is obtained as $y = f_{out\text{-}1}(z)$.

2) Subchannelization for the localized LRU in the unit of N_2 PRUs in frequency reuse 1 region

The relationship between LRU index as input *x* and PRU index as output *y* is derived as follows:

A. The direct mapping is applied to obtain the index of *t*.

- $t = x$

B. The remaining procedures are same as the steps from 1)-B in Section 15.3.6.3.4.

3) Subchannelization for the localized LRU in the unit of N_2 PRUs in frequency reuse N region

The relationship between LRU index as input *x* and PRU index as output *y* is derived as follows:

A. The mapping is applied to obtain the index of *t*.

- $t = x\text{-}L_2$.

The remaining procedures are same as the steps from 2)-B in Section 15.3.6.3.4.

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]. 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_{basic})	409	Number of all subcarriers used in WirelessMAN-OFDMA PUSC zone

		within a symbol, including DC carrier
Number of total used subcarriers (N_{used})	$409+n_1+n_2$	In case the subcarrier once reserved for guard band can be used for the data transmission. The summation of n1 and n2 shall be multiple of 24 subcarriers

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_{basic})	841	Number of all subcarriers used in WirelessMAN-OFDMA PUSC zone within a symbol, including DC carrier
Number of total used subcarriers (N_{used})	$841+n_1+n_2$	In case the subcarrier once reserved for guard band can be used for the data transmission. The summation of n1 and n2 shall be multiple of 24 subcarriers

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_{basic})	1681	Number of all subcarriers used in WirelessMAN-OFDMA PUSC zone within a symbol, including DC carrier
Number of total used subcarriers (N_{used})	$1681+n_1+n_2$	In case the subcarrier once reserved for guard band can be used for the data transmission. The summation of n1 and n2 shall be multiple of 24 subcarriers

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 3.

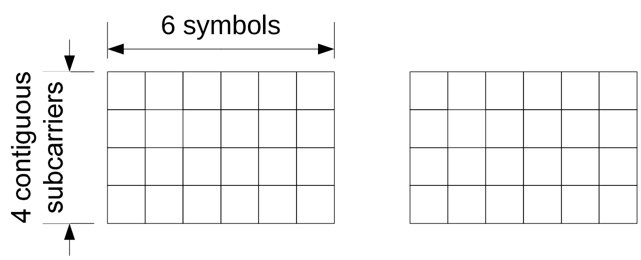

Figure 3 – Tile structure and pilot pattern for FDM based UL PUSC zone Support

(Pilot pattern is TBD)

15.3.6.4.3. Subchannelization for FDM based UL PUSC Zone Support

When supporting FDM based UL PUSC zone, UL subchannelization is as follows:

1. For system bandwidth, all usable subcarriers are divided into PUSC tiles.

2. For N_{basic} subcarriers, UL PUSC subchannelization is performed as described in section 8.4.6.2.2 [3].

3. Available subchannels for Advanced Air Interface MS shall be specified through signaling message broadcasted by [DL broadcasting control message].

4. All PUSC tiles are extended in time domain from 3 OFDM symbols to N_{sym} OFDM symbols, where N_{sym} is dependent of subframe type. These tiles are for distributed-LRUs.

5. Using subcarriers which belong to n1 and n2, 4x6 tiles and extra distributed LRUs are made up. Extra distributed LRUs can be obtained for n_1 and n_2 like as follows :

- For each of n_1 and n_2 subcarriers, combine consecutive 4 subcarriers and make them total L 4x6 tiles for distributed LRUs. L should be multiples of 3 and M=0…L/3-1 where M= L/3.

- The m-th extra distributed LRU, distributed-LRU_{ex}(m) is made up with combining m-th group of tiles and (m+M/2)th group of tiles, for m=0, …, M/2-1.

6. All distributed-LRU_{ex}(m) are added to the subchannels from step 4 where m= m=0, …, M/2-1.

7. Repeat step 4 and step 6 for every subframe in uplink transmission.

Overall process of subcarrier to subchannel mapping is shown in Figure 4.

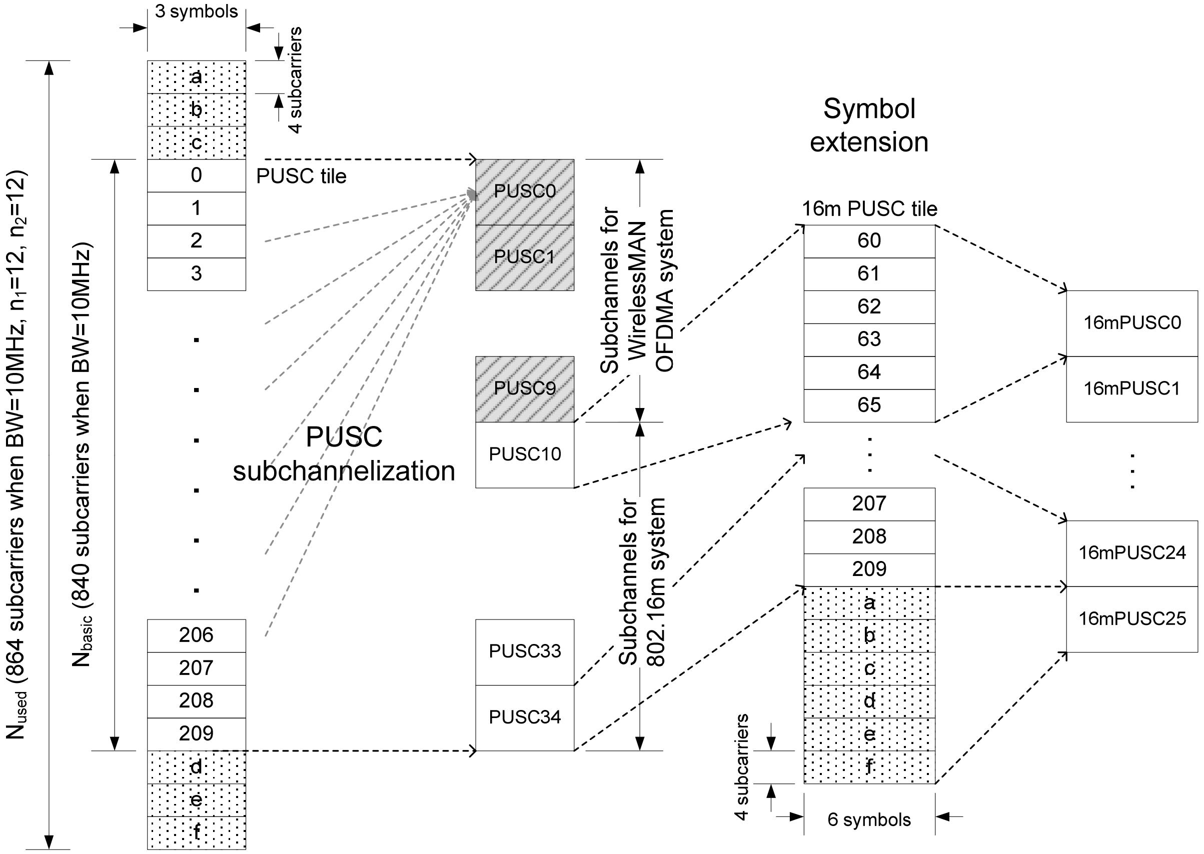

Figure 4 –Example of subchannelization for FDM based UL PUSC zone support (when n_1=12 and n_2=12)

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