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Source(s)	Shantidev Mohanty Jose Puthenkulam	shantidev.mohanty@intel.com jose.p.puthenkulam@intel.com
Re:	Call for Contributions on Project 802.16m System Description Document (SDD) – Specifically DL Control Channel design	
Abstract	Partial proposal for method to transmit system parameters and system configuration information required beyond basic connection establishment in DL control channels in IEEE 802.16m	
Purpose	Discussion and Approval	
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Proposal for Efficient Transmission of Certain System Parameters and System Configuration Information in IEEE 802.16m

Shantidev Mohanty and Jose Puthenkulam

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 C80216Mdl_ctrl-08_035-intel.doc. The classification of downlink control information in this contribution is summarized below.

1. Preamble (Synchronization channel (SCH)): This type of control information is required for system timing acquisition and synchronization by the terminals.
2. Broadcast information: Broadcast control information is transmitted with reliable MCS across the cell area. Information intended for all users within the coverage area of a BS with no user or group specific encryption or address is included in this category.
    a. Frame Control Header (FCH): The frame control header is located immediately after the preamble and contains frame control information required to decode the broadcast channel that immediately follows the FCH. It is encoded and modulated with a pre-defined MCS that is known to the terminals.
    b. Basic system parameters and system configuration information: This information also known as short-term system configuration information (SSCI) includes a minimal set of short term system configuration parameters essential for the MS to complete initialization procedures with the serving BS for system entry/re-entry. This information is carried in every super-frame header (SFH), i.e., the transmission frequency of SSCI is 20 ms.
    c. Extended system parameters and system configuration information: Additional system configuration parameters and information not critical for system entry/re-entry, but used by MSs in the long term after initialization procedures are completed. This information is also known as long-term system configuration information (LSCI) is carried in some of the super-frame header. It may be noted that unlike SSCI, LSCI is not present in all super-frame headers, e.g., the transmission frequency of LSCI could be 1 second.
3. Common control and signaling information: Common control and signaling information is intended for all or a specific subset of users as indicated by an explicit and/or implicit MAC layer address. This control information is typically used by users already initialized, but not necessarily registered with the BS. This information includes DL/UL traffic allocations, paging etc.
4. Dedicated control and signaling: Dedicated control and signaling information is intended for a specific user or group of users as indicated by a MAC layer address, in a dedicated resource previously allocated to the users. This control information is typically used by users already registered with the BS.

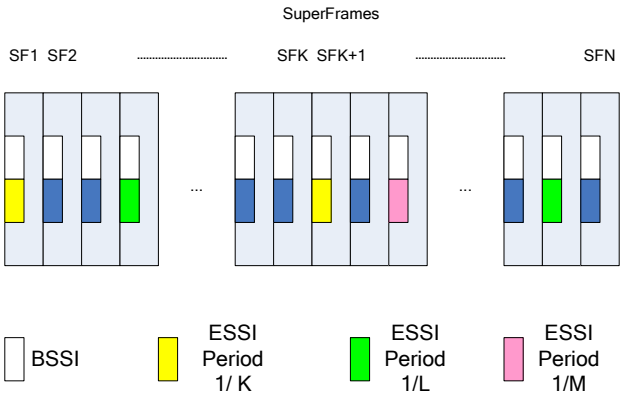

Figure 1: Basic DL control channel using Super Frame Header BSSI and ESSI information

As described earlier basic system parameters and system configuration information (BSSI) is essential for network entry/re-entry. Thus, a subscriber station needs to acquire this information before establishing association with a BS. Thus, the BS is unaware about the presence of SSs that are interested in BSSI. For this matter, the BS can not determine that a particular SS is in need for BSSI. Therefore, the BS needs to broadcast BSSI information so that interested SSs can learn about it. The Figure 1 shows such broadcast of BSSI information every 802.16m 20ms super frame.

On the other hand, some part of extended system parameters and system configuration information (ESSI) (as shown in figure 1) are required for operations after an SS performs successful network entry/re-entry, i.e., after an SS is associated with a BS. Thus, this information is used to perform connected mode related operations such as ESSI required for hybrid automatic repeat request (HARQ) operation, CQICH operation, bandwidth request, AMC operation, etc. This part of ESSI is referred to as ESSI-beyond-association (ESSI-A) in the remaining part of this document and also illustrated in Figure 2. Whenever a new SS performs association with a BS, the BS can determine what part of ESSI-A is required by the SS. For example, if the SS is not going to use AMC, then it does not require ESSI-A related to AMC. After the BS determines the exact ESSI-A information fields that are of interest to a newly associated SS, it can send these information fields using a unicast MAC management message to the SS. Therefore, the BS can use MCS that is suitable to SS's channel condition instead of using the most robust MCS that is used when it broadcast ESSI-A information fields.

In this contribution an attempt has been made to determine the control information fields that belong to ESSI-A. Then, different methods are proposed using which a BS can unicast ESSI-A control information fields to SSs.

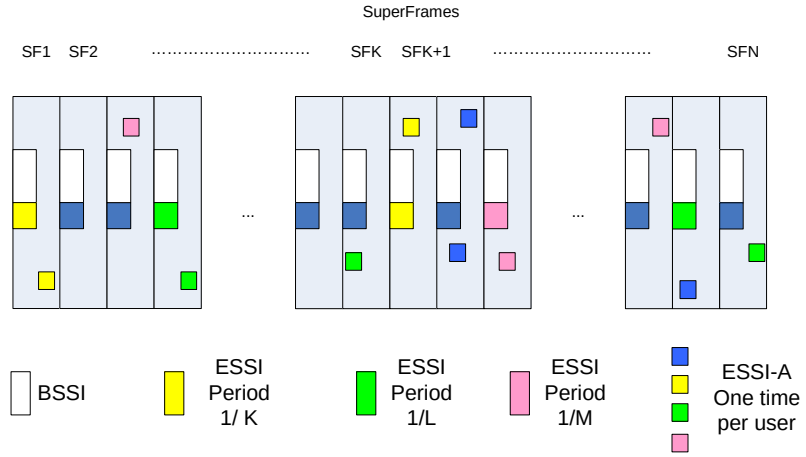

Figure 2: Basic DL control channel using Super Frame Header BSSI and ESSI and ESSI-A Unicast information one time per user

It is imperative to identify the issues associated with broadcasting ESSI-A information fields in the reference system [2] before providing details about the proposed solution. Therefore, in the following section the contents of DCD/UCD messages that carry majority of BSSI and ESSI information fields in mobile WiMAX reference system are critically reviewed.

1.1 **Analysis of ESSI-A transmission mechanism in IEEE 802.16e-2005 STD**

In IEEE 802.16e-2005 STD majority of ESSI is transmitted using downlink channel descriptor (DCD) and uplink channel descriptor (UCD) messages. Therefore, the following analysis focuses on DCD/UCD messages and determines the fields of these messages that belong to ESSI category.

- 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 SSs 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.

The information content of DCD and UCD messages can be classified into two groups: BSSI and ESSI. Table 1 and Table 2 shows the classification of DCD and UCD information fields, respectively.

Table 1: Analysis of DCD information fields.

Index	Information fields	Size (in bytes)	Category	ESSI-A (Yes/No)	Notes
1	Downlink burst profile	variable	BSSI		
2	BS EIRP	16	BSSI		
3	Channel Nr	8	BSSI		
4	TTG	16	BSSI		
5	RTG	8	BSSI		
6	$EIR_X P_{IR,\ MAX}$	16	BSSI		
7	Channel switch frame number	24	BSSI		Non-license operation
8	Frequency	32	BSSI		
9	BS ID	48	BSSI		
10	HARQ ACK delay for UL burst	8	ESSI	Yes	
11	MAC version	8	BSSI		
12	Permutation type for broadcast region in HARQ zone	8	BSSI		
13	maximum retransmissions	8	ESSI	Yes	
14	Default RSSI and CINR averaging parameters	8	BSSI		
15	DL AMC allocated physical bands bitmap	48	Not sure		
16	Available DL Radio resources	8	Not sure		
17	DL region definition		BSSI		
18	HO type support	8	ESSI	Yes	
19	H_Add_Threshold	8	ESSI	Yes	
20	H_Delete_Threshold	8	ESSI	Yes	
21	ASR (Anchor Switch Report) Slot Length (M) Switching Period (L)	8			
22	Paging Group ID	16	ESSI		
23	Hysteresis margin	8	Not sure		

24	Timer-to-trigger duration	8	Not sure		
25	Trigger		Not sure		
26	MIH capabilities	8	BSSI		
27	NSP change count TLV	8	BSSI		
28	cell type TLV	8	BSSI		
29	MBS zone identifier list		BSSI		
30	Default HO RSSI and CINR averaging parameters	16	ESSI	Yes	
31	Dowlink burst profile for multiple FEC types	8	BSSI		
32	BS restart count	8	BSSI		
33	TUSC1 permutation active subchannels bitmap	72	Not sure		
34	TUSC1 permutation active subchannels bitmap	104	Not sure		

Table 2: Analysis of UCD information fields.

Index	Information fields	Size (in bytes)	Category	ESSI-A (Yes/No)	Notes
1	Initial ranging codes	8	BSSI		
2	Periodic ranging codes	8	ESSI	Yes	
3	Bandwidth request codes	8	ESSI	Yes	
4	Periodic ranging backoff start	8	ESSI	Yes	
5	Periodic ranging backoff end	8	ESSI	Yes	
6	Start of ranging codes group	8	BSSI		
7	Permutation base	8	BSSI		
8	UL allocated subchannels bitmap	72	BSSI		
9	Optional permutation UL Allocated subchannels bitmap	104	Not sure		
10	Band AMC Allocation Threshold	8	ESSI	Not sure	
11	Band AMC Release Threshold	8	ESSI	Not sure	
12	Band AMC Allocation Timer	8	ESSI	Not sure	
13	Band AMC Release Timer	8	ESSI	Not sure	
14	Band Status Reporting MAX period	8	ESSI	Not sure	
15	Band AMC Retry Timer	8	ESSI	Not sure	
16	Safety Channel Allocation Threshold	8	ESSI	Not sure	
17	Safety Channel Release Threshold	8	ESSI	Not sure	
18	Safety Channel Allocation Timer	8	ESSI	Not sure	
19	Safety Channel Release Timer	8	ESSI	Not sure	
20	Bin Status Reporting MAX Period	8	ESSI	Not sure	
21	Safety Channel Retry Timer	8	ESSI	Not sure	
22	HARQ ACK delay for DL burst	8	ESSI	Yes	
23	CQICH Band AMC-Transition Delay	8	ESSI	Yes	
24	UL AMC Allocated physical bands bitmap	48	Not sure		
25	Maximum retransmission	8	ESSI	Yes	
26	Normalized C/N override	64	Not sure		
27	Size of CQICH_ID field	8	ESSI	Yes	
28	Normalized C/N override 2	8	Not sure		
29	Band AMC Entry Average CINR	8	Not sure		
30	$\text{UpperBound}_{\text{AAS\_PREAMBLE}}$	8	Not sure		
31	LowerBoundAAS_PREAMBLE	8	Not sure		
32	Allow AAS Beam Select Messages	8	Not sure		
33	Use CQICH indication flag	8	ESSI	Yes	
34	MS-specific up power offset adjustment step	8	ESSI	Yes	
35	MS-specific down power offset adjustment step	8	ESSI	Yes	
36	Minimum level of power offset adjustment	8	BSSI		
37	Maximum level of power offset adjustment	8	BSSI		
38	Handover Ranging Codes	8	ESSI	Yes	
39	Initial ranging interval	8	BSSI		
40	Tx Power Report	24	ESSI	Yes	
41	Normalized C/N for Channel Sounding	8	Not sure		
42	Initial ranging backoff start	8	BSSI		
43	Initial ranging backoff end	8	BSSI		
44	Bandwidth request backoff start	8	ESSI	Yes	
45	Bandwidth request backoff end	8	ESSI	Yes	

46	Uplink burst profile for multiple FEC types	8	BSSI		
47	UL PUSC Subchannel Rotation	8	BSSI		
48	Relative Power Offset For UL HARQ burst	8	Not sure		
49	Relative Power Offset for UL Burst Containing MAC Management Messages	8	Not sure		
50	Fast Feedback Region	40	ESSI	Yes	
51	HARQ Ack Region	32	ESSI	Yes	
52	Ranging Region	40	BSSI		
53	Sounding Region	40	BSSI		
54	MS Transmit Power Limitation Level	8	BSSI		
55	UL initial transmit timing	8	BSSI		

Using Table 1 and Table 2, it is observed that several fields of these messages belong to ESSI-A category.

- As discussed earlier, the BS could send these messages in a unicast manner to the SSs after they associate with it.
- It may be noted that if the BS determines that several SSs needs this information at a particular time and it could broadcast ESSI-A information instead of sending this in a unicast manner.
- Thus, the BS has the option to use either unicast or broadcast message format to send the ESSI-A information to the SSs based on the number of SSs that needs this information at a particular time.
- When the BS broadcasts the ESSI-A information to the SSs it usually transmit this information periodically. Thus, an SS upon successful association with a BS waits for average duration equal to half this periodicity to receive ESSI-A information. However, when the BS unicasts ESSI-A information to an SS, it could do so immediately after SS's successful association. This reduces ESSI-A acquisition time for the SS that could in tern reduce the time that the SS wait.

Thus, both broadcast and unicast of ESSI-A have advantages and disadvantages. For example, when large number of SSs require the same ESSI-A at a particular time, it is better to broadcast the information. On the other hand, when smaller number of SSs require ESSI-A information, it is better to unicast the information. As the BS has knowledge about the number of SSs that requires ESSI-A information it can determine which one of these two approaches is suitable at a particular time. The BS can use the following algorithm to decide whether broadcast ESSI-A or unicast that to the SS(s).

N = Number of SSs that needs ESSI-A at a given time
M_b = Amount of physical layer resources required to transmit 1 bit information using the MCS used to broadcast the ESSI-A
M_1-M_n= Amount of physical layer resources required to transmit 1 bit information using the MCS_1 to MCS_n when BS unicast ESSI-A
p_i = probability of selection of MCS_i

If N is such that

$$M_b > (\sum_{k=1}^{n} p_k M_k) N \quad \text{------- Eq (1)}$$

$$N < \frac{M_b}{\sum_{k=1}^{n} p_k M_k} \quad \text{------- Eq (2)}$$

Thus, when N satisfies Eq. (2) BS may unicast ESSI-A instead of broadcast. The MCS schemes that are used to derive N and their probability of selection for an SS are shown in Table 3. It may be noted that table should be considered as an example scenario. The remits of this proposal is valid for other distributions of p_k as well, although the value of N is different for different p_k distributions.

Table 3: Different MCS schemes and their probability distribution.

Burst Profile Index/MCS Index (k)	Burst Profile (M_k)	Repetition	Probability of this MCS (p_k)
1	QPSK 1/2	6	0
2	QPSK 1/2	4	0
3	QPSK 1/2	2	0.3074
4	QPSK 1/2 STBC	1	0.2131
5	QPSK 3/4 STBC	1	0.061
6	16 QAM 1/2 STBC	1	0.2195
7	16 QAM 3/4 STBC	1	0.0369
8	64 QAM 1/2 STBC	1	0.0862
9	64 QAM 2/3 STBC	1	0.0291
10	64 QAM 3/4 STBC	1	0.0221
11	64 QAM 5/6 STBC	1	0.0141
12	QPSK 1/2 SM	1	0.0007
13	QPSK 3/4 SM	1	0.0001
14	16 QAM 1/2 SM	1	0
15	16 QAM 3/4 SM	1	0.0061
16	64 QAM 1/2 SM	1	0.0036
17	64 QAM 2/3 SM	1	0.0001
18	64 QAM ¾ SM	1	0
19	64 QAM 5/6 SM	1	0

Using Table 3 and Eq. (2) the values of N when different types of MCS are used for broadcast are shown in.

Table 4: Value of N for different MCS used for broadcast.

Burst profile used for broadcast	Repetition used for broadcast	N
QPSK 1/2	6	9.6
QPSK 1/2	4	6.4
QPSK 1/2	2	3.2

The number of SSs that require ESSI-A depends on the number of new SSs that associate with a BS. This number depends on the interval over which the number is determined. This interval determines the average ESSI-A acquisition delay. Using Table 4 the BS decides to either broadcast or unicast the ESSI-A information. The numbers in Table 4 consider probability distribution of different MCS schemes to determine N. A BS could use real-time knowledge about the MCS requirements of

different SSs to determine more accurate N as it is aware about the SSs that are in need for ESSI-A at any given time and their MCS.

Comparison of amount of PHY resources used to transmit ESSI-A for broadcast and unicast scenarios are shown in Figure 3. It can be observed that for any given MCS for broadcast the amount of PHY layer symbols (that is also equal to the number of PHY layer sub-carriers) used to unicast the transmit ESSI-A is less compared to the scenario where ESSI-A is broadcasted as long as the number of SSs that require ESSI-A is less than a certain value, referred to as N in Eq. (2). The value of N depends on the MCS used for broadcast as shown in Table 4.

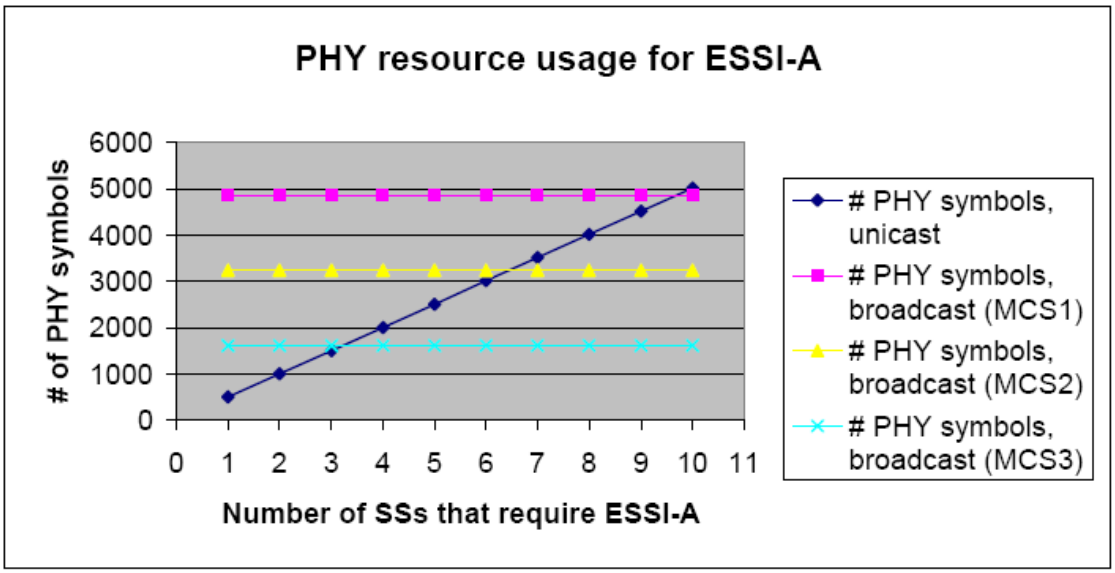

Figure 3: Comparison of PHY resources used for ESSI-A with broadcast and unicast for different number of SSs that require this information at a particular time.

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

As discussed in the earlier section, broadcasting of ESSI-A may not be efficient under certain condition. This may incur unnecessary overhead.

2. ESSI-A Transmission Mechanism Design Considerations

As discussed earlier a BS could use the parameters discussed in Section 1 to determine the appropriate method: broadcast or unicast to send ESSI-A information to the SSs.

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

As discussed when the BS broadcasts ESSI-A information to the SS periodically an SS the average ESSI-A acquisition delay is half of this period. This could potentially

increase the call set up time for an SS if the SS performs association with the BS just before the call. The proposed method to send the ESSI-A to SSs using unicast method can reduce this delay, especially for those applications that require low call set-up delay.

2.2 **Transmission format suitable for ESSI-A:**

IEEE 802.16m systems transmits ESSI-A information using either broadcast or unicast methods using criteria's discussed earlier. A BS can determine using Eq. (2) whether to broadcast or unicast the ESSI-A information to the SSs.

3. Proposed Downlink Control Channel Structure

In the previous sections, some important requirements and considerations in the design of transmission format for ESSI-A were discussed. Using this contribution BS uses both broadcast and unicast methods to send ESSI-A. When the BS unicasts ESSI-A information it uses one of following methods (shown in Figure 4).

- Individual MAC management message containing ESSI-A
- Piggybacking the ESSI-A information in another MAC management message.
- Piggybacking the ESSI-A in a data packet.

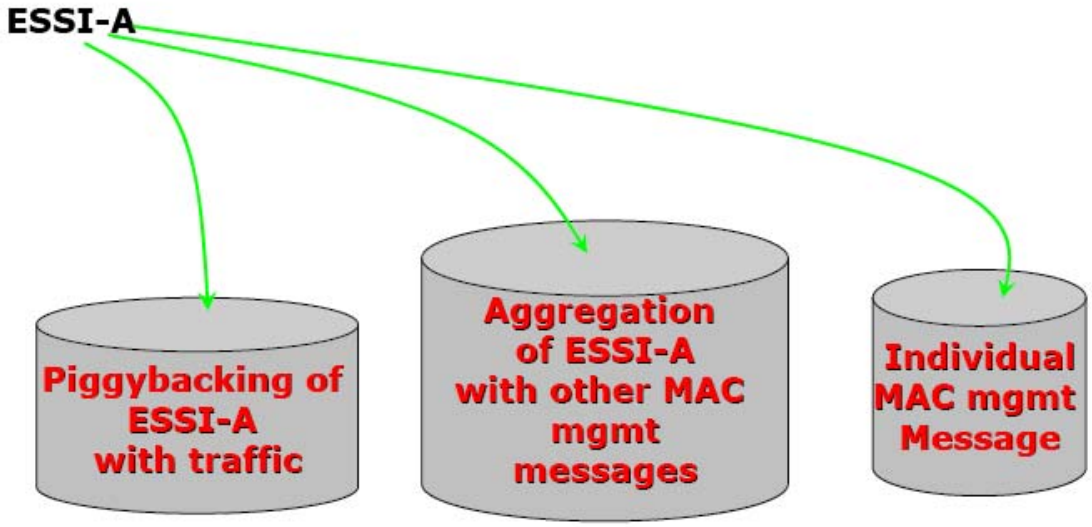

Figure 4: Methods used during unicast of ESSI-A.

4. Proposed Text for SDD

Insert the following text into Downlink Control Structure sub-clause (i.e. Chapter 11.x.1.7 in [3]):

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

In the table modify the table as follows:

Information/Type	Control Channel	Location
Synchronization information	Synchronization Channel (SCH)	TBD
Essential system parameters and system configuration information	[Broadcast Channel (BCH)] [Primary Broadcast Channel (PBCH)] [Primary Broadcast Channel (PBCH) and Secondary Broadcast Channel (SBCH]	Part of SFH
Extended system parameters and system configuration information	[Broadcast Channel (BCH)] [Secondary Broadcast Channel (SBCH)] [Broadcast or Unicast MAC management message]	[Part of SFH] [Outside SFH]
Control and signaling for DL notifications	TBD	Outside SFH, location TBD
Control and signaling for traffic	TBD	Outside SFH, location TBD

---------- 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-08/003, “The Draft IEEE 802.16m System Description Document”