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Re:	This is a response to a Call for Comments IEEE 802.16e-03/58 on IEEE 802.16e-03/07r5
Abstract	This document contains proposal to enhance the sleep mode operation by grouping of sleep mode terminals.
Purpose	The document is submitted for review by 802.16e Working Group members.
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Enhancement on Sleep Mode Operation by Grouping

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1. Background

In IEEE 802.16e-03/07r5, an MSS which is hoping to entering sleep mode sends a MOB_SLP-REQ message to the BS, then the BS responds with a SLP-RSP message with the sleep mode parameters of initial-sleep window, final-sleep window, listening interval and start frame. Each sleep mode parameters have no special constraints except for the minimum initial sleep window to be larger than 2 frames and final sleep window to be less than 1024 frames. Therefore, sleep interval expiration will be occurred in any frame. Thus, the BS should have manage all the sleep mode MSSs in each of the frame to check data buffered to them and indicate to the them.

BS assigns a SLPID to the sleep mode MSS when it is entering to a sleep mode as an index in a TRF-IND message. The SLPID has the meaning of its bit location on the bitmap indication field in the TRF-IND message. When there is a data buffered to a specific MSS, BS should set the bitmap field in the TRF-IND message and send it to the sleep mode MSSs.

An MSS 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 MSS, the MSS shall re-enter sleep mode by doubling 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. The duration of the k-th sleep interval I_k shall be determined by the following formula:

$$\begin{cases} I_0 = \text{initial - sleep window} \\ I_k = \min(2 \cdot I_{k-1}, \text{final - sleep window}\} \; k > 0 \end{cases}$$

The next sleep interval window shall start from the end of the previous one. When the MSS has reached the final-sleep window size, it shall continue in sleep mode without further increasing the sleep-interval. ~~The next sleep interval window shall start from the end of the previous one.~~

TRF-IND message indicate the presence of each MSS's downlink traffic by SLPID bitmaps. When the number of sleep mode MSSs (more precisely, the index of the largest numbered assigned SLPID of a sleep mode MSS) is N, then the SLPID bitmap size in the TRF-IND message will be the *Ceiling (N/8)*8* bits.

Since there are no restrictions to the sleep mode parameters of MSSs, TRF-IND messaging can be possible to concentrate in a certain frame. But the bitmap indication scheme is required no additional signaling overhead than the Basic CID list-up scheme. And it can be notified in only one frame not relating to the number of MSSs indicated by the TRF-IND message. Therefore, the listening interval of one frame is sufficient.

In spite of these advantages of this bitmap indication scheme, there are some problems. When we assume the index of the largest numbered assigned SLPID (not the same with the total number of SLPID) to N, and the number of MSSs notified by the TRF-IND in a certain frame to M, then in the following cases the Basic CID list-up scheme is more efficient than the SLPID bitmap scheme:

$$M < (1/2)\text{*Ceiling}(N/8).$$

What schemes are more efficient may depends on the traffic models and main service types provided by the BS.

To reduce the signaling overhead in SLPID bitmap scheme and to enhance the sleep mode management, we propose in this contribution the scheme of grouping of sleep mode MSSs by evenly distribute the sleep mode MSSs to each of the sleep groups. In each sleep group, the expiration time cannot be crossed to each other group's expiration frames. By applying this scheme, BS can reduce the signaling overhead in the SLPID bitmap to 1/(Number of Sleep Groups).

BS can manage the sleep mode MSSs by separate groups. In this case, the BS can independently assign SLPIDs to each sleep groups, and the sleep interval expiration frames shall not be crossed between each other sleep groups.

BS may use the sleep grouping scheme of the sleep mode MSSs.

To apply the sleep grouping scheme to the sleep mode MSSs, the following constraints shall be maintained:

1) Initial-sleep window are allowed to have the value of integer multiple of BS's minimum initial-sleep window.

2) Final-sleep window are allowed to have the value of integer multiple of BS's minimum initial-sleep window. For example, when the minimum initial-sleep window allowed by a BS is 2 frames, then the BS should set the initial-sleep window and final-sleep window to the values of the integer multiple of minimum initial-sleep window (such as initial-sleep window = 4, final-sleep window = 10).

3) BS assigns the sleep mode MSS to one of the sleep groups managed by itself. BS check the number of each sleep group's member elements, and assign the MSS to the group of having small member elements. And set the start frame value as the MSS can be the element of the assigned sleep group. When there are N different sleep groups operated by a BS, and sleep group assigned to the MSS is G_k, then the start frame will be the frame satisfying the relation:

$$k = \text{start\_frame\_value modulo } N.$$

4) The number of sleep groups BS can have shall be less than the number of the minimum initial-sleep window value (measured by frames) BS can manage.

For example, if we apply the Number of Sleep Groups = 4, then the initial-sleep window and final-sleep window allowed by the BS to each sleep mode MSS should be integer multiples of 4 (4, 8, 12, …). Then the SLPID bitmap size in the TRF-IND message will be 1/4 times of that of the ungrouped original scheme. These constrains of the cases of Number of Sleep Groups = 4 are reasonable and easily applicable to any situations.

Figure 1 shows an example of current sleep mode operation. Since the initial-sleep window, final-sleep window have no constraints, expiration frames of each MSS's sleep interval can coincide in the same frame.

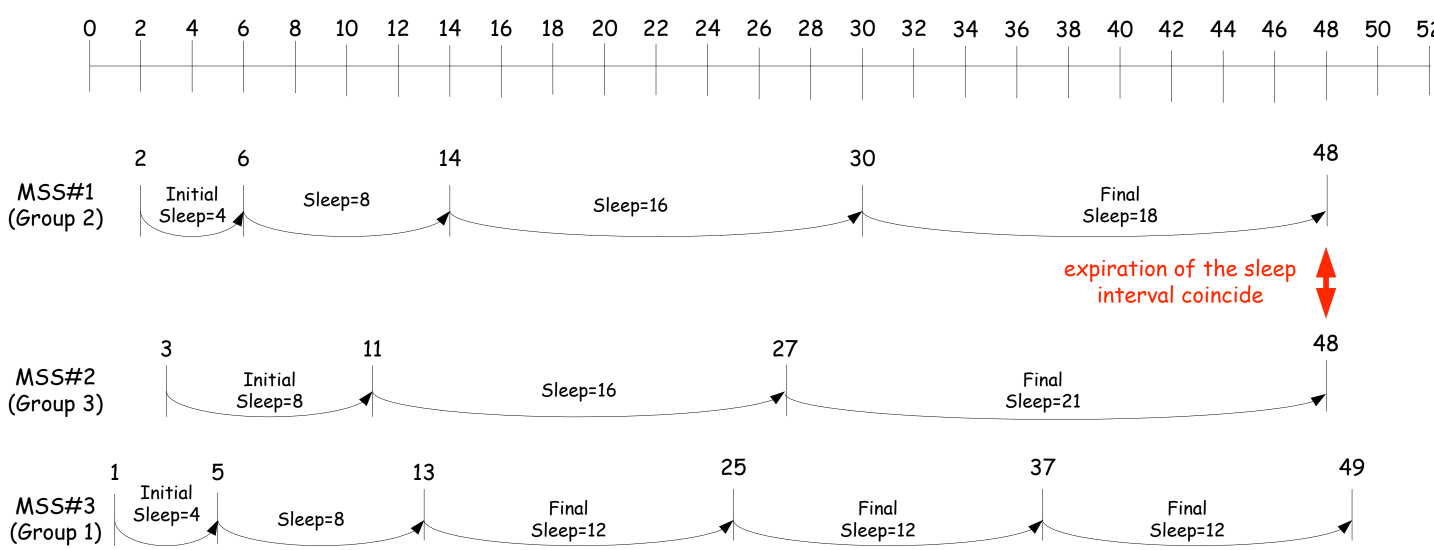

Figure 1. Example of the current sleep mode operation

Figure 2 shows an example of sleep mode operation when the MSSs are grouped by the scheme proposed in this contribution. As it can be seen, each MSS is expired in each group's frames.

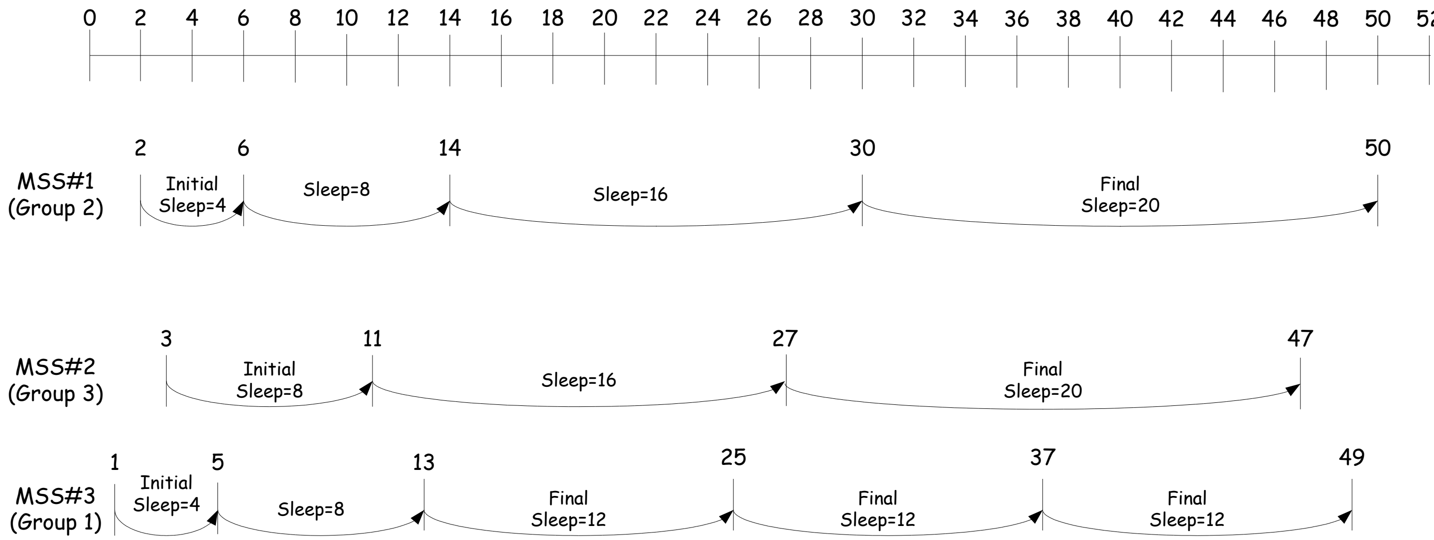

Figure 2. Example of the proposed sleep mode operation by grouping

2. Proposed changes on IEEE 802.16e-03/07r5 baseline text.

6.4.2.3.42 Sleep Request message (MOB_SLP-REQ)

MSS supporting sleep-mode use 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 MSS's basic CID.

Table 85a – Sleep-Request (MOB_SLP-REQ) message format

Syntax	Size	Notes
MOB_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 final value for the sleep interval (measured in frames).
~~**Listening interval**~~
~~Requested listening interval (measured in frames) to the MOB_SLP-REQ.~~

6.4.2.3.43 Sleep Response message (~~M0B~~MOB_SLP-RSP)

~~T~~The MOB_SLP-RSP message shall be sent from BS to a MSS on the MSS's basic CID in response to an MOB_SLP-REQ message, or may be sent unsolicited. The MSS shall enter sleep-mode using the parameters indicated in the message. In the case where sleep is denied (After-REQ-action = 1), it is recommended that the BS provide unsolicited MOB_SLP-RSP message.

Table 85b – Sleep-Response (MOB_SLP-RSP) message format

Syntax	ize	Notes
MOB_SLP-RSP_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) {		
After-REQ-action	1 bit	0: The MSS may retransmit the MOB_SLP-REQ message after the time duration (REQ-duration) given by the BS in this message. 1: The MSS shall not retransmit the MOB_SLP-REQ message and shall await the MOB_SLP-RSP message from the BS.
REQ-duration	~~4~~ 6 bits	The duration for case where After-REQ-action value is 001.
else {		

Start frame	7 bits	
initial-sleep window	6 bits	
final-sleep window	10 bits	
~~listening interval~~	~~8 bits~~	
SLPID	16 bits	Allowed range: 0..1023
}		
}		

Parameters shall be as follows:

Sleep approved
The activation indication of the MSS when the MSS receives this message from the BS.

After-REQ-~~duration~~action
On MSS request to enter sleep mode rejected by the BS, indicate recourse action.

REQ-duration
Waiting value for the MOB_SLP-REQ message re-transmission (measured in MAC frames).

Start-frame
Lower byte of the frame number in which the MSS shall enter into sleep mode.

Initial-sleep window
Requested start value for the sleep interval (measured in frames).

Final-sleep window
Requested final value for the sleep interval (measured in frames).

~~**Listening interval**~~
~~Requested listening interval (measured in frames) to the MOB_SLP-REQ.~~

SLPID
This is a number assigned by the BS whenever an MSS is instructed to enter sleep-mode. This number shall be unique in the sense that it is assigned to a single MSS that is instructed to enter sleep-mode. No other MSS shall be assigned the same number while the first MSS is still in sleep-mode.

[Add the followings to the end of this section]

BS can manage the sleep mode MSSs by separate groups. In this case, the BS can independently assign SLPID to each sleep group, and the sleep interval expiration frames shall not be crossed between each other sleep groups. BS may use the sleep grouping scheme of the sleep mode MSSs. To apply the sleep grouping scheme to the sleep mode MSSs, the following constraints shall be maintained:

1) Initial-sleep window are allowed to have the value of integer multiple of BS's minimum initial-sleep window.

2) Final-sleep window are allowed to have the value of integer multiple of BS's minimum initial-sleep window.

3) BS assigns the sleep mode MSS to one of the sleep groups managed by itself. BS check the number of each sleep group's member elements, and assign the MSS to the group of having small member elements. And set the start frame value as the MSS can be the element of the assigned sleep group. When there are N different sleep groups operated by a BS, and sleep group assigned to the MSS is G_k, then the start frame will be the frame satisfying the relation:

$$k = \text{start\_frame\_value modulo } N.$$

4) The number of sleep groups operated by a BS shall be less than the number of the minimum initial-sleep window value (measured by frames) the BS can manage.