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DL subchannelization for OFDM mode

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1. Introduction

It is proposed to enhance the OFDM mode by introducing DL subchannelization (DL OFDMA) as an optional extension. DL subchannelization can improve the reuse factor and the link budget. DL subchannelization can also reduce the overheads associated with preambles, when operating in conjunction with AAS techniques. In addition, it is proposed to enhance system robustness by introducing low rate codes.

2. DL Subchannelization: Principles of operation.

The key features of the DL subchannelization proposal are as follows:

- The DL subchannelization is used in a dedicated region of the DL sub-channel. Thus backward compatibility is maintained.
- Maximum re-use of elements from 802.16REVd OFDM mode:
  - Same number of subchannels.
  - Same pilot and sub carrier locations.
  - Same basic FEC and interleaving schemes.
  - Same midamble based training format.
- Robust operation in high interference scenarios.
  - Dedicated control channel
  - Low rate codes.
- Simple implementation:
  - No concurrent reception of bursts.
  - A SS needs to decode a single burst at a time, control or data.
- Designed in support of AAS.

3. Detailed description

The DL subchannelization is transmitted in a dedicated section of the DL sub-channel. This section is pointed to by the regular DL map, where it is marked by a new DL-subchannelization extended IE. 802.16REVd SSs interpret this new IE as a 'dummy IE'. Thus backward compatibility is maintained.

The DL subchannelization region is marked by at least one pair of preamble and FCH burst, of one symbol duration. The FCH contains a DLFP which points to the first burst of the control subchannel (CCH). The format of the DLFP is shown in Table 1. In an AAS systems, pairs of preamble and FCH may be repeated to create beam pattern diversity.

The CCH channel carries the DL and UL map information IE, termed CCH_MAP_Ies (See Table 3). Additional map IEs, termed EMBD_MAP_IEs, are embedded in the DL burst. All map information elements are relevant to the next frame. A BST shall assume that the SS is not capable of receiving more than one burst in a single frame.

The map structure defined above forms a chain of maps. The control channel is typically used to initiate such a chain. Additionally, the BST may echo some of the embedded DL map information elements on the control subchannel. This may be used for recovery in case one of the embedded DL map IEs was lost.

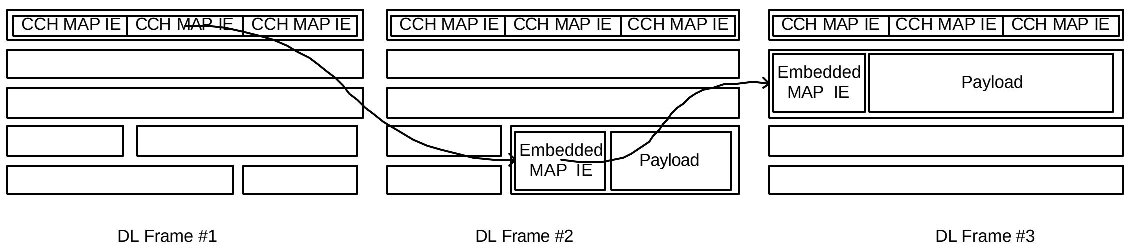


Figure 1 Map chaining

The control channel is composed of several bursts in descending order of robustness. Each burst contains a CCH_PRFX_IE (see Table 2) which contains the rate and length of the next burst. A SS decodes the chain of bursts until it decodes a CCH_MAP_IE designated to it or until it has reached a burst it cannot decode. This structure allows for a very robust control channel without compromising air efficiency. This is shown in Figure 2.

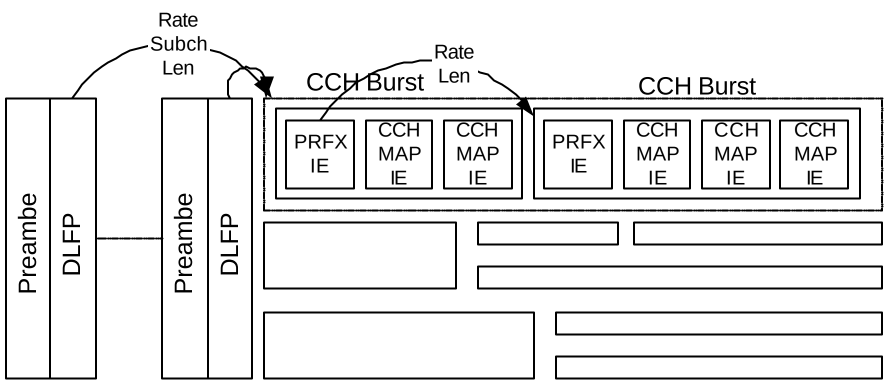


Figure 2 Format of DL Subchannelization section

In AAS systems, bursts on the CCH may be transmitted using a directed a beam, or using beam pattern diversity. These bursts are typically transmitted at the end of the CCH. When a SS cannot determine the rate and length parameters of the CCH burst it shall assume the same parameters as set in the DLFP.

Field	Size	Comments
DL_Frame_Prefix_Format() {		
Base_Station_ID	4 bits	4 LSBs of BS ID. The burst specified by the DFLP shall not be decoded if these bits do not match those of the BS on which it is registered
Frame_Number	4 bits	bits 4 LSBs of Frame Number field as specified in Table 214
Configuration_Change_Count	4 bits	4 LSBs of Change Count value as specified in 6.3.2.3.1
CCH Start	5bit	Points to the beginning of the CCH; expressed in terms of offset from the current preamble.
CCH subchannel index	5bits	The subchannel index, in which the CCH is transmitted. See table 192.
CCH_Rate ID	4bits	The Rate ID, according to table XXX, of the first burst of the CCH.
CCH duration	4bits	The duration of the first burst in the CCH.
CCH midamble repetition **HCS**	2bits 8bits	The midamble repetition rate of the first burst of the CCH. An 8-bit Header Check Sequence; calculated as specified in Table 5
}		
Total	40	

Table 1 Format of DLFP

Field	Size	Comments
PRFX_IE() {		
CCH_DIUC	4bits	The DIUCof the next burst of the CCH.
CCH duration	4bits	The duration of the next burst in the CCH.
CCH midamble repetition	2bits	The midamble repetition rate of the first burst of the CCH.
Reserved	2bits	
}		
Total	12	Reserved, shall be set to zero.

Table 2 Format of PRFX_IE

Field	Length, bits	Comments
Direction	1	0=This element defines a DL allocation 1=This element defines an UL allocation
Last MAP IE in the chain	1	If '1', points to burst that does not contain more MAP IEs. Otherwise points to burst that starts with similar IE pointing to the next burst etc.
UL MAP present	1	If '1', next in the burst is UL IE, otherwise regular MAC messages
Reserved	1	
IUC	4	IUC. Interpreted as UIUC if direction==1. Otherwise interpreted as DIUC
If (IUC!=1 && direction = =1)		
CID	16	
else {		
Frame index number	4	Identifies the frame in which the network entry request, which this message responds to, was transmitted. Indicates the number of DL frames elapsed since the network entry request was transmitted, to the current frame. If the request was transmitted in the previous frame, Frame index number=0.
Network entry code	4	
reserved	8	
}		
Length	10	Length of the UL burst in symbols
Offset	11	Offset in symbols from the beginning of the next frame
Subchannel index	4+4	start subchannel + width
Preamble code	3	Information about the preamble rotation and midamble repetition.
HCS Total	8 64	

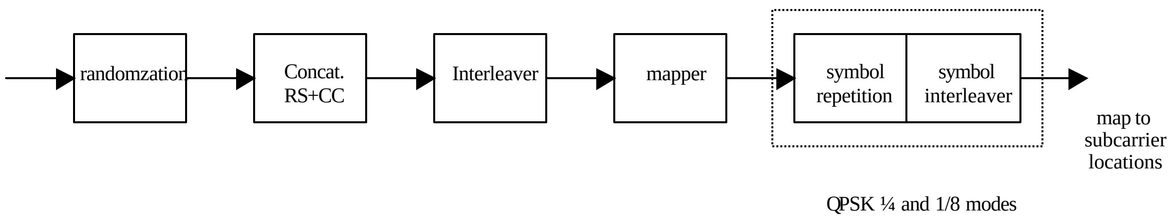
Table 3 Format of CCH_MAP_IE

4. Low rate Error correction codes

It is proposed to introduce low rate error correction codes by concatenating a repetition code with a convolutional code. This is a similar approach to that used in the OFDMA section of 802.16REVd. The operation is as described below.

The encoding path includes the following elements: randomization, FEC, interleaving, modulation and symbol repetition and symbol interleaving. With the exception of symbol repetition and symbol interleaving, all elements are the same as in 802.16REVd.

The FEC scheme shall implement all the mandatory FEC modes of 802.16d. In these modes the symbol repetition and symbol interleaver are bypassed. Additionally, two new FEC modes are introduced: QPSK rate ¼ and QPSK rate 1/8 mode. In these modes, every mapped QPSK symbol is duplicated 2 or 4 times, respectively. After duplication the symbols are multiplied by a cover sequence. The duplicated symbols are interleaved and mapped to subcarrier locations.



The operation in QPSK ¼ and QPSK 1/8 modes is as follows:

Let N_{scps} denote the number of subcarrier per symbol. Let r denote the overall code rate (i.e. ¼ or 1/8).

The bit stream is randomized and passed through CC code. No RS encoding is performed in this mode. The resulting coded bits are interleaved with a block size N_{cbps}= max(N_{scps}*2*r,12). The resulting bits are mapped to QPSK symbols. Let $x_0, x_1\ x_2 \ldots$ denote the resulting symbols.

The symbol repetition block duplicates the symbols and multiplies them by a cover sequence. In QPSK 1/4 mode, the resulting symbols are

$$x_0 \cdot w_0,\ x_0 \cdot w_1,\ x_1 \cdot w_2,\ x_1 \cdot w_3,\ x_2 \cdot w_4,\ x_2 \cdot w_5,\ \ldots,\ x_k \cdot w_{2k},\ x_k \cdot w_{2k+1}, \ldots$$

Where $\{w_k\}$ is the cover sequence. In QPSK 1/8 mode the output sequence is

$$x_0 \cdot w_0,\ x_0 \cdot w_1,\ x_0 \cdot w_2,\ x_0 \cdot w_3,\ x_1 \cdot w_4,\ x_1 \cdot w_5,\ x_1 \cdot w_6,\ x_1 \cdot w_7,\ \ldots,\ x_k \cdot w_{4k},\ \ldots,\ x_{k+3} \cdot w_{4k+3} \ldots$$

The cover sequence is generated using the polynomial $x^{11}+x^9+1$. The sequence is initiated at the beginning of each burst. The sequence is initiated with the word

[BSID0 BSID1 BSID2 BSID3 1 0 1 0 1 0 1]

Where BSID0 BSID1 BSID2 BSID3 are the 4 LSB of the base station ID. The sequence is initiated at the beginning of every burst.

The resulting symbols are further interleaved to maximize the frequency diversity. Let $\{y_k\}$denote the duplicated symbols. In the QPSK rate ¼ mode, the resulting symbols are given by:

$y_0, y_2, y_4, \dots y_{Nscps-2}, \ y_1, y_3, y_5, \dots y_{Nscs-1}$.

In the QPSK rate 1/8 mode, the resulting symbols are given by

$y_0, y_4, \dots y_{Nscps-4}, \ y_1, y_5, \dots y_{Nscps-3}, y_2, y_6, \dots y_{Nscps-2}, y_3, y_7, \dots y_{Nscs-1}$.

The interleaved symbols are mapped to subcarrier locations frequency first.