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Source(s)	Sassan Ahmadi (sassan.ahmadi@intel.com) Intel Corporation Shantidev Mohanty (shantidev.mohanty@intel.com) Intel Corporation
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Abstract	Proposal for IEEE 802.16m Super-frame Header Design and its contents
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Release	
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Proposal for IEEE 802.16m Super-frame Header Design

Sassan Ahmadi and Shantidev Mohanty

1. Introduction and Background

The downlink control channel delivers important control information that is required for the proper operation of an IEEE 802.16m system. Information carried in downlink control channel can be classified into different categories as described in contribution IEEE C802.16m-08/297.doc. The classification of system parameters and system configuration information in this contribution is summarized below.

1. Essential system parameters and system configuration information: This includes a minimal set of time critical system configuration information and parameters needed for the MS to complete access in a power efficient manner. Examples of such information are CP size, system bandwidth, etc. This group of information also includes the superframe configuration information related to the configuration of sub-frames within the superframe.
2. Extended system parameters and system configuration information: This category includes additional system parameters and system configuration information not critical for access, but needed and used by all MSs after system acquisition.

In this contribution an attempt has been made to provide a recommendation on design principles for the transmission of essential system parameters and system configuration information in the frame structure adopted in IEEE 802.16m group that is shown in Figure 1. In this frame structure, a super-frame comprises an integer number of radio frames and each frame consists of an integer number of sub-frames where each sub-frame is further composed of an integer number of OFDMA symbols as shown in Figure 1. The first frame in a super-frame contains super-frame header (SFH) that includes system configuration information. Including in the system configuration information is RS or BS type, cell type, duplex mode, etc.

This contribution proposes structure and transmission format for the transmission of essential system parameters and system configuration information in accordance with IEEE 802.16m frame structure. This essential system parameters and system configuration information is transmitted in the super-frame header (SFH).

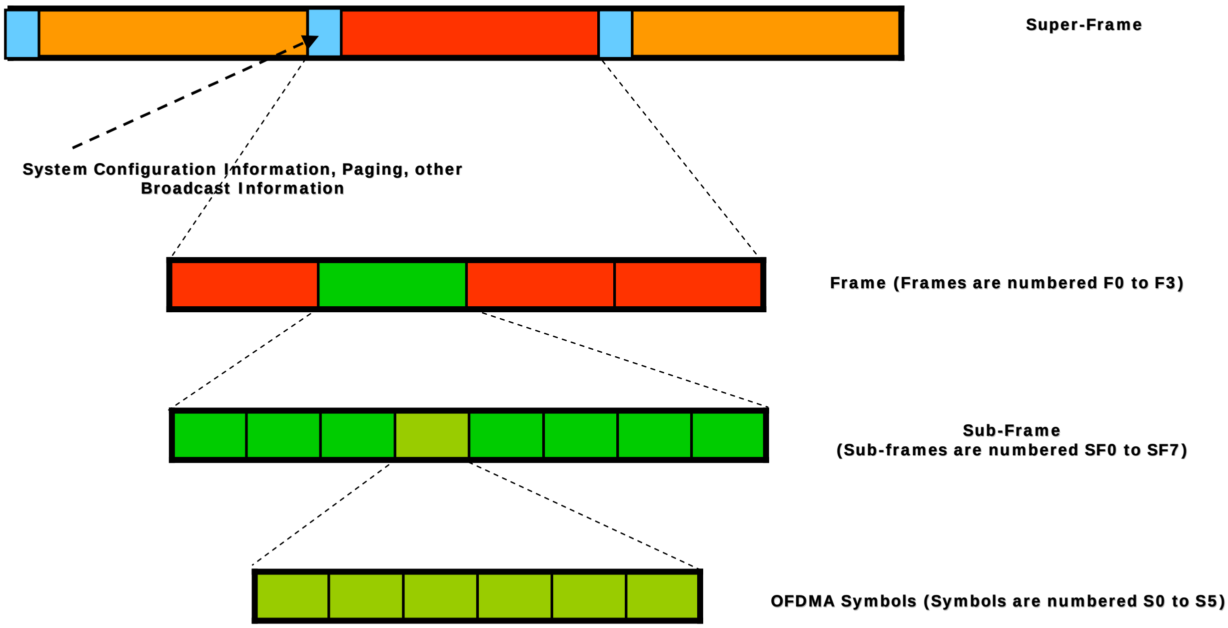

Figure 1: The super-frame/frame/sub-frame structure in IEEE 802.16m.

It is imperative to identify the issues with the structure and performance of control channel structure of the reference system [2] before providing any new solution. Therefore, in the following section the key attributes of a number of control channel structures specified in mobile WiMAX reference system are critically reviewed.

1.1 Analysis of broadcast control information transmission mechanism in IEEE 802.16e-2005 STD

In IEEE 802.16e-2005 STD control information is transmitted using the following mechanisms.

- Frame Control Header (FCH): FCH specifies the type of sub-channelization used in the OFDMA frame. In addition it specifies the MCS and length of the DL MAP. It is located at a fixed location immediately after the preamble and has fixed size, e.g., 48 bits for all FFT sizes except 128. These 48 bits are generated by duplicating the 24 bit information bits of FCH. It uses the fixed MCS (QPSK ½) and repetition coding (4). Thus, the size of FCH is always four DL PUSC slots and first four slots that immediately follow the preamble are used for FCH. As the location, MCS, and size of FCH are fixed it is easy to locate and process the FCH that provides MCS and length of DL MAP. Therefore, FCH enables the usage of flexible MCS and length for DL MAP. Furthermore, FCH specifies the sub-channels used in the first PUSC zone. In summary, FCH contains essential information to process the remaining part of the frame.
- DL/UL MAP: The DL/UL MAP message has a fixed header part that contains some system configuration information such as sector ID, operator ID,

DCD/UCD count, number of DL OFDMA symbols (DL/UL ratio), frame number, and frame duration code.

- DCD/UCD messages: Downlink Channel Descriptor (DCD) and Uplink Channel Descriptor (UCD) messages contain downlink and uplink channel configuration information, respectively. These messages contain majority of the system configuration information, e.g., system bandwidth, DL/UL frequencies, duplex mode (TDD/FDD), BS ID, TTG, RTG, MAC version, cell type, etc. Additional details about the DCD/UCD messages are provided below.

The DCD and UCD messages are transmitted by a BS at regular time intervals. The user terminals use the information contained in DCD and UCD messages to learn about the downlink (DL) and uplink (UL) channel parameters, respectively. The information contents of these two messages are used for different purposes. While some information fields are present in the DCD/UCD messages in all types of system configurations, some other fields are present only when certain system configurations are used. The information fields of the DCD message that are used for all types of system configurations are hereafter referred to as mandatory DCD information fields. On the other hand, the information fields of the DCD message that are used only for some system configuration are hereafter referred to as configuration-dependent DCD information fields. For example, BS equivalent isotropic radiated power (EIRP), transmit/receive transition gap (TTG), receive/transmit transition gap (RTG), base station identifier (BSID), etc. are mandatory DCD information fields, whereas DL adaptive modulation and coding (AMC) allocated physical bands bitmap is configuration-dependent DCD information fields as it is present only when AMC permutation is used. Similarly, tile usage of subchannels type 1 (TUSC1) permutation active subchannels bitmap is also configuration-dependent DCD information field as it is present only when TUSC1 permutation is used.

In a similar note, the information fields of the UCD message that are used for all types of system configurations are hereafter referred to as mandatory UCD information fields. On the other hand, the information fields of the UCD message that are used only for some system configuration are hereafter referred to as configuration-dependent UCD information fields. For example, frequency, periodic ranging codes etc are mandatory UCD information fields, where as Band AMC Allocation Threshold is configuration-dependent DCD information fields as it is present only when Band AMC permutations is used.

While the user terminals use mandatory DCD information fields and mandatory UCD information fields, hereafter collectively referred to as *mandatory system configuration information* (MSCI) for different types of control operations such as DL/UL synchronization, network discovery and selection, initial-network entry, handoff, network re-entry from idle mode, etc. The configuration-dependent DCD/UCD information fields, hereafter collectively referred to as *configuration-dependent system configuration information* (CSCI) are mostly used for traffic exchange by users in connected mode. In other words, the MSCI could be used by a user terminal that just powered up to learn the system information that is required to enter to the network. Similarly, when a user terminal moves from its serving BS to a target BS it requires the MSCI of the target BS to perform handoff and during inter-technology handoff when a user terminal moves from a non-WiMAX network, e.g., Wi-Fi or 3GPP it requires MSCI of WiMAX network to perform vertical handoff from non-WiMAX network to WiMAX network. It may be noted that MSCI is similar to the basic and extended system parameters and system configuration information described earlier.

Currently, a mobile WiMAX BS broadcasts the DCD and UCD messages containing both MSCI and CSCI. Furthermore, the mobile station (MS) or the subscriber station would be able to acquire DCD/UCD only after successful decoding of the DL common control channel also known as medium access protocol (DL-MAP). The location of the DCD/UCD in the DL sub-frame is determined through decoding of the broadcast information element (BIE) included in the DL-MAP at certain intervals.

Figure 2 illustrates a downlink IEEE 802.16e-2005 STD frame containing DCD and/or UCD messages. The downlink frame shown in Figure 2 corresponds to an IEEE 802.16e-2005 STD based wireless system employing time division duplex (TDD) mode of operation. The frame starts with a preamble that is used for synchronization followed by FCH. FCH is followed by downlink MAP (DL-MAP) and uplink MAP (UL-MAP) messages that contain sub-channel allocation and other control information for downlink (DL) and uplink (UL) sub-frames, respectively. The remaining part of the DL frame contains control and data traffic for different users.

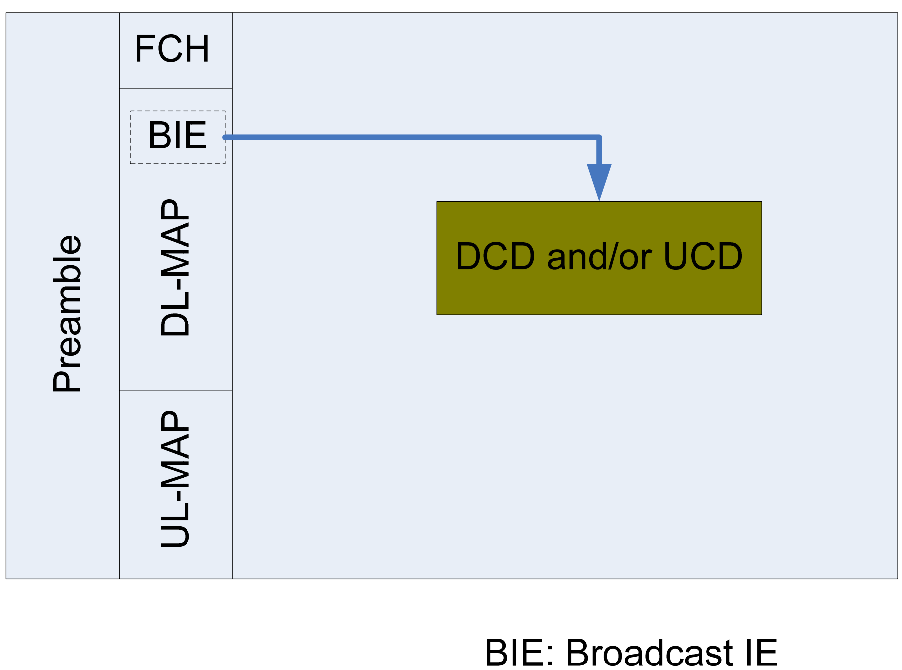

Figure 2: Methods used in IEEE 802.16e-2005 STD to transmit DCD/UCD messages.

When the BS needs to send DCD and/or UCD message(s), it includes a broadcast information element (BIE) in the DL MAP. The BIE indicates the location of the DCD and/or UCD message(s) in the DL frame. The user terminals learn about the presence of BIE by processing the DL-MAP message. Using the BIE the user terminals learn the location of the broadcast message in the DL sub-frame and process the corresponding DL sub-frame region to receive the DCD/or UCD message(s).

Analysis of the existing DCD/UCD message transmission and reception in IEEE 802.16e-2005 STD based systems:

Next, we present the analysis of the DCD/UCD message transmission procedures used in the reference system.

1. Disadvantages

a. When a user terminal wants to learn system configuration information, it processes the DL-MAP of all the received frames to search for the presence of BIE and then it processes the part of the frame pointed by the BIE to detect if DCD/UCD messages are present. This may require significant processing by the user terminals thus consuming more power.

b. Some of the network operations that use information contained in the DCD/UCD messages, especially MSCI present in the DCD/UCD have to meet latency support requirements of mobile WiMAX systems. For example, different network operations that use part of MSCI and their delay requirements per IEEE 802.16m standard are shown in Table 1. Thus, MSCI fields required for a procedure should be transmitted by the BS with appropriate periodicity that meets the delay requirement for this procedure. For example, to meet the intra-frequency handoff interruption delay of 30 ms, the average time to acquire MSCI required for this should be limited to 20 ms assuming that other steps involved in this operation could take up to 10 ms. If we want to limit the delay associated with acquiring MSCI to a maximum value of 20 ms, then the required MSCI should be transmitted every four mobile WiMAX frames further considering that the frame duration is 5 ms. Similarly, other MSCI that are used by other delay-constraint network operations needs to be transmitted once in every m*th* frame, where m is an integer. When some or all of MSCI is required to be transmitted once in every m*th* frame the existing approach of using BIE to specify the presence as well as location of DCD/UCD message may not be necessary and incurs unnecessary MAP overhead associated with BIE. This is because if some or all of MSCI is transmitted once in every mth frame, the user terminals can learn that the frame numbers 0, m, 2m, 3m, 4m etc. contain the information at a predetermined location. Thus, use of BIE to learn the presence of MSCI becomes redundant.

c. The existing approach of using BIE to indicate the presence as well as location of DCD/UCD message is not efficient when a user terminal connected to one BS, referred to as serving BS, wants to learn the MSCI of another BS. For example, a user terminal interested in handoff needs to learn the MSCI of the neighboring BSs and to receive and process all the frames of the neighboring BSs as it does not know in which frame the DCD/UCD messages are present. As the user terminal can communicate with only one BS at a particular time, it needs to take time off from its serving BS when it receives the frames of neighboring BSs. This time off interrupts SS's ongoing communication with the serving BS and results in more power consumption. This problem is aggravated as the number of neighboring BSs, whose MSCI the said user terminal wants to learn, increases.

d. To accommodate for the flexible design of DCD/UCD messages its contents are encoded using TLV format incurring larger overhead for these messages.

2. Advantages

a. The flexibility of DCD/UCD message structure makes it possible for the BS to transmit different system configuration information with required periodicity. In addition, new information fields can be easily added to these messages.

Table 1: MSCI of DCD and UCD messages used by operations with latency requirements per IEEE 802.16m

Network operation	Delay requirement	MSCI DCD fields that are required during the operation	MSCI UCD fields that are required during the operation
Idle_state_to_active_state_transition (this includes ranging as well as MAC, security, IP connection establishment etc)	100 ms	MSCI parameters used for DL/UL synchronization, ranging and MAC establishment	MSCI parameters used for ranging
Intra-frequency handoff interruption	30 ms	MSCI parameters used for DL/UL synchronization and ranging	MSCI parameters used for UL synchronization and ranging
Inter-frequency handoff interruption	100 ms		

1.2 **Summary of Issues with the Reference System DL Control Channel Structure**

There are several issues with the existing control channel structures that motivate a new design for the IEEE 802.16m control channel structure.

1. The size of the DL/UL control channel has a direct impact on the L1/L2 overhead. As discussed in Section 1.1 although DCD/UCD message structure that carries majority of the system configuration information in the reference system is flexible, they have large L2 overhead. This overhead associated with system configuration information transmission mechanism must be reduced in order to meet the requirements on spectral efficiency, sector throughput, and user throughput.
2. As the essential system configuration information are not located at a known location a user terminal has to process all the frames to learn this information. This is inefficient.

Also, there are a few desirable characteristics of SFH design as follows:

1. Meet the latency requirements of network procedures: The transmission mechanism of system configuration information must meet the latency requirement of operations that use this information.
2. Lower L2 overhead: The structure of system configuration information should provide mechanism to reduce L3 overhead associated with the transmission of such information.
3. Known location in IEEE 802.16m frame structure: Essential system parametrs and system configuration information (ESCI) is transmitted using mechanism that is in accordance with the IEEE 802.16m frame structure and has a known location in order for the user terminals to easily locate this.
4. Use of diversity techniques for SFH: SFH should use diversity to improve coverage especially better cell edge performance.

2. Super-frame Header Design Considerations

Discussion of the IEEE 802.16m BCH control channel structures would require a careful consideration of the desired features listed in Section 1.2. The following sub-section proposes methods to achieve each one of these features.

2.1 **Meet the latency requirements of network procedures**

As discussed earlier essential system parameters and system configuration information is used by different network procedures such as initial network entry, network re-entry from idle mode, handoff. In order to meet the latency requirements of these procedures a user terminal has to acquire the essential system parameters and system configuration information in timely manner. Thus, this information needs to be transmitted more frequently to meet the latency requirements of network entry/re-entry. The essential system parameters and system configuration information is transmitted in the broadcast channel (BCH). This contribution proposes methods for the transmission of this information in BCH.

BCH is divided into primary broadcast channel (PBCH) and secondary broadcast channel (SBCH). PBCH is transmitted once in every 20 ms, i.e., in every super-frame

(SFH). On the other hand, the information contents of SBCH are transmitted in every N super-frame. The contents of PBCH and SBCH are shown in shown in **Error! Reference source not found.** and Table 3, respectively.

Table 2: Information fields of PBCH

Information fields	Size (in bits)	Notes
Sector ID	8	
Super-frame number	22	
PHY protocol revision	3	
MAC protocol revision	3	
Number of Tx antennas	3	
System bandwidth (5, 10, 20, others)	3	
CP length (1/32, 1/16, 1/8, 1/4)	2	
Cell type (femto, pico, micro, macro)	2	
UL load indicator	1	
Relay station or BS station indicator	1	
DCD count, UCD count	16 (8, 8)	
Information required for handoff ranging	TBD	
Size, MCS, and repetition coding for CCSCH	TBD	
FFR info for DL region	TBD	
DL Resource configuration information	9	
FFR information for UL region	TBD	
UL Resource configuration information	9	
UL Control Channel's configuration information	4	

Table 3: Information fields of SBCH.

Information fields	Size (in bits)	Notes
Information required for initial ranging	TBD	
Duplex mode (TDD, FDD, HFDD)	2	
DL/UL ratio	3	
Additional subcarrier for multicarrier support	8	
Extended system information location	TBD	

2.2 **Lower L2 overhead**

It is desirable to minimize the L2 over head associated with the transmission of essential system parameters and system configuration information. Therefore, the information that needs to be transmitted frequently is transmitted in every SFH, i.e., PBCH and the remaining information is transmitted in every N SFH.

2.3 **Pre-determined location and transmission format of BCH in IEEE 802.16m frame structure**

A user terminal needs to know the location of the BCH in order to acquire the essential system parameters and system configuration information. The location information of SFH has two aspects: starting location of the SFH and the size of SFH in terms of amount of physical resources, e.g., number of slots. This contribution proposes to transmit SFH in such a way that the starting point of SFH is fixed relative to the IEEE 802.16m preamble. MCS of the SFH is fixed. TX diversity or other multi-antenna techniques that improves control channel reliability at the cell-edge should be used for SFH.

2.4 **Transmission format robustness for BCH**

The transmission format of PBCH and SBCH should increase the probability of successful reception by ussers in different parts of the cell. Towards this both time diversity and macro diversity techniques should be employed without compromising the latency and overhead requirements described in Sections 2.1 and 2.2.

3. Proposed Downlink Control Channel Structure

In the previous sections, some important requirements and considerations in the design of the SFH were discussed. The proposed SFH control channel structures are similar for TDD and FDD duplex schemes resulting in maximal baseband processing commonalities in both duplex schemes (which further include H-FDD) that is highly desirable from implementation perspective. The structure of SFH is described in Section 2.1. Details about location, size, and transmission format of SFH are described in various subsections of Section 2.

4. Proposed text changes for SDD

Modify the text in 11.7.2.2.1 as follows (i.e. Chapter 11 in [3]):

------------------------------- Text Start ---

11.7.2.2.1 Primary Broadcast Channel (PBCH) and Secondary Broadcast Channel (SBCH)

The Primary Broadcast Channel (PBCH) and the Secondary Broadcast Channel (SBCH) carry essential system
parameters and system configuration information. ~~The PBCH carries deployment wide common information.~~ PBCH carries essential system parameters and system configuration information that is required for time critical operations, i.e., operations that have latency requirements., such as handoff, sleep to active transition, idle to active transition etc. ~~The SBCH carries sector~~

~~specific information~~ SBCH carries essential system parameters and system configuration information that is required for non-time critical operations, such as initial network entry, inter-RAT handover etc. The information in the PBCH is transmitted every super-frame ~~and~~ whereas information in SBCH is ~~may be~~ transmitted over N ~~one or more~~ superframes. The value of N is FFS. The information contents of the PBCH and SBCH are shown in Table X and Table Y, respectively.

Table X: Information fields of PBCH

Information fields	Size (in bits)	Notes
Sector ID	8	
Super-frame number	22	
PHY protocol revision	3	
MAC protocol revision	3	
Number of Tx antennas	3	
System bandwidth (5, 10, 20, others)	3	
CP length (1/32, 1/16, 1/8, 1/4)	2	
Cell type (femto, pico, micro, macro)	2	
UL load indicator	1	
Relay station or BS station indicator	1	
DCD count, UCD count	16 (8, 8)	
Information required for handoff ranging	TBD	
Size, MCS, and repetition coding for CCSCH	TBD	
FFR info for DL region	TBD	
DL Resource configuration information	9	
FFR information for UL region	TBD	
UL Resource configuration information	9	
UL Control Channel's configuration information	4	

Table Y: Information fields of SBCH.

Information fields	Size (in bits)	Notes
Information required for initial ranging	TBD	
Duplex mode (TDD, FDD, HFDD)	2	
DL/UL ratio	3	
Additional subcarrier for multicarrier support	8	
Extended system information location	TBD	

11.7.2.2.2 ***Location of BCH***

The SFH is transmitted in first sub-frame within a superframe. The SFH is transmitted over all available symbols in the subframe and spans the minimum system bandwidth in frequency. It is located around the center frequency. The PBCH is located in the SFH and follows the SCH. The SBCH follows the PBCH in the SFH.

------------------------------- Text End --

5. References

[1] IEEE Std. 802.16e-2005, IEEE Standard for Local and metropolitan area networks, Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, and P802.16Rev2/D3 (February 2008).

[2] WiMAX Forum™ Mobile System Profile, Release 1.0 Approved Specification (Revision 1.4.0: 2007-05-02), http://www.wimaxforum.org/technology/documents.

[3] IEEE 802.16m-08/003r4, "The Draft IEEE 802.16m System Description Document"