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Title	**Proposed amendment text on 802.16m Downlink Physical Structure**
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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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Patent Policy	

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. The size of a frequency partition 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 frequency partition.

Inner permutation for distributed resource

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

- The subcarriers of one distributed LRU 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 a frequency partition as N_s ($N_s = N_D + N_L$). We propose a “two-step” inner permutation to meet the above targets:

- 1st step: The minimum unit for the inner permutation is a pair of adjacent tones. After pilot subcarriers are allocated in each OFDMA symbol in all the N_s PRUs, the subcarriers are reordered in the unit of tone-pair. The 16e OFUSC permutation is performed to the tone-pairs in all the N_s PRUs, before the distributed/localized resource separation. The 16e OFUSC permutation 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 distributed LRUs". The number of virtual distributed LRUs equals the number of PRUs in the frequency partition.
- 2nd step: The tone-pairs of the N_L PRUs for localized resource are punctured from the virtual distributed LRUs. The tone-pairs of the N_L virtual distributed LRUs with highest indexes are filled in the "holes" (the punctured tone-pairs) in the other N_D virtual distributed LRUs. Finally, we get N_D distributed LRUs.

The detailed description on the proposed inner permutation is given in the proposed amendment text.

The rationale of the two-step inner permutation is as follows. 16e subcarrier-based permutation has good frequency diversity and interference averaging properties. The interference averaging comes from the fact that the permutation sequence is generated from cyclic linear code, e.g. Reed-Solomon (RS) code. In 16m, distributed resource in adjacent sectors may have different size. If 16e permutation is reused in 16m without any modification, the permutation sequence of adjacent sectors will have different length, i.e., adjacent sectors have to use different RS code as the basic permutation sequence. It will corrupt the interference averaging property of RS code. Using the proposed two-step inner permutation, the permutation sequence length is decided by the size of frequency partition, not the size of distributed resource. Adjacent sectors will still use the same RS code as basic permutation sequence. The first step permutation is the same as 16e. In the second step, the localized resources are punctured. The remaining data tones in the virtual distributed LRUs still have the good interference averaging property. In this way, the interference averaging property is kept. By the proposed method in the "hole-filling" procedure, the frequency diversity is also maximized.

An example is given in Figure 1 to help understand the proposed inner permutation scheme. In the example, we make the following assumptions:
- The frequency partition is made up of N_s=4 PRUs, where the highest-indexed PRU is selected as the localized resource and the other 3 PRUs are distributed resource.
- The pilot pattern uses the one given in Figure 32 of [2].
- The permutation base (DL_permBase) is equal to 1.

The detailed inner permutation in Figure 1 is explained below:
- Step 1, for each the t-th OFDMA symbol:
  - o n_t Pilots are allocated in all the 4 PRUs in the frequency partition. [Note: Although n_t always equals 2 in the example, n_t does not need to be constant across different OFDMA symbols.]
  - o The data tones are reordered from 0 to 31, in the unit of tone-pair.
  - o Equation (1) (see Proposed amendment text) is used to permute the tone-pairs. E.g. for the 1st OFDMA symbol, after permutation we get $pair(0,0:7,0)=[2,7,9,14,19,21,26,31]$; $pair(1,0:7,0)=[30,3,6,8,15,18,20,27]$; $pair(2,0:7,0)=[24,29,0,5,11,12,17,23]$; $pair(3,0:7,0)=[22,25,28,1,4,10,13,16]$, for the 4 virtual distributed LRUs. $pair(s,0:7,0)$ means the indexes of the 8 tone-pairs of virtual distributed LRU *s* in OFDMA symbol 0.
- Step 2, for each the t-th OFDMA symbol:
  - o The data subcarriers of the PRU for localized resource are punctured from virtual distributed LRUs. E.g. for the 1st OFDMA symbol, we get $pair(0,0:7,0)=[2,7,9,14,19,21,\ ,\ ]$; $pair(1,0:7,0)=[\ ,3,6,8,15,18,20,\ ]$; $pair(2,0:7,0)=[\ ,\ ,0,5,11,12,17,23]$; $pair(3,0:7,0)=[22,\ ,\ ,1,4,10,13,16]$, for the 4 punctured virtual distributed LRUs.
  - o The tone-pairs of the 4-th virtual distributed LRUs are filled in the other virtual distributed LRUs. E.g. for the 1st OFDMA symbol, we get $pair(0,0:7,0)=[2,7,9,14,19,21,22,1]$; $pair(1,0:7,0)=[4,3,6,8,15,18,20,10]$; $pair(2,0:7,0)=[13,16,0,5,11,12,17,23]$, to form the 3 distributed LRUs.

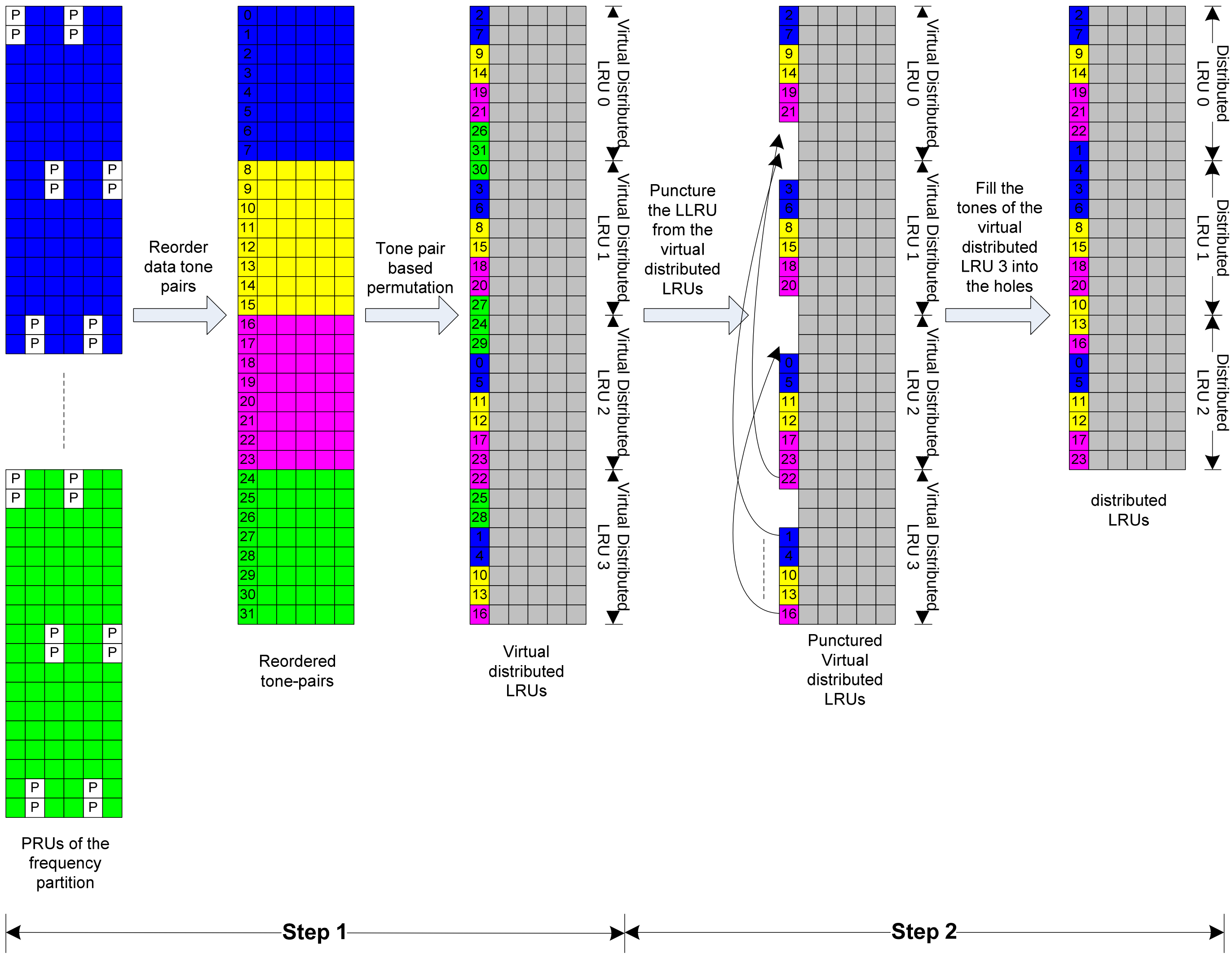

Figure 1 Example for the proposed inner permutation

Note: In one frequency partition, the PRU for localized resource could have different pilot pattern with distributed resources. However, in step 1, all the PRUs (including both LDRU and LLRU) are allocated the same pilot pattern, because the two-step inner permutation is only related to subchannelization for distributed resource. After step 2, the PRUs for localized resource are punctured, and the right pilot pattern will be allocated to those LLRUs during subchannelization for localized resource.

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 a pair of adjacent 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. [Notes: The usage of frequency partitions should be based on FFR concept specified in section 20.1 in [2].] A frequency partition contains $N_s=2^n$ PRUs, where n is an integer. See Table 4 for all the valid N_s.
- A frequency partition is further divided into localized and distributed resources. Inner permutation is done

within each frequency partition 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 frequency partition. Denote the size of a specific frequency partition as N_s PRUs. The PRUs are numbered as $\{0,1,\cdots,N_s-1\}$. U_D is a subset of the frequency partition 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 frequency partition 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 frequency partition into N_s virtual distributed LRUs. Note that the number of virtual distributed LRUs equals the number of PRUs in the frequency partition. Step 2 further forms N_D distributed LRUs based the N_s virtual distributed LRUs.

- 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 tones to be N_s*(P_{sc}-n_t)/2 tone-pairs, from 0 to N_s*(P_{sc}-n_t)/2-1. The whole data tone-pairs are partitioned into groups of contiguous data tone-pairs. Each virtual distributed LRU consists of one tone-pair from each of these groups. The number of groups is equal to the number of tone-pairs in the t-th OFDMA symbol per LDRU, and its value is (P_{sc}-n_t)/2. The number of the tone-pairs in each group is equal to the number of virtual distributed LRUs N_s. The exact partitioning into virtual distributed LRUs is according to (1), which is modified based on Equation (75) in [1].

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

  where k is mod(m+s×23, P_{sc}-n_t); k' is mod(k+t, N_s-1); $pair(s,m,t)$ is the tone-pair index of the m-th tone-pair in the t-th OFDMA symbol in the s-th virtual LDRU; m is the tone-pair index in the t-th OFDMA symbol in the s-th virtual distributed LRU from the set [0~(P_{sc}-n_t)/2-1]; 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; $c_1=\text{mod}(\text{DL\_PermBase}, N_s)$; $c_2=\text{floor}(\text{DL\_PermBase}/N_s)$. 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.

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 distributed LRUs, data tone-pairs 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 distributed LRUs.

  a. Initiate *x*=0.

  b. $N'=N_s-x$. All the virtual distributed LRUs are numbered 0 to N’-1. Take out all the data tone-pairs of PRU i_x from the virtual distributed LRUs. $i_x \in \{i_0, i_1, \cdots, i_{N_L-1}\}$. Then, in the t-th OFDMA symbol, there are $(P_{sc}-n_t)/2$ data tone-pairs punctured from the virtual distributed LRUs.

  c. For each t-th OFDMA symbol, t=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 $(P_{sc}-n_t)/2$ punctured tone-pairs (or $(P_{sc}-n_t)/2-q$ “punctured tone-pairs” if q tone-pairs of the $(N'-1)^{th}$ virtual distributed LRU belong to PRU i_x). During the filling process, the largest possible frequency diversity is ensured by the following method:

       - Assume an integer variable j = 0,1,…, $(P_{sc}-n_t)/2-q-1$. For each j, take the j-th tone-pair from the (N’-1)-th virtual distributed LRU. The index of the tone-pair is s_j. 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_j 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_j in it.

  d. N’ new virtual distributed LRUs 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 distributed LRUs are N_D distributed LRUs 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