Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**IEEE802.16e Sleep Mode**
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Re:	Call for contribution IEEE 80216e-02_01
Abstract	This document presents the needed enhancements that can be done to the IEEE802.16a standard in order to support mobility operation by reducing the power consumption of the mobile SS. In order to reduce the power consumption of the SS, we propose to use a sleeping mode technique. The contribution provides a general description of the proposed technique and provides the exact addition required to add this mode to the standard.
Purpose	Present how the IEEE802.16a can be enhanced in order to support mobility.
Notice	
Release	
Patent Policy and Procedures	

IEEE802.16e Sleep Mode

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1 General

This document presents the needed enhancements that can be done to the IEEE802.16a standard in order to support mobility operation by reducing the power consumption of the mobile SS.

In order to reduce the power consumption of the SS, we propose to use a sleeping mode technique.
The contribution provides a general description of the proposed technique and provides the exact addition required to add this mode to the standard.

2 Power consumption reduction

2.1 The traffic model

In a mobile system, in which mobile SS are moving within the BS's sector, minimizing the energy usage of each SS is an important goal in the system design.
The typical traffic profile of a SS is of a bursty nature. According to the 4IPP (four Interrupted Poisson Process) traffic model suggested in [3], the SS has an *off* and an *on* period. An interrupted Poisson process is generating packets during the *on* period and not generating packets during the *off* period. Two probabilities, *c1* and *c2,* are defined for switching between the periods.
The model was claimed to generate an accurate representation of traffic for Ethernet and Internet.

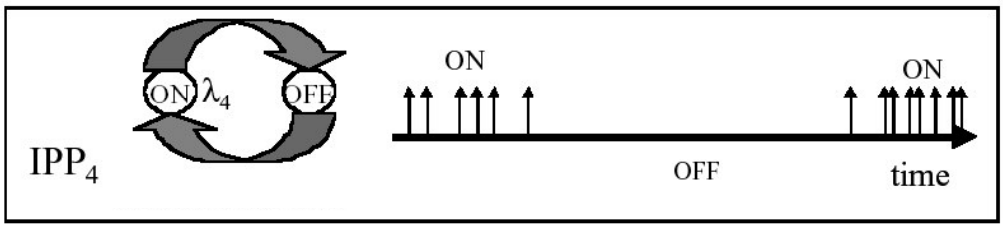

Figure 1: 4IPP traffic model

The 4IPP model presents (possibly) long idle periods, in which the SS does not generate traffic. This gives a motivation of using a *sleep-mode* mechanism for the SS, e.g. enable the SS to reduce power consumption in the idle intervals by turning off it's air-interface.

2.2 Proposed sleep-mode

A working SS that supports sleep-mode can be in one of two modes:

- Awake
- Sleep

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

The two following intervals are defined:
Sleep-interval – The time duration from the point the SS has entered *sleep-mode* until it returns to *awake-mode*. During consecutive sleep periods the *sleep-interval* will be updated using an exponentially increasing algorithm with adjustable minimum and maximum limits.
Listening-interval – The time duration during which the SS, after waking up and synchronizing with the DL transmissions, can demodulate downlink transmissions and decides whether to stay awake or go back to sleep. The *Listening-interval* is agreed between the BS and the SS and is adjustable.

Before entering sleep mode the SS must inform the BS and obtain its approval. The BS may buffer (or it may drop) incoming PDUs addressed to the sleeping SS, and will send notification to the SS in it's awakening periods about whether data has been addressed for it. The SS will awake according to the *sleep-interval* and will check whether there were PDUs addressed for it. If such PDUs exist, it will remain awake. An SS may terminate *sleep-mode* and return to *awake-mode* anytime (i.e. there is no need to wait until the *sleep-interval* is over).

The following points are summary of necessary items for supporting sleeping mode:

- The *sleep-interval* and the algorithm for increasing it
- BS support for buffering (or dropping) of packets for a SS that is in sleep mode
- BS and SS are synchronized with regards to the times in which the SS awakes
- The BS notifies the SS, about existence PDUs addressed for it

2.3 Sleep Mode Messages

The following messages are defined to support sleep-mode:

- ***Sleep-Request*** (SS→ BS): Request of the SS to enter into sleep mode. The message will include requested *sleep-interval* parameters (e.g. *min-window*, *max-window* and *listening-interval*).
- ***Sleep-Response*** (BS→SS): Authorization from the BS to the SS to enter *sleep-mode.* The message will include requested *sleep-interval* parameters (e.g. *min-window* and *max-window*), the *listening-interval* and a reference time for starting the process. This message is sent as a response to ***Sleep-Request*** or as an unsolicited instruction.
- ***Traffic-Indication*** (BS→SS): Indication of the BS to an SS in one of the frames during the *listening-interval*, that there have been PDUs addressed for it. For efficiency reasons, this message is a broadcast message.

3 Text to be inserted in the standard

3.1 Power consumption reduction

6.2.2.3.40 Sleep Request message (SLP-REQ)
SS supporting sleep-mode uses the SLP-REQ message to request permission from the BS to enter sleep-mode. The SLP-REQ message is sent from SS to the BS on the SS's basic CID. The message includes sleep-mode parameters as requested by the SS.

Table xxx: Sleep-Request (SLP-REQ) message format

Syntax	Size	Notes
SLP-REQ_Message_Format() {		
Management message type = 45	8 bit	
min-window	6 bit	
Max-window	10 bit	
listening interval	8 bit	
}		

Parameters shall be as follows:

Min window
Requested start value for the sleep interval (measured in frames).
Max window
Requested stop value for the sleep interval (measured in frames).
Listening interval
Requested listening interval (measured in frames).

6.2.2.3.41 Sleep Response message (SLP-RSP)

The SLP-RSP message shall be sent from BS to a SS on the SS's basic CID in response to an SLP-REQ message. The SS shall enter sleep-mode using the parameters indicated in the message.

Table xxx: Sleep-Response (SLP-RSP) message format

Syntax	Size	Notes
SLP-RSP_Message_Format() {		
Management message type = 46	8 bit	
Sleep-approved	1 bit	0: Sleep-mode request denied 1: Sleep-mode request approved
If (Sleep-approved == 0) {		
Reserved	7 bit	
} else {		
Start-time	7 bit	
min-window	6 bit	
max-window	10 bit	
listening interval	8 bit	
}		
}		

Parameters shall be as follows:

Sleep approved
Defines whether or not the request to enter sleep-mode has been approved by the BS.
Start-time
The number of frames (not including the frame in which the message has been received) until the SS shall enter the first sleep-interval.
Min window
Start value for the sleep interval (measured in frames).
Max window
Stop value for the sleep interval (measured in frames).
Listening interval
Value for the listening interval (measured in frames).

6.2.2.3.42 Traffic Indication message (TRF-IND)

This message is sent from BS to SS on the broadcast CID. The message is intended for SS that are in sleep-mode, and is sent during those SS listening-interval. The message indicates whether or not there has been traffic addressed to each SS that is in sleep-mode. A SS that is in sleep-modem, during its listening-interval, shall decode this message seek an indication addressed to itself.

Table xxx: Traffic-Indication (TRF-IND) message format

Syntax	Size	Notes
TRF-IND_Message_Format() {		
Management message type = 47	8 bit	
Positive_Indication_List() {		Traffic has been addressed to these SS
Num-positive	8 bit	
for (i=0; i< Num-positive; i++) {		
CID	16 bit	Basic CID of the SS
}		
Negative_Indication_List() {		Traffic has not been addressed to these SS
Num-negative	8 bit	
for (i=0; i< Num-negative; i++) {		
CID	16 bit	Basic CID of the SS
}		
}		

Parameters shall be as follows:

Num-positive
Number of CIDs on the positive indication list.
Num-negative
Number of CIDs on the negative indication list.

6.2.16 Sleep-mode for mobility-supporting SS

6.2.16.1 Introduction

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

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

- Awake
- Sleep

When SS is in awake-mode, it is receiving and transmitting PDUs in a normal fashion. When 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 – A time duration, measured in whole frames, during which the SS, shall be able to demodulate downlink transmissions. During this interval the SS shall decides whether to stay awake or go back

to sleep based on an indication from the BS. The Listening-interval is agreed between the BS and the SS and is adjustable.

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 a send notification to the SS in it's awakening periods about whether data has been addressed for it.

A SS shall awake according to the sleep-interval and check whether there were PDUs addressed for it. If such PDUs exist, it shall remain awake. A SS may terminate sleep-mode and return to awake-mode anytime (i.e. there is no need to wait until the sleep-interval is over). If the BS receives data from a SS that is supposed to be in sleep-mode, the BS shall assume that the SS is no longer in sleep-mode.

6.2.16.2 Sleep-interval update algorithm

A 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 min-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 an double the duration of the sleep-interval. This procedure shall be repeated as long as the resulting sleep-interval does not exceed the max-window value.

6.2.16.3 Traffic indication signaling

The BS shall indicate for each SS in sleep-mode, during its listening-interval, whether or not traffic has been addressed to it. The indication is sent on the TRF-IND broadcast message. If a SS fails to find an indication addressed to it, it shall assume that the BS no longer considers it in sleep-mode, and shall continue with normal operation. Once a SS has identified the indication addressed to it, it may skip the rest of the listening interval and return to sleep-mode.

6.2.16.4 Example of sleep-mode operation

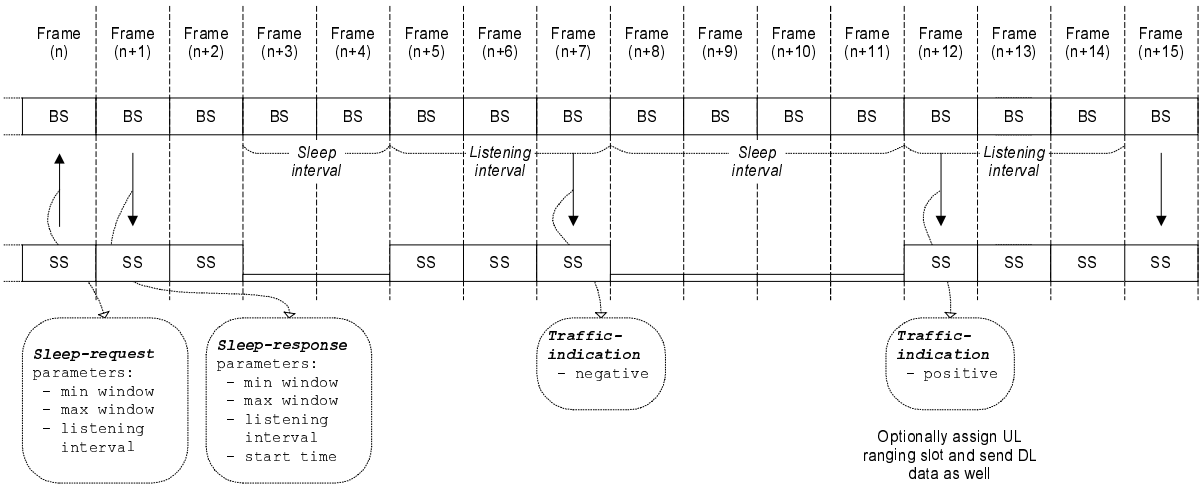

Figure xxx: Example of sleep-mode operation

4 References

[1] IEEE Std 802.16-2001 “Part 16: Air Interface for Fixed Broadband Wireless Access Systems”
[2] IEEE P802.16a/D7-2002 “Part 16: Air Interface for Fixed Broadband Wireless Access Systems – Medium Access Control Modifications and Additional Physical Layer Specifications for 2-11 GHz”
[3] IEEE 802.16.3c-01/30r1 “Traffic Model for 802.16 TG3 MAC/PHY Simulations”
[4] IEEE 80216e-02_01 “Call for Contributions on Project 802.16e”
[5] IEEE 802.16e-03/02, “Call for Proposals on IEEE Project 802.16e: Mobility Enhancements to IEEE Standard 802.16/802.16a”