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Title	**Enhancement on Sleep Mode operation in the 802.16e**
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Re:	This is a response to a Call for Comments IEEE 802.16e-03/18 on IEEE 802.16e-03/07r3
Abstract	This document contains suggestions on enhancement of Sleep Mode operation in 802.16e.
Purpose	The document is submitted for review by 802.16e Working Group members.
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Patent Policy and Procedures	

Enhancement on Sleep Mode operation in 802.16e

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I. Background

To support mobility operation by reducing the power consumption of the mobile SS, the sleep mode operation for the IEEE 802.16e was suggested [1]. And the other ideas to enhance the original ideas have been proposed [2-3], and was reflected in the 802.16e working document [4].

But it leaves much room for improvements. We suggest in this document the enhancement of the Sleep Mode to enable grouped management and announcing by slight change of the original idea.

We suggest the following ideas:

1. We should not see the listening interval as the awake mode because in this period the MSSs should only listen (or receive) the traffic indication but not transmission. We can see this period as the half sleeping state and as the parts of the incoming sleeping interval. Thus we suggest the next sleeping interval doubled from the former sleeping interval to be started from the very next frame after the sleeping interval expires whatever the listening interval is set.
2. In the original Sleep Mode concept, the initial-sleep window, final-sleep window, and even the listening intervals can be different for each MSS, and the sleeping interval is started from the next frame after the listening interval. Generally for these situations, the BS should manage the sleep mode operations of all MSSs in the sleep mode virtually in every frame. Since the sleep intervals of each MSS cannot be aligned, that will give lots of the processing burdens to the BS. We will show some advantages of grouping by some examples.
3. We will suggest to add a DSS (Data to the Sleep Mode SSs) field to the DL_Frame_Prefix by using a reserved bit to indicate the presence of the Traffic Indication messages in this frame and also direct the listening interval adaptively under the consideration of the amount of the traffic and cell loading. Thus we cannot necessary to negotiate and apply the fixed length of the listening interval, and it will improve the power saving efficiency of the MSSs in the sleep mode. Furthermore, it also reduce the signaling overhead by not transmitting the unnecessary listening intervals between the BS and the MSSs.

II. Suggestions on changes in IEEE 802.16e-03/07r3

[Change 6.2.2.3.40 in IEEE 802.16e-03/07r3 to:]

6.2.2.3.40 Sleep Request message (MOB_SLP-REQ)

SS supporting sleep-mode uses the MOB_SLP-REQ message to request permission from the BS to enter sleep-mode. The MOB_SLP-REQ message is sent from the SS to the BS on the SS's basic CID.

Table 56aa-Sleep-request (MOB_SLP-REQ) message format

Syntax	Size	Notes
SLP-REQ_Message_Format( ) {		
Management Message type = 45	8 bits	
Initial-sleep window	6 bits	
Final-sleep window	10 bits	
~~Listening interval~~	~~8 bits~~	
}		

Parameters shall be as follows:

Initial-sleep window
Requested start value for the sleep interval (measured in frames)
Final-sleep window
Requested stop value for the sleep interval (measured in frames)
~~**Listening interval**~~
~~Requested listening interval (measured in frames)~~

[Change 6.2.2.3.41 in IEEE 802.16e-03/07r3 to:]

6.2.2.3.41 Sleep Response message (MOB_SLP-RSP)

The MOB_SLP-RSP message shall be sent from BS to an MSS on the SS's basic CID in response to an MOB_SLP-REQ message, or may be sent unsolicited. The SS shall enter sleep-mode using the parameters indicated in the message.

Table 56ab-Sleep-Response (MOB_SLP-RSP) message format

Syntax	**Size**	**Notes**
SLP-REQ_Message_Format( ) {		
Management Message type = 46	8 bits	
Sleep-approved	1 bit	0: Sleep-mode request denied 1: Sleep-mode request approved
If (Sleep-approved == 0) {		
Duration	7 bits	
} else {		
Start frame	7 bits	Lower byte of the frame number, in which the SS shall enter into sleep mode
Initial-sleep window	6 bits	
Final-sleep window	10 bits	
~~Listening interval~~	~~8 bits~~	
}		

Parameters shall be as follows:

Sleep approved
Defines whether or not the request to enter sleep-mode has been approved by the BS.
Start-frame
Defines the lsb 7 bits of the frame number, in which the SS shall enter into sleep mode.
Initial-sleep window
Requested start value for the sleep interval (measured in frames)
Final-sleep window
Requested stop value for the sleep interval (measured in frames)
~~**Listening interval**~~
~~Requested listening interval (measured in frames)~~

[Change 6.2.16.1 in IEEE 802.16e-03/07r3 to:]

6.2.16.1 Introduction

Sleep-mode is a mode in which SS's supporting mobility may power down. Sleep-mode is intended to enable mobility-supporting SS's to minimize their energy usage while staying connected to the network. Implementation of power-save mode is optional.

An SS that supports sleep-mode can be in one of the two modes:

Awake
Sleep

When an SS is in awake-mode, it is receiving and transmitting PDUs in a normal fashion. When the SS is in a sleep-mode, it does not send or receive PDUs. In sleep-mode the SS may power down.

Two intervals are defined:

Sleep-interval
A time duration, measured in whole frames, where the SS is in sleep-mode. During consecutive sleep periods the sleep-interval shall be updated using an exponentially increasing algorithm with adjustable minimum and maximum limits.
Listening-interval
Length, measured in whole frames, of the listening period in the sleep mode of operation. It is the period of the frames which the DSS (Data to the Sleep mode SSs) indicator bit field is enabled (set to "1") in the DL_Frame_Prefix (in OFDM and OFDMA) or DL-MAP (in SC and SCa). ~~of the listening interval.~~ During this interval the SSs shall decide whether to stay awake or go back to sleep based on an indication from the BS. The listening-interval duration is determined by the BS considering the amount of the Traffic Indication messages to indicate and cell loading. ~~negotiated between the BS and the SS.~~

Before entering sleep-mode the SS shall inform the BS and obtain its approval. The BS may buffer (or it may drop) incoming PDUs addressed to the sleeping SS, and shall send a notification to the SS in its ~~awakening~~ listening periods about whether data has been addressed for it.

An SS shall ~~awake~~ listen according to the sleep-interval indicated by the DSS field in the DL_Frame_Prefix and check whether there were PDUs addressed for it. If such PDUs exist, it shall ~~remain~~ awake. An SS may terminate sleep-mode and return to awake-mode any-time (i.e., there is no need to wait until the sleep-interval is over). If the BS receives an MPDU from an SS that is supposed to be in sleep-mode, the BS shall assume that the SS is no longer in sleep-mode.

Traffic indication message (TRF-IND) shall be sent by the BS on the broadcast CID periodically. ~~If the number of positive indications is zero, the BS sends an empty indication message, that is, TRF-IND message with num-positive = 0.~~

When its sleeping-interval timeouts, the SSs shall ~~awake to~~ listen to DSS (Data to Sleep Mode SSs indicator) and the DL transmissions until it receives a TRF-IND message in the case of positive DSS. If there is a positive indication to the SS, it shall ~~remain~~ awake. Otherwise, the SSs may return to its sleep-mode by power down the receiving parts. The BS can select the duration of the listening interval by setting the DSS fields to "1" of the corresponding frame and thus the listening interval can be changed adaptively without notifying explicitly fixed duration of the frames.

~~In this way, the listening interval parameter is no longer needed to be negotiated between SS and BS in the SLP-REQ and SLP-RSP messages. The interval between two TRF-IND messages sent by the BS is the maximum listening interval for all SS's supporting sleep-mode. It can be sent in the SLP-RSP message only.~~

[Change 6.2.16.2 in IEEE 802.16e-03/07r3 to:]

6.2.16.2 Sleep-interval update algorithm

An SS shall enter sleep-mode after receiving an SLP-RSP message from the BS. In the first time it enters sleep-mode, it shall use the initial-sleep window value for the sleep interval. If during the following listening interval the BS has not signaled that traffic has been addressed for the SS, the SS shall re-enter sleep-mode counted from the first frame after the last listening interval with a doubled duration of the sleep interval.~~sleep-mode an double the duration of the sleep-interval.~~ This procedure shall be repeated as long as the resulting sleep-interval does not exceed the final-sleep window value.

[In 8.5.4.3 in IEEE 802.16a-2003 change the table 116bm and its descriptions as follows:]

8.5.4.3 DL Frame Prefix

Table 116bm – OFDMA DL Frame Prefix

Syntax	Size	Notes
DL_Frame_Prefix_Format( ) {		
Rate_ID	4 bits	
~~Reserved~~	~~4 bit~~	
Data_to_SleepMode_SSs	1 bit	Indicator bit for the presence of the Data to

		Sleep Mode SSs in this frame.
Reserved	3 bit	
DL_Information_Message_Rectangle( ) {		
No_OFDM_Symbols	6 bits	
No_Subchannels	10 bits	
}	8 bits	
Prefix_CS		
}		

The fields in Table 116bm are defined as:

Rate_ID:
Enumerated field that describes the modulation/coding of the DL-MAP message. Encoding values of the Rate_ID field are defined in Table 116ao.

Data_to_Sleep Mode_SSs:
Indicates the presence of the data to the sleep mode SSs in this frame.

No_OFDM_Symbols:
Indicates the number of OFDM symbols for the Dl_MAP message starting from the first symbol of the frame.

No_Subchannels:
Indicates the number of subchannels for the DL_MAP message starting from subchannel 0.

Prefix_CS:
An 8-bit checksum for the DL-frame prefix fields, with the generator polynomial:
$g(D) = D^8 + D^2 + D + 1$.

The remaining bytes of the first FEC block may contain the beginning of the frame control information (Dl-MAP).

References:

[1] IEEE C802.16e-03/15r1 “IEEE 802.16e Sleep Mode”
[2] IEEE C802.16e-03/32 “Supporting Material for Comments on Sleep Mode”
[3] IEEE C802.16e-03/37 “Mode change deny in IEEE 802.16e Sleep Mode”
[4] IEEE 802.16e-03/07r3 “IEEE 802.16 TGe Working Document”