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Re:	802.16m amendment text Target Topic: Downlink Physical Structure
Abstract	This contribution proposes amendment text on 802.16m Downlink Physical Structure
Purpose	To incorporate the proposed text into the 802.16m amendment.
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Proposed amendment text on 802.16m Downlink Physical Structure

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Introduction

In this contribution, we propose amendment text on 802.16m Downlink Physical Structure. The proposed text is inline with section 11.5 of 802.16m SDD [2].

The following key points are proposed in the contribution:

- The outer permutation and frequency partitioning
- The detailed inner permutation for distributed resource

Outer permutation and frequency partitioning

- The bands (each band with 4 adjacent PRUs) for link adaptive transmission should be reserved before the outer permutation.
- Frequency partitions should be formed by outer permutation. Adjacent sectors should have the same configuration of frequency partitions, so that the FFR (fractional frequency reuse) concept could be implemented.
- Each frequency partition is associated with a specific frequency reuse factor. PRU group are defined within each frequency partition.
    - If the frequency partition has reuse factor of 1, there is no need for another level of PRU-based permutation inside the frequency partition. All the PRUs of the partition form a PRU group.
    - If the frequency partition has reuse factor > 1, there should be another level of PRU-based permutation inside the frequency partition. After the permutation, the PRUs of the frequency partition are grouped into 3 PRU groups.

  The size of PRU group is proposed to be 2^n, where n is an integer. The reason is twofold: 1. The size of frequency partition does not need to be very flexible (any integer number). 2. The inner permutation can easily reuse the 16e (O)FUSC permutation.
- The distributed/localized resource partitioning is performed inside one PRU group.

Inner permutation for distributed resource

To design the inner permutation, we target at the following benefits.

- The subcarriers of one LDRU are spread over the whole frequency band for distributed resource in all the N_{sym} OFDMA symbols, which ensures that the largest possible frequency-time diversity could be gained.
- Regardless of how many and which PRUs are chosen for distributed/localized resources, the same basic permutation sequence and the same permutation/subchannelization procedure will be used for distributed resource. The advantage of inter-cell interference averaging inherited from 16e distributed resource should be kept.

Denote the number of PRUs for distributed resource as N_D, and the number of PRUs for localized resource as N_L, and the number of PRUs in the PRU group as N_s ($N_s = N_D + N_L$). We propose a “two-step” inner permutation to meet the above target:

- 1st step: After pilot subcarriers are allocated in each OFDMA symbol, subcarrier-based permutation is performed to all the PRUs in a PRU group, before the distributed/localized resource partitioning. The 16e OFUSC permutation scheme is proposed to be used here, since it is good in terms of frequency diversity and interference averaging. After this step, we get the so-called virtual LDRUs. The number of virtual LDRUs equals the number of PRUs in the PRU group.
- 2nd step: The data subcarriers of the N_L PRUs for localized resource are punctured from the virtual LDRUs. Then, the subcarriers for the N_L virtual LDRUs with highest indexes are filled in the "holes" (the punctured subcarriers) in the other N_D virtual LDRUs. Then, we get N_D LDRUs.

The detailed procedures are given in the proposed amendment text.

Proposed Amendment Text

X.5 Downlink Physical Structure

X.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. N_{sym} is 6 OFDMA symbols for type-1 subframes, and N_{sym} is 7 OFDM symbols for type-2 subframes. A logical resource unit (LRU) is the basic logical unit for distributed and localized resource allocations. A LRU is composed of $P_{sc}*N_{sym}$ subcarriers for both type-1 subframes and type-2 subframes. Note that the LRU includes the pilots that are used in a PRU. So, the effective number of subcarriers in an LRU depends on the number of allocated pilots.

X.5.1.1 Logical Distributed resource unit

The logical distributed resource unit (LDRU) contains a group of subcarriers which are spread across the distributed resource allocations within a frequency partition. The size of the LDRU equals the size of PRU, i.e., P_{sc} subcarriers by N_{sym} OFDMA symbols. The minimum unit for forming the LDRU is one subcarrier.

X.5.1.2 Logical Localized resource unit

The logical localized resource unit (LLRU) contains a group of subcarriers which are contiguous across the localized resource allocations. The size of the LLRU equals the size of the PRU, i.e., P_{sc} subcarriers by N_{sym} OFDMA symbols.

X.5.2 Subchannelization and Resource mapping

The subcarriers of an OFDMA symbol are partitioned into DC subcarrier, $N_{g,left}$ 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 N_{PRU} 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 MSs, as well as the type of the subframe, i.e., type-1 or type-2. The values of the parameters depend on system bandwidth, which are given in Table 1 to Table 3.

Table 1 -- 2048-FFT OFDMA DL subcarrier allocations

Parameter	Value	Comments
Number of DC subcarriers	1	Index 1024 (counting from 0)
Number of left Guard subcarriers, $N_{g,left}$	160	
Number of right Guard subcarriers, $N_{g,right}$	159	
Number of used subcarriers, N_{used}	1729	Number of all subcarriers used within an OFDMA symbol, including all possible allocated pilots and the DC carrier.
Number of subcarriers per PRU, P_{sc}	18	
Number of PRUs, N_{PRU}	96	

Table 2 -- 1024-FFT OFDMA DL subcarrier allocations

Parameter	Value	Comments
Number of DC subcarriers	1	Index 512 (counting from 0)
Number of left Guard subcarriers, $N_{g,left}$	80	
Number of right Guard subcarriers, $N_{g,right}$	79	
Number of used subcarriers, N_{used}	865	Number of all subcarriers used within an OFDMA symbol, including all possible allocated pilots and the DC carrier.
Number of subcarriers per PRU, P_{sc}	18	
Number of PRUs, N_{PRU}	48	

Table 3 -- 512-FFT OFDMA DL subcarrier allocations

Parameter	Value	Comments
Number of DC subcarriers	1	Index 256 (counting from 0)
Number of left Guard subcarriers, $N_{g,left}$	40	
Number of right Guard subcarriers, $N_{g,right}$	39	
Number of used subcarriers, N_{used}	433	Number of all subcarriers used within an OFDMA symbol, including all possible allocated pilots and the DC carrier.
Number of subcarriers per PRU, P_{sc}	18	
Number of PRUs, N_{PRU}	24	

X.5.2.2 Downlink subcarrier to resource unit mapping

The DL subcarrier to resource unit mapping process is defined as follows:

1. Outer permutation is applied to the PRUs in the units of N1 and N2 PRUs, where N1=4 and N2 =1. The reordered PRUs are distributed into frequency partitions according to the procedure defined in section X.5.2.2.1.
2. The PRUs of frequency partition are divided into localized (LLRU) and/or distributed (LDRU) resources, according to the procedure defined in section X.5.2.2.1. The sizes of the distributed/localized resources are flexibly configured per sector.
3. The localized and distributed groups are further mapped into LRUs (by direct mapping of LLRU and by “Subcarrier permutation” on LDRUs).

X.5.2.2.1 Outer permutation, frequency partitioning, Localized/distributed resource grouping

- N_B PRU bands (each band of N1=4 continuous PRUs) should be reserved for band-based localized resource allocation. There are multiple predefined configurations of band reservation. Each configuration corresponds to a specific N_B value.
- The other PRUs should be partitioned into frequency partitions by outer permutation in the unit of N2=1 PRU. The configuration of frequency partitions should be the same across adjacent sectors.
- For each frequency partition, frequency reuse factor is selected from 1, 3, or TBD. If the reuse factor is larger than 1, the PRUs in the frequency partition are grouped into 3 PRU groups. If the reuse factor equals 1, the PRUs in the frequency partition form 1 single PRU group. [Notes: The usage of PRU group(s) in a frequency partition should be based on FFR concept specified in section 20.1 in [2].] A PRU group contains $N_s=2^n$ PRUs, where n is an integer. See Table 4 for all the valid N_s.

- A PRU group is further divided into localized and distributed resources. Inner permutation is done within each PRU group according to the procedure defined in section X.5.2.2.2.

X.5.2.2.2 Subchannelization for DL distributed resource

Inner permutation is done within a PRU group. Denote the size of a specific PRU group as N_s PRUs. The PRUs are numbered as $\{0,1,\cdots,N_s-1\}$. U_D is a subset of the PRU group for distributed resource. Denote the size of U_D as N_D PRUs. The indexes of the PRUs in U_D are $\{k_0,k_1,\cdots,k_{N_D-1}\}$. Denote the complement of U_D in the PRU group as U_L. The PRUs in U_L are localized resources. Denote the size of U_L as N_L, $N_D+N_L= N_s$. The indexes of the PRUs in U_L are $\{i_0,i_1,\cdots,i_{N_L-1}\}$. Let n_t denote the number of pilot tones in the t-th OFDMA symbol in a PRU, t=0,1,…, N_{sym}-1. The inner permutation is performed in two steps. Step 1 permutes the PRU group into N_s virtual LDRUs. Note that the number of virtual LDRUs equals the number of PRUs in the PRU group. Step 2 further forms N_D LDRUs based the N_s virtual LDRUs.

- Step 1: For each t-th OFDMA symbol in the subframe, t=0,1,…,N_{sym}-1
  a. Allocate the n_t pilots in the t-th OFDMA symbol within each PRU according to the pilot pattern defined in section X.5.3;
  b. Renumber the remaining N_s*(P_{sc}-n_t) data subcarriers in order, from 0 to N_s*(P_{sc}-n_t)-1.
     - For the case where Space Frequency Block Code (SFBC) is not used: The whole data subcarriers are partitioned into groups of contiguous data subcarriers. Each virtual LDRU consists of one subcarrier from each of these groups. The number of subcarrier groups is equal to the number of data subcarriers in the t-th OFDMA symbol per LDRU, and its value is P_{sc}-n_t. The number of the subcarriers in each subcarrier group is equal to the number of virtual LDRUs N_s. The exact partitioning into virtual LDRU is according to (1), which is modified based on Equation (75) in [1].

$$Carrier(s,m,t)=\begin{cases} N_s*k+\left[s+P_{1,c_1}(k')+P_{2,c_2}(k')\right], 0<c_1,c_2<N_s \\ N_s*k+\left[s+P_{1,c_1}(k')\right], c_1\neq 0, c_2=0 \\ N_s*k+\left[s+P_{2,c_2}(k')\right], c_1=0, c_2\neq 0 \\ N_s*k+s, c_1=0, c_2=0 \end{cases} \quad (1)$$

where k is mod(m+s×23, P_{sc}-n_t); k' is mod(k+t, N_s-1); $Carrier(s,m,t)$ is the subcarrier index of the m-th subcarrier in the t-th OFDMA symbol in the s-th virtual LDRU; m is the subcarrier index in the t-th OFDMA symbol in the s-th virtual LDRU from the set [0~ P_{sc}-n_t-1]; s is the virtual LDRU index from the set [0~N_s–1]; $P_{1,c_1}(j)$ 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; $c_1=\mathrm{mod}(\mathrm{DL\_PermBase}, N_s)$; $c_2=\mathrm{floor}(\mathrm{DL\_PermBase}/N_s)$, where . The operation in [ ] is over GF(N_s). Specifically, in GF(2^n), addition is binary XOR operation. The basic permutation sequences are given in Table 4.

     - For the case where Space Frequency Block Code (SFBC) is used: The contiguous renumbered subcarriers are paired before applying permutation, i.e. renumbered subcarriers 0 to N_s * (P_{sc} - n_k)-1 are first paired into N_s * (P_{sc} - n_k)/2 pairs, which are further partitioned into groups of contiguous data subcarrier pairs. Each virtual LDRU consists of one pair from

each of these groups. The number of subcarrier groups is $(P_{sc}-n_t)/2$. The number of the subcarrier pairs in a group is equal to the number of virtual LDRUs N_s. The exact partitioning into virtual LDRU is also according to (1), where the unit of the permutation is changed to be a subcarrier pair instead of 1 subcarrier.

Table 4 – 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 LDRUs, data subcarriers from the PRUs in U_L are for localized resource. In this step, the localized resources (i.e. the N_L PRUs of U_L) are "punctured" from the virtual LDRUs. The N_D LDRUs is formed by performing the following procedure
    a. Initiate x=0.
    b. N'=N_s-x. All the virtual LDRUs are numbered 0 to N'-1. Take out all the data subcarriers of PRU i_x from the virtual LDRUs. $i_x \in \{i_0, i_1, \cdots, i_{N_L-1}\}$. Then, in the t-th OFDMA symbol, there are P_{sc}-n_t data subcarriers punctured from the virtual LDRUs.
    c. For each t-th OFDMA symbol, t=0,1,…, N_{sym}-1,
        - Sequentially, take the subcarriers from the (N'-1)-th virtual LDRU (Note that "virtual LDRU with index N'-1" is the virtual LDRU with the highest index in all the virtual LDRUs) one-by-one and fill them into the P_{sc}-n_t punctured subcarriers (or P_{sc}-n_t-q "punctured subcarriers" if q subcarriers of the (N'-1)-th virtual LDRU belong to PRU i_x). During the subcarrier filling process, the largest possible frequency diversity is ensured by the following method:
            - Assume an integer variable j = 0,1,…, P_{sc}-n_t-q-1. For each j, take the j-th subcarrier from the (N'-1)-th virtual LDRU. The index of the subcarrier is s_j. Assume that there are V virtual LDRUs that have 1 or more data subcarriers punctured. Denote these V

virtual LDRUs 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_j belongs to, and denote the number as t_v.

- Find the 1st virtual LDRU with the smallest t_v among all the V virtual LDRUs. Fill subcarrier s_j in it.

d. N' new virtual LDRUs are formed. If $x<N_L-1$, $x=x+1$, go to b); If $x=N_L-1$, the subchannelization for distributed resources are done. The resulted virtual LDRUs are N_D LDRUs for distributed resource allocation, which are renumbered from 0 to N_D-1.

X.5.2.2.3 Subchannelization for DL localized resource

The PRUs in U_L are directly mapped to N_L LLRUs, which are renumbered from 0 to N_L-1.

----------end of proposed amendment text----------

Reference

[1] IEEE 802.16Rev2/D7, "IEEE draft standard for Local and Metropolitan Area Networks – Part 16: Air interface for fixed Broadband Wireless Access systems", June 2008

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