Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Sleep Mode and Idle Mode Operations for IEEE 802.16j**
Date Submitted	**2006-11-15**
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Re:	IEEE 802.16j-06/027:"Call for Technical Proposals regarding IEEE Project P802.16j"
Abstract	This document presents sleep mode and idle mode operations for IEEE 802.16j. The existing IEEE 802.16e messages are reused and new parameters are introduced in order to facilitate the sleep mode and idle mode management in IEEE 802.16j.
Purpose	Propose the sleep mode and idle mode operations for IEEE 802.16j
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Sleep Mode and Idle Mode Operations for IEEE 802.16j

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Abstract

This document presents sleep mode and idle mode operations for IEEE 802.16j. The existing IEEE 802.16e messages are reused and new parameters are introduced in order to facilitate the sleep mode and idle mode management in IEEE 802.16j.

I. Basics of Sleep Mode and Idle Mode Operations for IEEE 802.16e

IEEE 802.16e defines sleep-mode operations for MSs that have data connections but does not have packets to send or receive. Three power-saving classes for sleep mode operations are defined to accommodate network connections with different characteristics. According to the specification, each connection on an MS can be associated with a power-saving class, and connections with a common demand property can be grouped into one power-saving class. The parameters of a power-saving class, i.e. the time to sleep and listen, the length of a sleep period and a listen period can be negotiated by a BS and an MS. Then, an MS can sleep during the sleep periods, and wakes up to listen the incoming packets during listen periods. Once an MS has packets to send or it receives DL-MAP which indicates packets to receive, the MS must return to normal mode to send/receive the packets.

On the other hand, while an MS does not have any connection for a period, an MS might want to switch to a deeper sleep state, called idle mode, to conserve the energy. IEEE 802.16e defines its own idle-mode operations and a paging network architecture. Four logical entities for idle-mode and paging operations are defined in a Mobile WiMAX network. First, a paging controller (PC) is associated with a paging group (PG) which comprises one or several paging agents (PAs) in the same NAP. The major task of a PC is to administer the activities of all idle-mode MSs situated in the PG managed by the PC. A PC can function as an anchor PC which is in charge of the paging and idle-mode management, and/or a relay PC which only forwards paging related messages from an anchor PC to its PAs. A PC could either co-locate with a BS or implemented on a network node and uses an R6 interface to communicate with its PAs. PCs can also access a distributed database, called location register (LR), which contains information such as paging parameters for idle-mode MSs. PAs which are normally implemented on BSs interact with the PC to perform paging over the air interface.

While an MS decides to switch to idle mode, it first sends a de-registration message (DREG-REQ) to the PC via the serving BS. The serving BS/PA and PC exchange messages and release the resources occupied by the MS and then update the information of the MS to the LR. Finally, the MS receives an acknowledgement message containing the paging parameters such as paging cycle, paging offset, anchor PC identifier and etc., and can enter the idle mode. Based on the paging cycle (PAGING_CYCLE) and paging offset (PAGING_OFFSET), an MS can derive BS paging available intervals. The MS has to stay awake during the entire BS paging available interval in order to receive BS broadcasting paging messages (MOV_PAG-ADV). A BS paging interval shall begin from the PAGING_OFFSETth frame in every PAGING_CYCLE and lasts for *N* frames which *N* is the length of a paging interval. An MS shall perform a location update (LU) upon LU evaluation conditions. While receiving an incoming packet, the anchor PC first obtains the information of the MS from the LR and informs the relay PCs to page the MS. Once an MS is paged, the MS shall exit idle mode, performs ranging with the serving BS, and completes the network (re)-entry procedures.

II. Sleep Mode Operations for IEEE 802.16j

II.A Centralized approach

The admission control of sleep mode operations requested by MSs and buffering of the incoming packets to the MSs could be done by the MR-BS if a centralized control approach is adopted. An MS first requests the sleep mode operation by sending an MOB_SLP-REQ message which contains the power saving class associated with a connection identifier (CID), start frame of the sleep mode, initial sleep window, listen window and etc. Once the serving RS receives the message, it forwards the messages to the MR-BS via RSs. Then, the MR-BS processes the request and responses an MOB_SLP-RSP message to the MS. The centralized approach of the sleep mode operations for IEEE 802.16j reuses the existing Sleep Request/Response messages and the parameters of the these two messages remain unchanged.

While an MR-BS receives incoming packets to an MS in sleep mode, the MR-BS may buffer the packets The MR-BS needs to take the additional relay delay into account while it forwards the packets. Assume the MS wakes up and listens the incoming packets at frame i, and the total relay delay from the MR-BS to the serving RS is j frames. If the packet arrives at frame k, the MR-BS needs buffer the packet for $i - j - k$ frames and transmits the packet to the MS through RSs. Therefore, the MS can receive the packet at frame i.

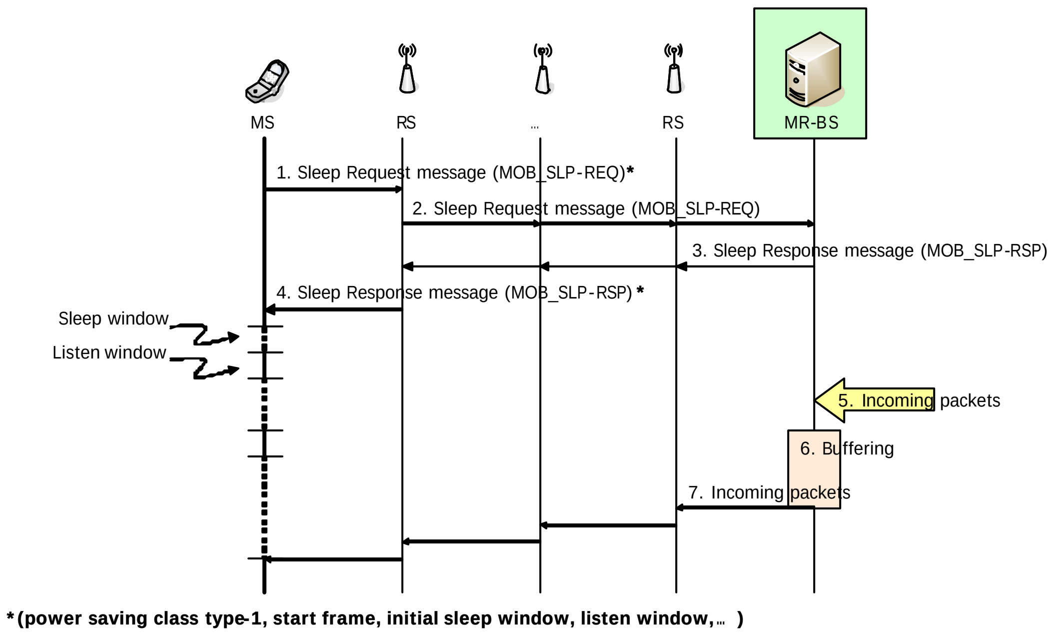

Figure 1. Admission control and buffering on MR-BS

II.B Decentralized approach

Through in distributed case, MR-BS still mainly manages sleep mode, RSs may be involved the sleep mode operations and buffering the incoming packets to MSs in the sleep mode. This decentralized approach reduces the buffer requirement of a MR-BS, increases the scalability of a MR-BS and may support more MSs in the sleep mode. In this case, an MS who wants to enter the sleep mode first sends a standard MOB_SLP-REQ message to the serving RS. The serving RS or any RS in the relay path may apply some constraints based its available resources such as remaining buffer size and modifies the parameters of the Sleep Request message. The Sleep Request/Response messages are reused for exchanging sleep mode parameters between RSs and between an RS and an MR-BS. A new parameter RSID is added in the Sleep Request/Response message to indicate the MR-BS which RS will buffer the incoming packets. Finally, the RS forwards the message to the

MR-BS, and the MR-BS processes the request and responses an MOB_SLP-RSP message to the MS. The new parameter RSID in MOB_SLP-RSP is to confirm the RS to buffer incoming packets. While an MR-BS receives incoming packets to an MS, the MR-BS forwards the packets to the MS directly if RS buffering is enabled. The RS buffers the incoming packets and sends to the MS during the MS's listen windows. Besides the RS who buffers the incoming packets needs to involve the admission control of the sleep mode operations and to maintain the parameters and state of the sleep mode for an MS, the MR-BS also needs to maintain the state and parameters. The MR-BS serves as an anchored node to transfer the sleep-mode context to the new RS/BS without involving context transfers between RSs while an MS handovers from one RS to another RS or BS.

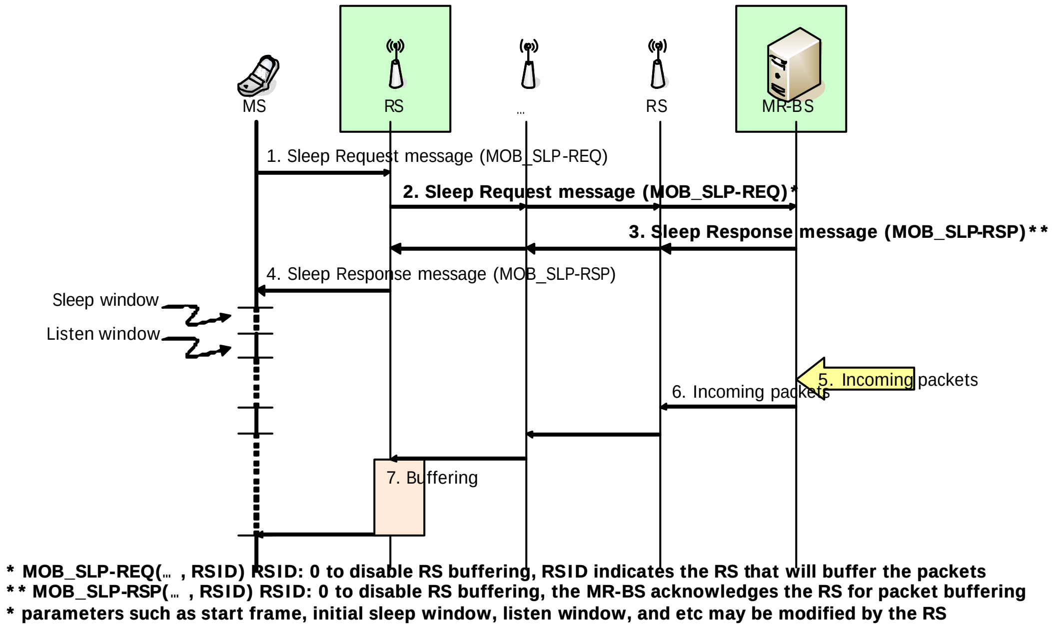

Figure 2. Admission control on MR-BS/RS and buffering on RS

Idle Mode Operations for IEEE 802.16j

The paging architecture and functional entities are revised to accommodate IEEE 802.16j relay architecture. The paging controller (PC) may be either co-located with a BS, an MR-BS or separated from a BS across R6 reference point. The paging agent could be co-located with a BS, an MR-BS or an RS. The paging group (PG) is defined as a set of BSs, MR-BSs and RSs which are managed by the same MR-BSs. In other words, RSs and their control MR-BS belong to the same paging group. Figure 3 shows an example of a paging network for IEEE 802.16j.

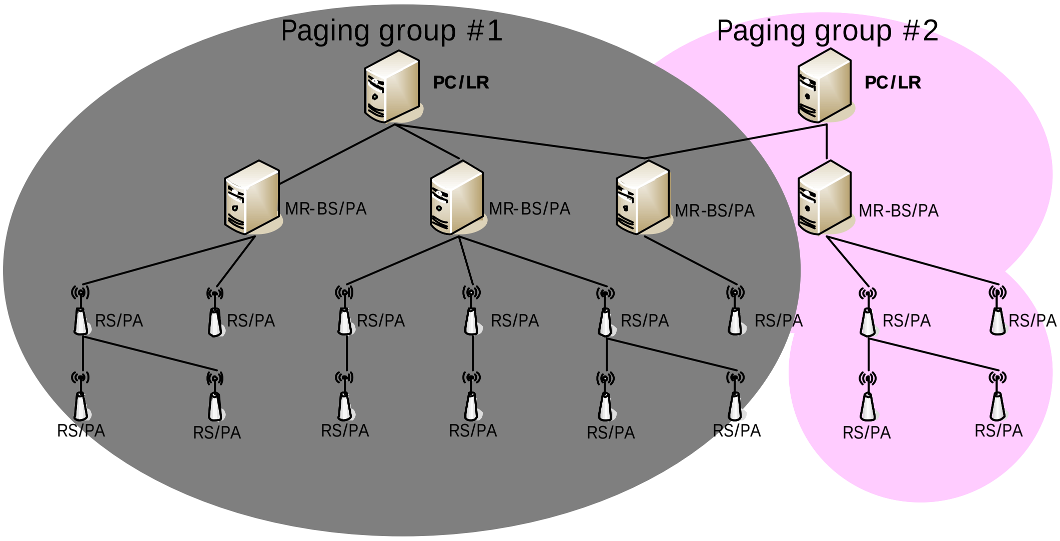

Figure 3. Paging architecture and functional entities

The messages between an MS and the serving RS remain unchanged and these messages for idle mode operations such as DREG-REQ, DREG-RSP, MOB_PAG-ADV, RNG-REQ, and RNG-RSP messages are enhanced to support parameter exchanges between RSs, and between an RS and an MR-BS. While an MS decides to switch to idle mode, it sends an SS De-registration request message (DREG-REQ) to the MR-BS via RSs. The serving RS picks up the message, adds its ID, i.e. RSID, to the message, and forwards the message to the MR-BS. The RSID or the serving BSID is carried in the MS information request message and is stored on the LR. The RSID can be used to identify an MS under the coverage of a RS. Once the de-register command message (DREG-CMD) is received, the MS turns off its interface and switches to the idle mode. Both the serving RS and MR-BS must keep the paging parameters such PAGING_CYCLE and PAGING OFFSET in order to page the MS in the future.

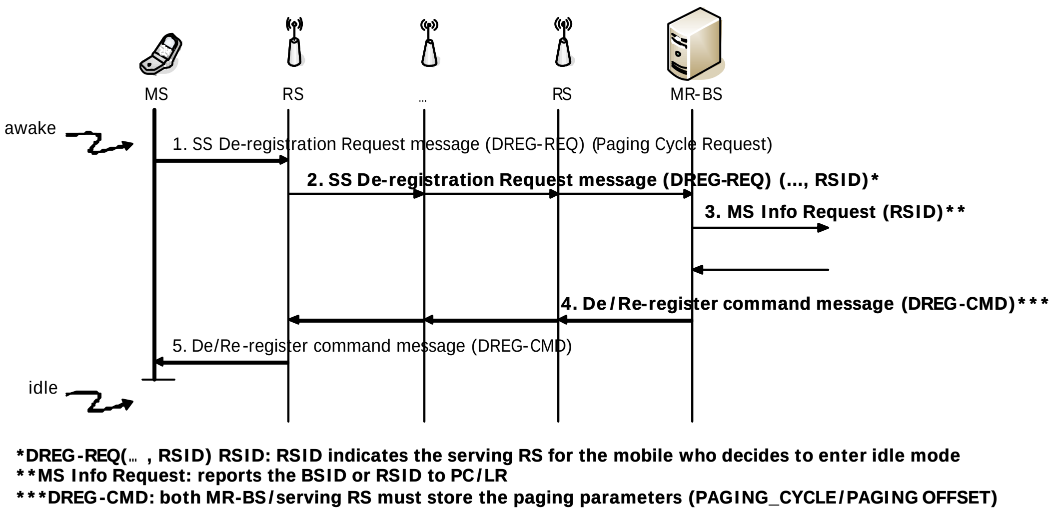

Figure 4. Enter idle mode

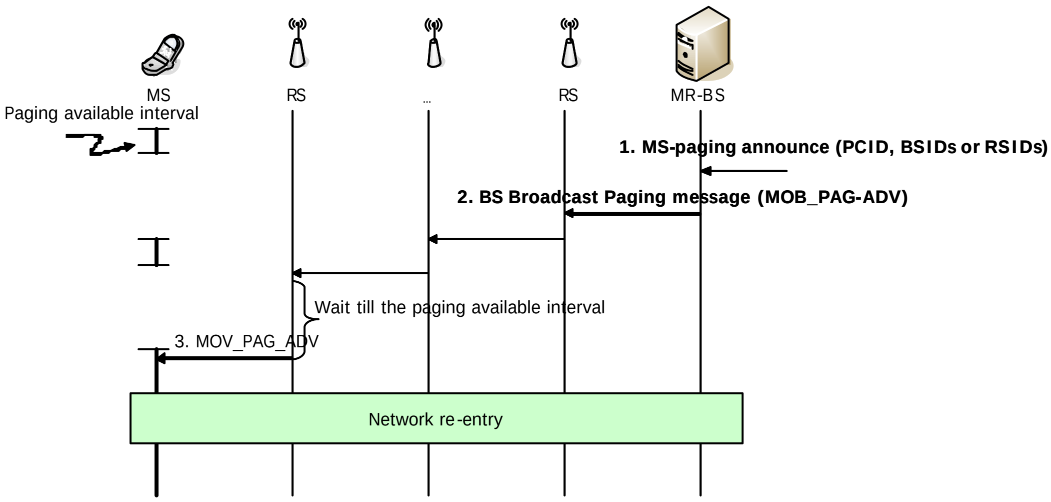

Figure 5. Paging procedures

To page an MS, BS Broadcast Paging message (MOB_PAG-ADV) is used between the serving RS and an MS, and between RSs and the MR-BS. The PC knows its associated BSs and RSs. Once it receives the MS-paging announce issued by the Anchored PC, it obtains the BSIDs and RSIDs in the paging group. It can either page all BSs and RSs in the paging group or only pages subset of RSs and BSs in a PG that the MS last reported. The serving RS who knows the paging parameters may wait for MS's paging available intervals and then broadcasts the paging message.

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6.3.21 Sleep mode for mobility-supporting MS

Sleep mode operations for MSs in relay mode could be managed by either the centralized approach or decentralized approach. In both approach, the admission control of sleep mode operations requested by MSs and buffering of the incoming packets to the MSs are mainly done by the MR-BS. However, in centralized case, RSs just relay these messages between the MS and the MR-BS without checking their content. All messages related to sleep mode operations such as Sleep Request/Response messages and their parameters and their parameters remain unchanged. While an MR-BS receives incoming packets to an MS in sleep mode, the MR-BS may buffer the packets The MR-BS needs to take the additional relay delay into account while it forwards the packets. The MR-BS needs to take the additional relay delay into account while it forwards the packets to the MS through RSs. For the decentralized approach, RSs may involve sleep mode operations and buffers the incoming packets to MSs in the sleep mode. This decentralized approach reduces the buffer requirement of a MR-BS, increases the scalability of a MR-BS and may support more MSs in the sleep mode. In this case, an MS who wants to enter the sleep mode first sends a standard MOB_SLP-REQ message to the serving RS. The serving RS or any RS in the relay path may apply some constraints based its available resources such as remaining buffer size and modifies the parameters of the Sleep Request message. The Sleep Request/Response messages are reused for exchanging sleep mode parameters between RSs and between an RS and an MR-BS. A new parameter RSID is suggested for the Sleep Request/Response message. The MOB_SLP-REQ/MOB_SLP-REQ shall include the following parameters encoded as TLV tuples while it is transmitted between RSs and between a RS and an MR-BS:

RSID

RSID = 0 implies RS buffering is disabled. Otherwise, RSID is the identifier of a RS which buffer the incoming packets the MS.

The RSID shown in MOB_SLP-REQ indicates the MR-BS which RS will buffer the incoming packets to the MS. Finally, the RS forwards the message to the MR-BS, and the MR-BS processes the request and responses an MOB_SLP-RSP message to the MS via RSs. The new parameter RSID in MOB_SLP-RSP is to confirm the RS to buffer the incoming packet. While an MR-BS receives incoming packets to an MS, the MR-BS forwards the packets to the MS via RSs directly if RS buffering is enabled. The RS buffers the incoming packets and sends to the MS during the MS's listen windows.

6.3.24 MS Idle Mode (optional)

The paging controller (PC) may be either co-located with a BS, an MR-BS or separated from a BS across R6 reference point. The paging agent could be co-located with a BS, an MR-BS or an RS. The paging group (PG) is defined as a set of BSs, MR-BSs and RSs which are managed by the same MR-BSs. In other words, RSs and their control MR-BS belong to the same paging group. Figure A shows an example of a paging network for IEEE 802.16j.

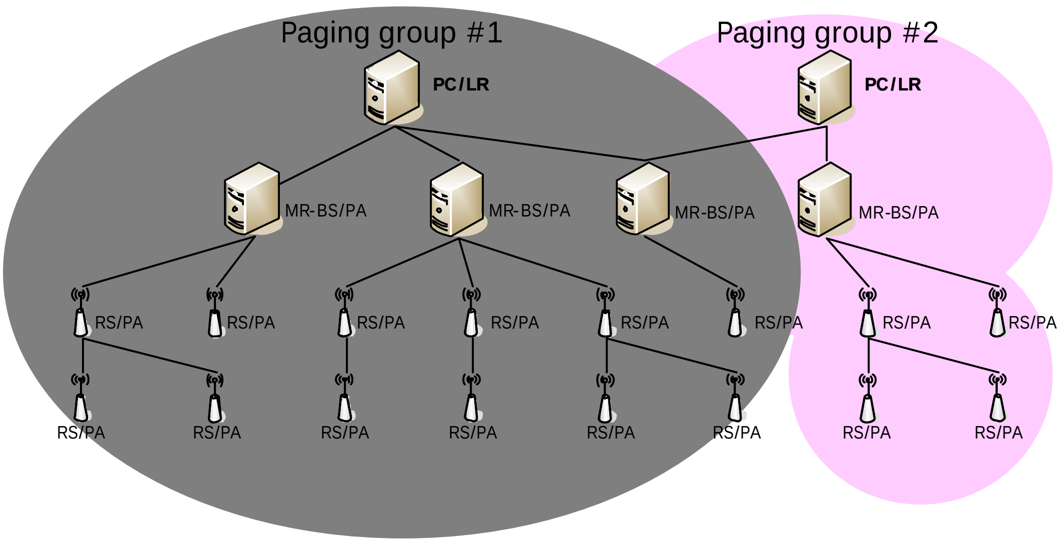

Figure A. Paging architecture and functional entities

The messages between an MS and the serving RS remain unchanged and these messages for idle mode operations such as DREG-REQ, DREG-RSP, MOB_PAG-ADV, RNG-REQ, and RNG-RSP messages are enhanced to support parameter exchanges between RSs, and between an RS and an MR-BS. While an MS decides to switch to idle mode, it sends an SS De-registration request message (DREG-REQ) to the MR-BS via RSs. The serving RS picks up the message, adds its ID, i.e. RSID, to the message, and forwards the message to the MR-BS. The DREG-REQ shall include the following parameters encoded as TLV tuples while it is transmitted between RSs and between a RS and an MR-BS:

RSID

RSID is the identifier of a serving RS.

The RSID can be used to identify an MS under the coverage of a RS. To page an MS, BS Broadcast Paging message (MOB_PAG-ADV) is used between the serving RS and an MS, and between RSs and the MR-BS. The PC knows its associated BSs and RSs. Once it receives the MS-paging announce issued by the Anchored PC, it obtains the BSIDs and RSIDs in the paging group. It can either page all BSs and RSs in the paging group or only pages subset of RSs and BSs in a PG that the MS last reported. The serving RS who knows the paging parameters may wait for MS's paging available intervals and then broadcasts the paging message.

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