Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Proposed Text of DL Subchannelization Section for the IEEE 802.16m Amendment**
Date Submitted	**2008-11-03**
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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: "Downlink Physical Structure".
Abstract	The contribution proposes the text of frame structure section to be included in the 802.16m amendment.
Purpose	To be discussed and adopted by TGm for the 802.16m amendment.
Notice	
Release	
Patent Policy	

Proposed Text of DL Subchannelization Section for the IEEE 802.16m Amendment

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1. Introduction

The contribution proposes the text of DL 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 it follows the style and format guidelines in [3].

2. Proposal in Section 15.3.5.3

The text proposed in this contribution is to detail design the DL subchannelization including outer permutation, second permutation and subcarrier permutation. The key proposal for DL subchannelization is as follows:

- Details on the procedure of DL subcarrier to resource unit mapping including outer permutation, second permutation and subcarrier permutation.
- Design the permutation sequence generation (Section 15.3.5.3.2)
- Detailed design the outer permutation and second permutation (Section 15.3.5.3.3.1 and 15.3.5.3.3.2)
- Details on subcarrier permutation based on tone-pairs. (Section 15.3.5.3.3.3)

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 C802.16m-08/043, "Style guide for writing the IEEE 802.16m amendment"

[4] IEEE 802.16m-08/003r5, "The Draft IEEE 802.16m System Description Document"

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

15.3.5.3. Subchannelization and resource mapping

15.3.5.3.1. Basic symbol structure

15.3.5.3.2. Permutation sequence generation

All permutations used for DL and UL subchannelization shall be generated using a permutation sequence generation algorithm. The algorithms takes a 20-bit seed (S_{n-20}, S_{n-19}, … , S_{n-1}) and a permutation size *M* as inputs and outputs a permutation of a set {0, 1, … , *M*-1}.

The permutation sequence generation algorithm shall generate a permutation sequence of size *M* by the following process:

1) Initialization

A. Initialize the variables o*f* 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*

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. Repeat the following steps if *y* ≥ *i* and *j* < *N*,

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.

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=A[i], A[i]=A[y], A[y]=Temp).

E. Decrement i by 1.

3) The permuted sequence is represented by $Perm(M, \text{SEED}) = \{A[0], A[1], \ldots, A[M-1]\}$.

15.3.5.3.3. Downlink subcarrier to resource unit mapping

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

1. The 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 subcarrier permutation on DRUs, as shown in Figure 1.

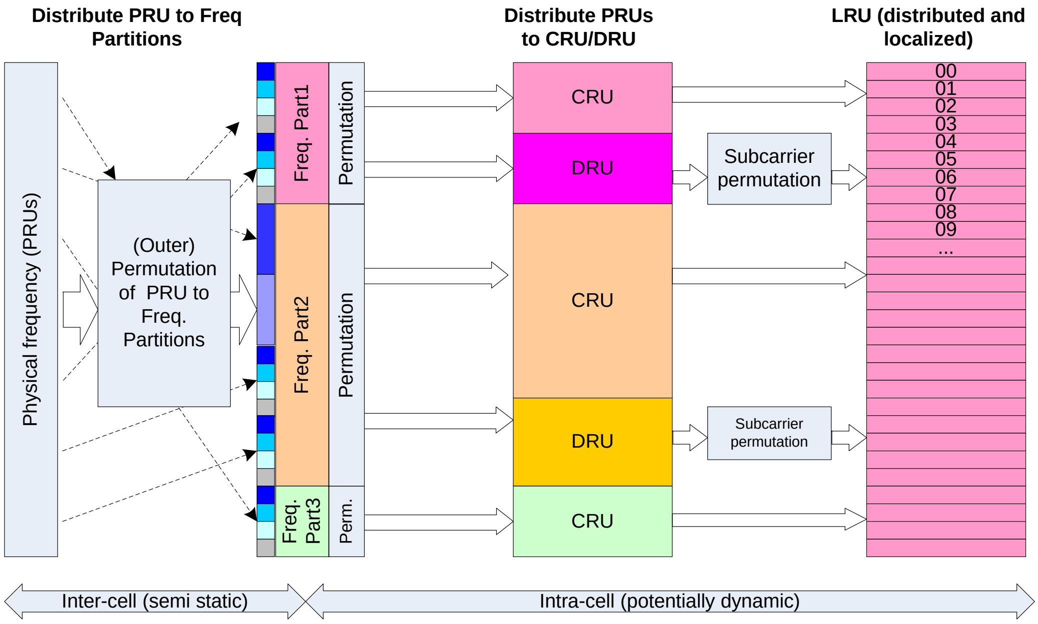

Figure 1 – Illustration of the downlink subcarrier to resource block mapping.

In Figure 2, for an example bandwidth of 10MHz with N_1=4, N_2=1, the steps in the downlink subcarrier to resource block mapping are shown in detail. For the example in Figure 2, the values of the parameters defined in the detailed procedure description in Section 15.3.5.3.3.1 are N_{tot_band}=12, N_{res_band}=3 and N_{band}=4.

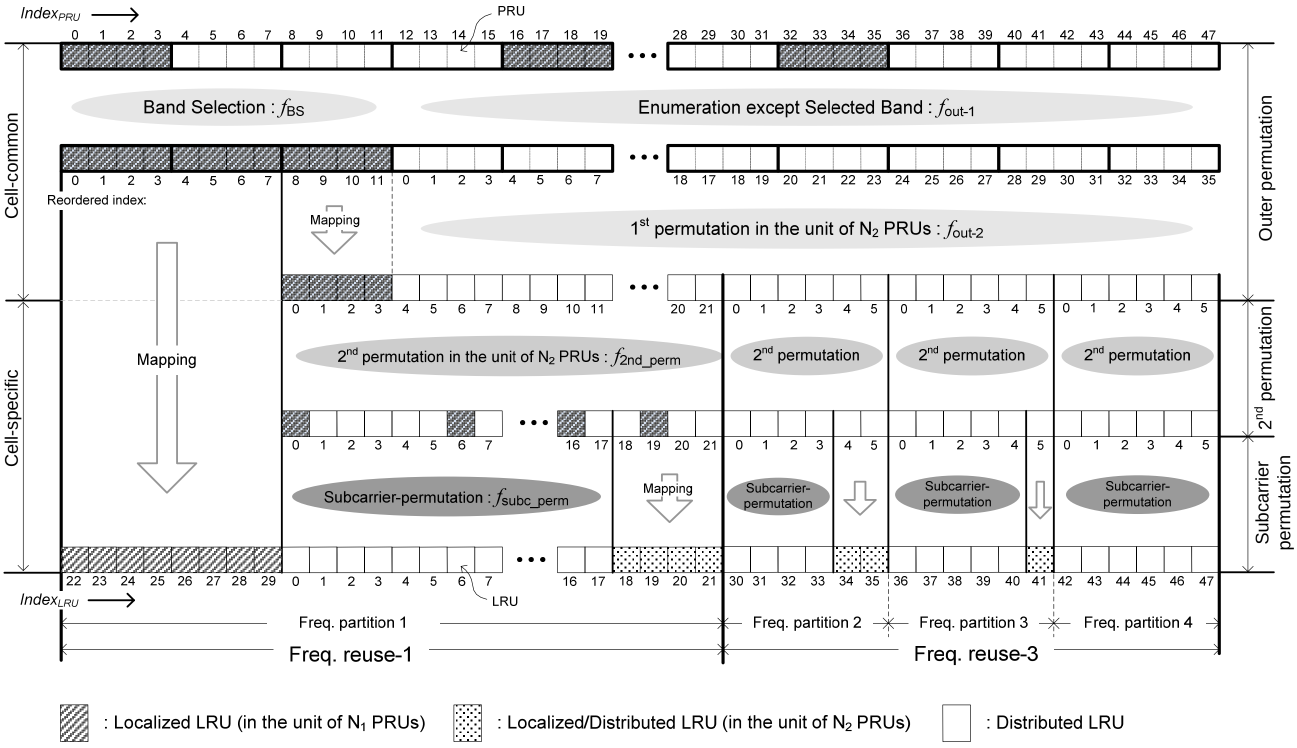

Figure 2 – Detailed description of downlink subcarrier to resource block mapping (BW=10MHz, N_1=4, N_2=1)

15.3.5.3.3.1. Outer permutation

Outer permutation has two stage procedures:

1) The first stage is to reserve frequency resources in the unit of N_1 PRUs and to enumerate the remaining PRUs which are not reserved, as shown in Figure 2. In the following description, the term "band" implies a set of N_1 PRUs contiguous in frequency domain.

- Band selection function, f_{BS} is given as follow.

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

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 [4]. The input to f_{BS}, x, is from the set of contiguous indices [0,…,(N_{band}*N_{res_band})-1]. The output of f_{BS} is the index of PRU as shown in Figure 2.

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

- Except for the selected bands, the enumeration is applied to the remaining PRUs. Enumeration function, $f_{\text{out-1}}$ is given as follows:

i. Initialization

1. N_{PRU} is the total number of PRUs according to the system bandwidth.

2. Initialize x to 0

3. Initialize i to 0

ii. Repeat the following step if $i < N_{PRU}$,

1. If the i-th PRU is reserved for band selection,

A. Set the function of enumeration, $f_{\text{out-1}}(x) = i$

B. Increase x by 1

2. Increase i by 1

2) The second stage is for the enumerated PRUs which are passed through the function of $f_{\text{out-1}}$.

- Using first permutation in the unit of N_2 PRUs as shown in Figure 2, the enumerated PRUs 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 $[0,\ldots,(N_{tot\_band}-N_{res\_and})\times N_{band}-1]$. The output of f_{out-2} is the reordered PRU index.

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

15.3.5.3.3.2. 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 [4].

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 [4]. 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.

15.3.5.3.3.3. Subcarrier permutation

The subcarrier permutation defined for the DL distributed resource allocations within a frequency partition spreads the subcarrriers of the DRU across the whole distributed resource allocations. The granularity of the subcarrier permutation is equal to a pair of tones which are adjacent subcarrier in the frequency domain.

After mapping all pilots, the remaining usable subcarriers are used to define the data subchannel. To allocate the data, the remaining subcarriers are paired into contiguous tone-pairs. Each distributed LRU consists of a group of tone-pairs. Let the number of tone-pairs per distributed LRU be denoted by N_{pair}. The number of DRUs for the distributed LRU is denoted by N_{DRU}.

To obtain the value of N_{DRU}, the number of PRUs for localized/distributed LRU in the unit of N_2 PRUs, as shown in Figure 3, is needed. For each frequency reuse region, the number of PRUs for localized/distributed LRU in the unit of N_2 PRU is given by PBCH [4]. In addition, the partition configuration and N_{BS_N1} are also necessary to calculate the value of N_{DRU}.

The exact partitioning of tone-pairs into distributed LRU is according to the following equation called the subcarrier permutation formula.

$$f_{subc\_perm}(s,k) = N_{DRU} \times n_k + P_s\left[\left(n_f + 3\times n_t\right) \bmod N_{DRU}\right]$$

where

- $f_{subc\_perm}(s,k)$ is the tone-pair index of the *k*-th tone-pair in the *s*-th distributed LRU.
- *s* is the index number of a distributed LRU, from the set [0,…,N_{DRU}–1].
- $n_k = (k + 13\times s) \bmod N_{pair}$, where *k* is the tone-pair index within one distributed LRU from the set [0,…,N_{pair}-1].
- $n_f = n_k \bmod N_{DRU}$ and $n_t = \left\lfloor \frac{n_k}{N_{DRU}} \right\rfloor$.

- $P_s[j]$ is the j-th element in the series obtained by rotating the generated permutation sequence cyclically to the left s times. The specific permutation sequence is generated by the algorithm of $Perm(N_{DRU}$, SEED) which is described in Section 15.3.5.3.2.

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

The indexing of tone-pair across DRUs assigned to the distributed LRUs is given as follows:

- Initialization

  i. Let the index of OFDMA symbol be denoted by i (e.g., $i \in [0, N_{sym}-1]$). N_{sym} means the number of OFDMA symbols per subframe.

  ii. Let the index of DRU assigned to distributed LRU be denoted by s (e.g., $s \in [0, N_{DRU}-1]$).

  iii. Initialize i to 0.

- Repeat the following step if $i < N_{sym}$,

  i. Initialize the counter k to i.

  ii. Initialize s to 0.

  iii. Repeat the following step if $s < N_{DRU}$,

    1. Starting from the k-th OFDMA symbol at the lowest tone-pair within the s-th DRU and continuing in an ascending manner throughout the tone-pairs within one DRU.

    2. Increase s and k by 1.

    3. Set $k = k \bmod N_{sym.}$

  iv. Increase i by 1.

For example, when the number of DRUs is equal to 1, the indexing of tone-pair is as shown in Figure 3.

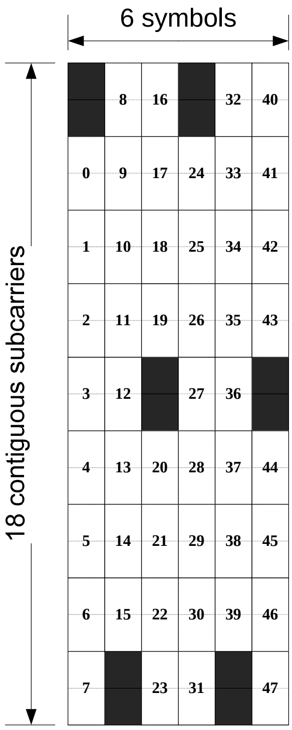

Figure 3 – Tone-pair indexing for the pilot pattern of 1 or 2 Tx streams (N_{DRU}=1).

15.3.5.3.4. Subchannelization for DL distributed resource

As shown in Figure 2, there are two different types of subchannelization for DL distributed resource according to frequency reuse 1 or N region.

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

   - TBD

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

   - TBD

15.3.5.3.5. Subchannelization for DL localized resource

As shown in Figure 2, there are three different types of subchannelization for DL localized resource according to frequency reuse 1 or N region. It includes the localized/distributed 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

   - TBD

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

- TBD

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

- TBD

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