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Re:	IEEE 802.16j-06/027: " Call for Technical Proposals regarding IEEE Project P802.16j"	
Abstract	This contribution proposes MS sleep mode interworking with RS. It also proposes RS sleep mode procedure.	
Purpose	Add proposed spec changes.	
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# Sleep Mode with RS

## 1 Introduction

In MS sleep mode, an MS or RS conducts pre-negotiated periods of absence from the Serving BS air interface. These periods are characterized by the unavailability of the MS or RS, as observed from the Serving BS, for DL or UL traffic. The sleep mode minimizes MS or RS power usage and decreases usage of the air interface resources.

With Relay, the following aspects of the sleep mode need consideration:

- Working of the existing MS sleep mode through the RS
- Introducing RS sleep mode

### 1.1 MS Sleep mode working with RS

The relay functionality may introduce two types of scheduling. Centralized Scheduling, where MR-BS controls all the scheduling and MAP allocation. Distributed Scheduling, where scheduling and MAP allocation is distributed on relays also. This contribution proposes text for both type of scheduling.

#### 1.1.1 Centralized Scheduling

This contribution proposes that RS relays the sleep mode messages, such as MOB\_SLP-REQ/RSP, between MS and MR-BS. The RS doesn't keep any state information related to the MS sleep mode. The existing MS sleep mode feature does not require any extra support from relays in centralized scheduling.

#### 1.1.2 Distributed Scheduling

In distributed scheduling, RS may buffer and schedule relay traffic at different time instances than MR-BS. This requires MR-BS to send MS sleep intervals to RSs, so RSs won't schedule bursts in the MS sleep intervals. This contribution suggests a procedure for sending sleep intervals from MR-BS to the RSs on the relay path.

### 1.2 RS Sleep Mode

This contribution proposes to introduce a sleep mode procedure for RS. The sleep mode feature for RS is useful for providing power efficiency, especially in the mobile RS with battery power source or low-power fixed RS powered by the solar power or equipped with the battery-powered UPS. Also, it is useful for the nomadic RS and client owned fixed RS. In these cases, RS is desired to be installed without being attached to a continuous power source. While the RS is in sleep mode, it decreases usage of the air interface resources to conserve power consumption.

#### 1.2.1 Broadcast in RS Sleep Mode

Depending on the RS type, an RS either relays or generates broadcast messages. If RS relays broadcast messages, e.g. DCD, UCD, then the MR-BS needs to coordinate the broadcast message intervals with the RS,

such that the RS stays in the available mode during the broadcast message relay. This coordination is described in this section. If RS generates broadcast messages, then there is no need for the coordination.

In order to facilitate network entry/network-re-entry/handover for an RS while in sleep mode, two RS sleep modes are defined in next two sections, namely Full RS Sleep Mode and Partial RS Sleep Mode.

### **1.2.2 Full RS Sleep Mode**

There is no traffic at relay link and access link. In his mode, the MR-BS ceases traffic with the RS, and the RS also stops serving all of the involved client RSs and MSs.

### **1.2.3 Partial RS Sleep Mode**

There exists no traffic at relay link or access link except that RS still periodically sends DL Start Frame Preamble, FCH, DCD, UCD, DL\_MAP, UL\_MAP, and broadcast messages at predefined intervals for supporting MS mobility and MS network entry/re-entry/handover.

### **1.2.4 RS Sleep Mode In Centralized Scheduling**

The proposed changes for supporting MS Sleep mode on RS for the distributed scheduling also enables the RS sleep mode for the centralized scheduling. It is noteworthy that the proposed RS Sleep Mode does not cause any change to the MS sleep mode, it works on top of the MS sleep mode.

In centralized scheduling MR-BS controls all the scheduling and MAP allocation in addition to all sleep states of MS & RS. First, the MR-BS informs the RS and MS in proper sequence about the listening and sleep windows of the MSs and RSs along the relay path. Then, all associated RSs enter into the listening/sleep mode according to the listening/sleep windows of the attached MSs. When attached MSs are in sleep mode, the RS on the relay path could go into sleep mode and conserve its power. The activation of RS sleep mode is fully managed by MR-BS. Alternatively a RS can request the activation of RS sleep mode (due to battery-powered UPS being activated for example) by exchanging RS\_SLP-REQ/RS\_SLP-RSP messages with MR-BS. Furthermore, RS could get the sleep schedules of each attached MS in RS\_SLP-CMD message, and it can use the schedule for its own sleep mode.

### **1.2.5 RS Sleep Mode In Distributed Scheduling**

For distributed scheduling, the serving RS of the access link could utilize the information in the RS\_SLP-CMD message creates sleep and listening interval for itself, and sends its response in RS\_SLP-ACK to the MR-BS. However, other RS along the relay path won't be affected by this procedure. This procedure is optional and independent of the MS sleep mode.

## **2 Spec Changes**

This section contains the suggested text for the 802.16 specification changes.

*Change Table 14 as indicated:*

Type	Message name	Message description	Connection
<u>67-255</u>		<u>Reserved</u>	-
<u>67</u>	<u>RS_SLP-CMD</u>	<u>RS Sleep Command</u>	<u>Basic</u>
<u>68</u>	<u>RS_SLP-ACK</u>	<u>RS Sleep ACK</u>	<u>Basic</u>
<u>69</u>	<u>RS_SLP-REQ</u>	<u>RS Sleep Request</u>	<u>Basic</u>
<u>70</u>	<u>RS_SLP-RSP</u>	<u>RS Sleep Response</u>	<u>Basic</u>
<u>70-255</u>		<u>Reserved</u>	-

### 6.3.21.7 Relay sleep mode support for mobility supporting MS

#### 6.3.21.7.1 Relay sleep mode support for centralized scheduling

MS sleep mode, for the MS attached through an RS, works as in the section 6.3.21. RS only relays the signaling and doesn't need any additional functionality for supporting sleep mode procedure. The RS doesn't keep any state information related to the MS sleep mode.

#### 6.3.21.7.2 Relay sleep mode support for distributed scheduling

MR-BS informs the pre-negotiated periods of MS absence to the RS for sleep mode coordination. The MR-BS knows the MSs attached to an RS. If the MSs activate MS Sleep Mode, the MR-BS sends RS\_SLP-CMD message to the RS. The message contains the listening and sleep interval information of the MSs. The RS saves and uses this information in scheduling traffic for the MS. The RS sends a response in RS\_SLP-RSP to the MR-BS. The MR-BS shall activate MS sleep mode, after confirmation from RS.

For the power saving class type-1, MMR BS also assigns a SLPID to RS. The MOB\_TRF-IND message is also used for indicating traffic to RS without any change. When there is any traffic indication for an MS under a sleeping RS, it also includes SLPID of the RS in the MOB\_TRF-IND message. The RS reads it and stays up for its UL allocation. In this way there is no change in the MOB\_TRF-IND message. When an RS receives MOB\_TRF-IND, it relays the message to the next level of RS and MS.

#### 6.3.21.7.3 RS sleep mode

In centralized scheduling MR-BS controls all the scheduling and MAP allocation in addition to all sleep states of MS & RS. First, the MR-BS informs the RS and MS in proper sequence about the listening and sleep windows of the MSs and RSs along the relay path. Then, all associated RSs enter into the listening/sleep mode according to the listening/sleep windows of the attached MSs. When attached MSs are in sleep mode, the RS on the relay path could go into sleep mode and conserve its power. The activation of RS sleep mode is fully managed by MR-BS. Alternatively a RS can request the activation of RS sleep mode (due to battery-powered UPS being activated for example) by exchanging RS\_SLP-REQ/RS\_SLP-RSP messages with MR-BS. Furthermore, RS could get the sleep schedules of each attached MS in RS\_SLP-CMD message, and it can use the schedule for its own sleep mode.

For distributed scheduling, the serving RS of the access link could utilize the information in the RS\_SLP-CMD message creates sleep and listening interval for itself, and sends its response in RS\_SLP-ACK to the MR-BS. However, other RS along the relay path won't be affected by this procedure. This procedure is optional and independent of the MS sleep mode.

The MR-BS also coordinates the broadcast message intervals with the RS, such that the RS stays in the available mode during the broadcast message relay. For MOB\_PAG-ADV, the MR-BS sends PAGING\_CYCLE and PAGING OFFSET of the MSs to the RS. For DCD/UCD, the MR-BS sends the DCD/UCD message interval. For MOB\_NBR-ADV, the MR-BS sends the MOB\_NBR-ADV interval to the RS.

#### 6.3.21.7.3.1 Full RS Sleep Mode

There is no traffic at relay link and access link. In his mode, the MR-BS ceases traffic with the RS, and the RS also stops serving all of the involved client RSs and MSs.

#### 6.3.21.7.3.2 Partial RS Sleep Mode

There exists no traffic at relay link or access link except that RS still periodically sends DL Start Frame Preamble, FCH, DCD, UCD, DL\_MAP, UL\_MAP, and broadcast messages at predefined intervals for supporting MS mobility and MS network entry/re-entry/handover.

*Insert new subclause (6.3.2.3.62):*

#### 6.3.2.3.62 RS\_SLP-CMD message

An MR-BS sends the RS\_SLP-CMD message to RS for activating/deactivating RS sleep mode. The RS sleep mode message is sent on RS's basic CID. This message conveys sleep mode information for all the MS attached through the RS. If any of an MS's connection is removed from the sleep mode to idle mode, the MR-BS sends RS\_SLP-CMD with Definition=0 and Operation=0 for that particular CID. This removes only the corresponding sleep information from the RS.

Syntax	Size	Notes
RS_SLP-CMD_Message_format() {	-	-
Management message type = xx	8 bits	-
Activate/Deactivate RS Sleep Mode	1 bit	Value=0 – Deactivate. Value=1 – Activate.

RS SLPID	10 bits	Sleep ID for the RS; assigned only when an attached MS needs SLPID; this is used in Traffic Indication  SLPID= 0 – No Sleep ID assigned. This is the case when there is no attached MS with SLPID.
Reserved	5 bits	
Number of MS	8 bits	Number of MS included in the message.
for (i=0; i<Number of MS; i++) {		
MS Basic CID	16 bits	Identification of an MS
Number of Classes	8 bits	Number of power saving classes
for (i=0; i<Number of Classes; i++) {	-	-
Definition	1 bit	-
Operation	1 bit	-
Power_Saving_Class_ID	6 bits	-
if (Operation = 1) {	-	-
Start_frame_number	6 bits	-
Reserved	2 bits	-
}	-	-
If (Definition = 1) {	-	-
Power Saving Class Type	2 bits	
Direction	2 bits	
Traffic_triggered_wakening_flag	1 bit	
TRF_IND required	1 bit	

Reserved	2 bits	
Initial sleep window	8 bits	
Listening window	8 bits	
Final-sleep window base	10 bits	
Final-sleep window exponent	3 bits	
Number_of_Sleep_CIDs	3 bits	
for (i=0; i<Number_of_Sleep_CIDs; i++ {		
CID		
}	16 bits	
If (TRF-IND required) {		
SLPID	10 bits	
Reserved	6 bits	
}		
}		
}		

The following parameters shall be included in the message:

Activate/Deactivate RS Sleep Mode

0 = Deactivate RS Sleep Mode

1 = Activate RS Sleep Mode

RS SLPID

SLPID assigned to RS. When there is any traffic indication for an MS under a sleeping RS, the BS includes RS SLPID in the MOB\_TRF-IND message. The RS reads it and stays up for its UL allocation. RS SLPID = 0 implies that there is no SLPID assigned.

Number of MS

Total number of MS in the message.

Definition

0 = Definition of Power Saving Class absent; in this case the message shall request activation or deactivation of Power Saving Class identified by

Power\_Saving\_Class\_ID.

1 = Definition of Power Saving Class present.

#### Operation

0 = Deactivation of Power Saving Class (for types 1 and 2 only).

1 = Activation of Power Saving Class.

#### Power\_Saving\_Class\_ID

Assigned Power Saving Class identifier. The ID shall be unique within the group of Power Saving Classes associated with the MS. This ID may be used in further MOB\_SLP-REQ/RSP messages for activation / deactivation of Power Saving Class.

#### Start\_frame\_number

Start frame number for first sleep window.

#### Power Saving Class Type

Power Saving Class Type of a connection.

#### Direction

Defined the directions of the class's CIDs.

0b00 = Unspecified. Each CID has its own direction assign in its connection creation. Can be DL, UL, or both (in the case of management connections).

0b01 = Downlink direction only.

0b10 = Uplink direction only.

0b11 = Reserved.

#### Traffic\_triggered\_wakening\_flag (for Type I only)

0 = Power Saving Class shall not be deactivated if traffic appears at the connection as described in 6.3.19.2.

1 = Power Saving Class shall be deactivated if traffic appears at the connection as described in 6.3.19.2.

#### TRF-IND\_Required

For Power Saving Class Type I only.

1 = BS shall transmit at least one TRF-IND message during each listening window of the Power Saving Class.

This bit shall be set to 0 for other types.

#### Initial-sleep window

Assigned initial duration for the sleep window (measured in frames). For Power Saving Class type III, it is not relevant and shall be encoded as 0.

#### Listening window

Assigned Duration of MS listening window (measured in frames). For Power Saving Class type III, it is not relevant and shall be encoded as 0.

#### Final-sleep window base

Assigned final value for the sleep interval (measured in frames). For Power Saving Class type II, it is not relevant and must be encoded as 0. For Power Saving Class type III, it is the base for duration of single sleep window requested by the message.

#### Final-sleep window exponent

Assigned factor by which the final-sleep window base is multiplied in order to calculate the final-sleep window. The following formula is used:  

$$\text{final-sleep window} = \text{final-sleep window base} \times 2^{(\text{final-sleep window exponent})}$$
 For Power Saving Class type III, it is the exponent for the duration of single sleep window requested by the message.

#### SLP\_ID

This is a number assigned by the BS whenever an MS is instructed to enter sleep mode.

If Activate/Deactivate RS sleep mode is 1, the RS\_SLP-CMD message shall include the following parameter encoded as TLV tuple:

Broadcast message intervals (see 11.20.1)

#### 6.3.2.3.63 RS\_SLP-ACK message

An RS supporting sleep mode accepts RS\_SLP-CMD message by sending the following message with Accept Flag=1. If RS can't support the sleep mode, it sends the following message with Accept Flag=0. An RS could send RS\_SLP-ACK unsolicited to end its sleep mode. It could also send any other message to end the RS sleep mode.

Syntax	Size	Notes
RS_SLP-ACK_Message_format() {	-	-
Management message type = xx	8 bits	-
MS Sleep Mode Approved/Disapproved	1 bit	Approved =1 , Disapproved =0
RS Sleep Mode Activated/Deactivated	1 bit	Activated =1 , Deactivated =0

The following parameters shall be included in the message:

MS Sleep Mode Approved/Disapproved

0 = MS Sleep mode is approved

1 = RS Sleep mode is disapproved

RS Sleep Mode Activated/Deactivated

0 = RS Sleep mode is rejected

1 = RS Sleep mode is accepted

#### 6.3.2.3.64 RS\_SLP-REQ message

An RS supporting sleep mode uses the RS\_SLP-REQ message to request definition and/or activation of RS sleep mode. The RS\_SLP-REQ message is sent from the RS to the MR-BS on the RS's basic CID. The RS\_Sleep\_Mode bit indicates what kind of RS sleep mode is requested.

Syntax	Size	Notes
RS_SLP-REQ_Message_format() {	-	-
Management message type = xx	8 bits	-
RS_Sleep_Mode	1 bit	Value=0 – Full RS Sleep Mode Value=1 – Partial RS Sleep Mode
RS_Operation	1 bit	Value=0 – Deactivate Value=1 – Activate
RS_start_frame_number	6 bits	
RS_direction	2 bits	
RS_traffic_triggered_wakening_flag	1 bits	
RS_initial-sleep_window	8 bits	
RS_listening-window	8 bits	
RS_final-sleep_window_base_	10 bits	
RS_final-sleep_window_exponent	3 bits	
Scheduling_type	1 bits	Value=0 – Centralized Scheduling Value=1 – Distributed Scheduling
Number_of_all attached_RSs and MSs	10 bits	
Reserved	5 bits	
for (i=0; i< Number_of_all attached_RSs and MSs; i++) {		
Attached_MS/RS_basic_CID	16 bits	

}		
}		

Parameters shall be as follows:

RS\_Sleep\_Mode

- 0 = Full RS Sleep Mode
- 1 = Partial RS Sleep Mode

RS\_Operation

- 0= Deactivation of RS Sleep Mode
- 1= Activation of RS Sleep Mode

RS\_start\_frame\_number

Start frame number for the sleep window.

RS\_direction

- 0b00 = Both
- 0b01 = Downlink direction only
- 0b10 = Uplink direction only
- 0b11 = Reserved

RS\_traffic\_triggered\_wakening\_flag

- 0 = activate
- 1= deactivate

RS\_initial-sleep\_window

Assigned Duration of RS listening window (measured in frames).

RS\_listening-window

Assigned initial duration for the RS sleep window (measured in frames).

RS\_final-sleep\_window\_base\_

Assigned final value for the RS sleep interval (measured in frames).

RS\_final-sleep\_window\_exponent

Assigned factor by which the final-sleep window base is multiplied in order to calculate the RS\_final-sleep window. The following formula is used:  

$$\text{RS\_final-sleep window} = \text{RS\_final-sleep window base} \times 2^{(\text{RS\_final-sleep window exponent})}$$

Scheduling\_type

- 0 = Centralized Scheduling
- 1 = Distributed Scheduling

Attached\_MS/RS\_basic\_CID

The basic CID that is belong to the attached RS or MS.

#### 6.3.2.3.64 RS\_SLP-RSP message

The RS\_SLP-RSP message shall be sent from MR-BS to an RS on the RS's basic CID in response to an RS\_SLP-REQ message, or may be sent unsolicited. The RS\_Sleep\_Mode bit indicates what kind of RS sleep mode is allowed.

Syntax	Size	Notes
RS_SLP-RSP_Message_format() {	-	-
Management message type = xx	8 bits	-
RS_Sleep_Mode	1 bit	Value=0 – Full RS Power Sleep Mode Value=1 – Partial RS Power Sleep Mode
RS_Operation	1 bit	Value=0 – Deactivate. Value=1 – Activate.
RS_start_frame_number	6 bits	
RS_direction	2 bits	
RS_traffic_triggered_wakening_flag	1 bits	
RS_initial-sleep_window	8 bits	
RS_listening-window	8 bits	
RS_final-sleep_window_base_	10 bits	
RS_final-sleep_window_exponent	3 bits	
Scheduling_type	1 bits	Value=0 – Centralized Scheduling Value=1 – Distributed Scheduling
Number_of_all attached_RSs and MSs	10 bits	
RS_SLPID	10 bits	
REQ-duration	8 bits	
Reserved	3 bits	

for (i=0; i< Number_of_all attached_RSs and MSs; i++ {		
Attached_MS/RS_basic_CID	16 bits	
}		
}		

Parameters shall be as follows:

RS\_Sleep\_Mode

- 0 = Full RS Sleep Mode
- 1 = Partial RS Sleep Mode

RS\_Operation

- 0= Deactivation of RS Sleep Mode
- 1= Activation of RS Sleep Mode

RS\_start\_frame\_number

Start frame number for the sleep window.

RS\_direction

- 0b00 = Both
- 0b01 = Downlink direction only
- 0b10 = Uplink direction only
- 0b11 = Reserved

RS\_traffic\_triggered\_wakening\_flag

- 0 = activate
- 1 = deactivate

RS\_initial-sleep\_window

Assigned Duration of RS listening window (measured in frames).

RS\_listening-window

Assigned initial duration for the RS sleep window (measured in frames).

RS\_final-sleep\_window\_base\_

Assigned final value for the RS sleep interval (measured in frames).

RS\_final-sleep\_window\_exponent

Assigned factor by which the final-sleep window base is multiplied in order to calculate the RS\_final-sleep window. The following formula is used:  

$$\text{RS\_final-sleep window} = \text{RS\_final-sleep window base} \times 2^{(\text{RS\_final-sleep window exponent})}$$

Scheduling\_type

- 0 = Centralized Scheduling
- 1 = Distributed Scheduling

RS\_SLPID

This is a number assigned by the MR-BS whenever an RS is instructed to enter sleep mode. This number shall be unique in the sense that it is assigned to a single RS that

is instructed to enter sleep mode. No other RS shall be assigned the same number while the first RS is still in sleep mode

**REQ-duration**

Waiting value for the RS\_SLP-REQ message re-transmission (measured in MAC frames): the RS may retransmit the RS\_SLP-REQ message after the time duration (REQ-duration) provided in the message.

**Attached\_MS/RS\_basic\_CID**

The basic CID that is belong to the attached RS or MS.

### 11.20 RS\_SLP-CMD management message encodings

The encodings described in this subclause are specific to RS\_SLP-CMD message.

#### 11.20.1 Broadcast message intervals

This TLV carries intervals for the broadcast messages. This also indicates to RS

<b>Type</b>	<b>Length</b>	<b>Value</b>
153	Variable	See the following table

<b>Field</b>	<b>Length</b>	<b>Note</b>
DCD Interval	4 bits	In seconds
UCD Interval	4 bits	In seconds
NBR_ADV Interval	8 bits	In seconds
PAGING_CYCLE	16 bits	
PAGING_OFFSET	8 bits	