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Title	**Hibernate mode for 802.16e mobile SS**
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Re:	Work Group Review of IEEE P802.16e/D1-2004
Abstract	A new mode for minimizing power consumption of mobile SS
Purpose	Enhance the low-power capabilities of mobile SS
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Hibernate mode for 802.16e mobile SS

1 Statement of the problem

Currently, a MSS, even during sleep mode is required to transmit in the UL from time to time in order to perform ranging, HO, and re-entry to the network after HO. These transmissions occur even though there may be no traffic for the MSS for the entire period.

2 Hibernate mode essentials

Hibernate mode is designed to improve he MSS power consumption by reducing the requirements on UL maintenance transmissions when the MSS has no data to transmit. This is accomplished by following the principles below,

- The MSS synchronizes to the DL, and receives the DL channel of a BS of its choice (typically, the one from which it receives with the best S/N+I)
- The BS are divided into logical groups called paging-groups. A BS may belong to more than one paging group. The MSS is assigned to a paging group upon entering hibernate-mode.
- The MSS does not listen to all DL frames, but rather conforms to a duty cycle defined for the paging-group.
- As long as the MSS remains within the same paging-group and can detect the paging message, it need not transmit in the UL.
- When there is traffic originating from a MSS in hibernate-mode, the MSS performs a network re-entry sequence (the same as the one performed after HO).
- When there is traffic for a MSS in hibernate-mode, the traffic is routed to the BS in which it entered hibernate-mode. That BS uses the backbone to request other BS belonging to the MSS paging-group to page the MSS.
- After being paged, the MSS performs a network re-entry sequence (the same as the one performed after HO).
- All the BS are synchronized with respect to the frame number.
- The backbone messages used are described as though they are sent directly between the BS involved, but they may also be sent through the ASA server.

3 Hibernate mode operation details

3.1 Paging groups

The BS are divided into logical groups called paging groups. The purpose of these groups is to offer a contiguous coverage region in which the MSS does not need to transmit in the UL, yet can be paged in the DL if there is traffic targeted at it. The paging groups should be large enough so that most MSS will remain most of the time within the same paging group, and small enough such that the paging overhead is reasonable. Figure 1 shows an example of 4 paging groups defined over multiple BS arranged in a hexagonal grid.

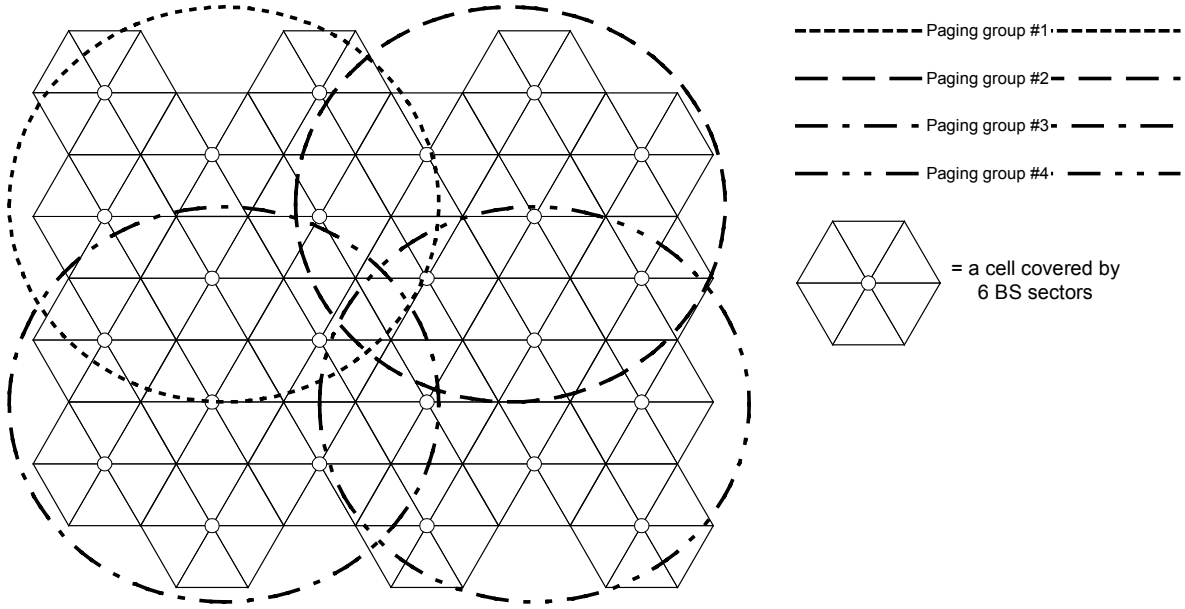

Figure 1: Paging-groups example

The paging-groups are be defined the management system. One possible method of definition is by using the following backbone primitive,

Field	Size	Notes
Message Type = ?	8-bit	
Sender BS-ID	48-bit	Base station unique identifier (Same number as that broadcasted on the DL-MAP message)
Target BS-ID	48-bit	Base station unique identifier (Same number as that broadcasted on the DL-MAP message)
Time Stamp	32-bit	Number of milliseconds since midnight GMT (set to 0xffffffff to ignore)
Action	4-bit	0 – Assign target BS to paging groups 1 – Remove target BS from paging groups 2 – Query (which paging groups target BS belongs to?) 3 – Information (paging groups sender BS belongs to)
Num Records	4-bit	Number of paging-group-ID records
For (j=0; j<Num Records; j++) {		
Reserved	1-bit	-
Paging-group-ID	15-bit	Paging-group-ID
Paging-group-Cycle	16-bit	Cycle in which the paging message is transmitted within the paging group
Paging-group-Cycle-Base	16-bit	16 LS-bits of the frame number closest to the time in which the message is sent, in which the paging message is transmitted within the paging group
}		
Security field	TBD	A means to authenticate this message
CRC field	32-bit	IEEE CRC-32

Table 1: Paging-group-action message

Another backbone primitive is used to initiate paging of the MSS on all BS belonging to the paging group,

Field	Size	Notes
Message Type = ?	8-bit	
Sender BS-ID	48-bit	Base station unique identifier (Same number as that broadcasted on the DL-MAP message)
Target BS-ID	48-bit	Set to 0xffffff to indicate broadcast
Time Stamp	32-bit	Number of milliseconds since midnight GMT (set to 0xffffffff to ignore)
Frame number where to page	32-bit	Frame number, where the MSS should be paged. The frame number that should be consistent with the paging group cycle, and should allow enough time for all BS to process this message
Num MSS	8-bit	Number MSS to page
For (j=0; j<Num MSS; j++) {		
MSS 48-bit MAC address	48-bit	-
}		
Security field	TBD	A means to authenticate this message
CRC field	32-bit	IEEE CRC-32

Table 2: Paging-announce message

3.2 Entry to hibernate-mode

An HBRN-REQ message may be transmitted by a MSS to request entry to hibernate-mode. The following message format is used,

Syntax	Size	Notes
HBRN-REQ_Message_Format() {		
Management Message Type = ?	8 bits	
}		

Table 3: HBRN-REQ message format

A MSS shall generate HBRN-REQ messages in the format shown in Table 3.
The BS shall respond with an HBRN-RSP message that will assign the MSS to a paging group, and a paging cycle. The HBRN-RSP message may also be sent unsolicited by the BS.
The format of the IE is PHY dependent as shown in Table 4.

Syntax	Size	Notes
HBRN-REQ_Message_Format() {		
Management Message Type = ?	8 bits	
Hibernate approved	1 bits	0 = MSS should not enter Hibernate mode 1 = MSS may enter Hibernate mode
Paging-group-ID	15 bits	ID of the paging group the MSS is assigned to
Paging-group-Cycle	16-bit	Cycle in which the paging message is transmitted within the paging group
Paging-group-Cycle-Base	16-bit	Number of frames left to the first frame in which the paging message is transmitted (0 = this frame)
}		

Table 4: HBRN-RSP message format

3.3 Paging in hibernate-mode

When in hibernate mode, and as long as the MSS remains in the same paging-group, all that is required of the MSS is to listen to the paging message. The paging message includes the paging group ID, so as long as the MSS receives the paging message, it can determine whether or not it can continue to remain in hibernate mode.

The paging message shall be transmitted by all BS that belong to the same paging group with the same transmission cycle, and therefore at the same frame. The paging message shall be transmitted regardless of the number of MSS that need paging. The MSS may listen to any BS that belongs to the paging group.
The format of the paging message is shown in Table 5.

Syntax	Size	Notes
Paging_Message_Format() {		
Management Message Type = ?	8 bits	
Reserved	1-bit	
Paging-group-ID	15-bit	ID of the paging group the MSS is assigned to
For (n=0; n<num_elements; n++) {		num_elements is implicitly determined from the message length
MSS MAC address hash	24 bits	The hash is obtained by computing a CRC24 on the MSS 48-bit MAC address. The polynomial for the calculation is 0x864CFB
}		
}		

Table 5: Paging message format

The following field shall be included in the message,

MSS MAC address hash
This is a 16-bit field used to hash the MSS 48-bit MAC address. The hash value shall be the remainder of the division (Modulo 2) of the 48-bit MAC address by the generator polynomial $g(D)= D^{16} + D^{12} + D^5 + 1$ of the polynomial D^{16} multiplied by the content of the MSS 48-bit MAC address. (Example: [MSS 48-bit MAC address]= 00:D0:59:0F:E2:2E, hash should then be set to TBD).

3.4 Exit from hibernate-mode and network re-entry

3.4.1 MSS side

The MSS shall exit hibernate-mode if either of the following conditions is met,

- The MSS has traffic to send
- The MSS has detected a hash value matching its 48-bit MAC address in the paging message
- The MSS has lost synchronization with the paging message
- The MSS has detected crossing of a paging-group boundary

In all the above situations the MSS should re-enter the network, and may use the short network re-entry sequence similar to the behavior after HO or drop event. When re-entering the network, to prevent collisions from multiple MSS trying to wake from hibernate mode at the same time, the MSS shall use special initial-ranging back-off values that will be advertised in the UCD message.

3.4.2 BS side

The BS at which the MSS entered the network shall report to the BS that initiated the paging about the MSS network re-entry, using the **MSS-info-request** backbone message. If the BS that has initiated the paging does is not informed about MSS reentry into the network, it shall initiate another paging sequence for the MSS. The **MSS-info-request** backbone message will also be used to inform the BS where the MSS has entered hibernate mode that the MSS has transitioned to a different paging group.

4 References

[1] IEEE P802.16e/D1-2004, “Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems — Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands”

5 Specific changes to the document

Add these new sections after 6.4.2.3.52 with the following text

6.4.2.3.53 Hibernate request (HBRN-REQ) message

An HBRN-REQ message may be transmitted by a MSS to request entry to hibernate-mode. The following message format is used,

Syntax	Size	Notes
HBRN-REQ_Message_Format() {		
Management Message Type = ?	8 bits	
}		

Table aaa: HBRN-REQ message format

A MSS shall generate HBRN-REQ messages in the format shown in Table aaa.

6.4.2.3.54 Hibernate response (HBRN-RSP) message

A BS shall respond to the HBRN-REQ message with an HBRN-RSP message. The HBRN-RSP message may also be sent unsolicited by the BS.
The format of the message is shown in Table bbb.

Syntax	Size	Notes
HBRN-REQ_Message_Format() {		
Management Message Type = ?	8 bits	
Hibernate approved	1 bits	0 = MSS should not enter Hibernate mode 1 = MSS may enter Hibernate mode
Paging-group-ID	15 bits	ID of the paging group the MSS is assigned to
Paging-group-Cycle	16-bit	Cycle in which the paging message is transmitted within the paging group
Paging-group-Cycle-Base	16-bit	Number of frames left to the first frame in which the paging message is transmitted (0 = this frame)
}		

Table bbb: HBRN-RSP message format

6.4.2.3.55 Paging message

The paging message shall be transmitted regardless of the number of MSS that need paging. The MSS may listen to any BS that belongs to the paging group. The format of the paging message is shown in Table ccc.

Syntax	Size	Notes
Paging_Message_Format() {		
Management Message Type = ?	8 bits	
Reserved	1-bit	
Paging-group-ID	15-bit	ID of the paging group the MSS is assigned to
For (n=0; n<num_elements; n++) {		num_elements is implicitly determined from the message length
MSS MAC address hash	24 bits	The hash is obtained by computing a CRC24 on the MSS 48-bit MAC address. The polynomial for the calculation is 0x864CFB
}		
}		

Table ccc: Paging message format

The following field shall be included in the message,

MSS MAC address hash
This is a 16-bit field used to hash the MSS 48-bit MAC address. The hash value shall be the remainder of the division (Modulo 2) of the 48-bit MAC address by the generator polynomial $g(D)= D^{24} + D^{23} + D^{18} + D^{17} + D^{14} + D^{11} + D^{10} + D^{7} + D^{6} + D^{5} + D^{4} + D^{3} + D^{1} + 1$ of the polynomial D^{24} multiplied by the content of the MSS 48-bit MAC address. (Example: [MSS 48-bit MAC address]= 00:D0:59:0F:E2:2E, hash should then be set to TBD).

Add a new section 6.4.18 with the following text

6.4.18 Hibernate mode

Hibernate mode is a mode that may be entered by a MSS, and in which a MSS need not perform any UL transmission until there is traffic to or from the MSS. This is accomplished by following the principles below,

- The MSS synchronizes to the DL, and receives the DL channel of a BS of its choice (typically, the one from which it receives with the best S/N+I)
- The BS are divided into logical groups called paging-groups. A BS may belong to more than one paging group. The MSS is assigned to a paging group upon entering hibernate-mode.
- The MSS does not listen to all DL frames, but rather conforms to a duty cycle defined for the paging-group.
- As long as the MSS remains within the same paging-group and can detect the paging message, it need not transmit in the UL.
- When there is traffic originating from a MSS in hibernate-mode, the MSS performs a network re-entry sequence (the same as the one performed after HO).
- When there is traffic for a MSS in hibernate-mode, the traffic is routed to the BS in which it entered hibernate-mode. That BS uses the backbone to request other BS belonging to the MSS paging-group to page the MSS.
- After being paged, the MSS performs a network re-entry sequence (the same as the one performed after HO).
- All the BS are synchronized with respect to the frame number.
- The backbone messages used are described as though they are sent directly between the BS involved, but they may also be sent through the ASA server.

6.4.18.1 Hibernate mode operation details

6.4.18.1 Paging groups

The BS are divided into logical groups called paging groups. The purpose of these groups is to offer a contiguous coverage region in which the MSS does not need to transmit in the UL, yet can be paged in the DL if there is traffic targeted at it. The paging groups should be large enough so that most MSS will remain most of the time within the same paging group, and small enough such that the paging overhead is reasonable. Figure 2 shows an example of four paging groups defined over multiple BS arranged in a hexagonal grid.

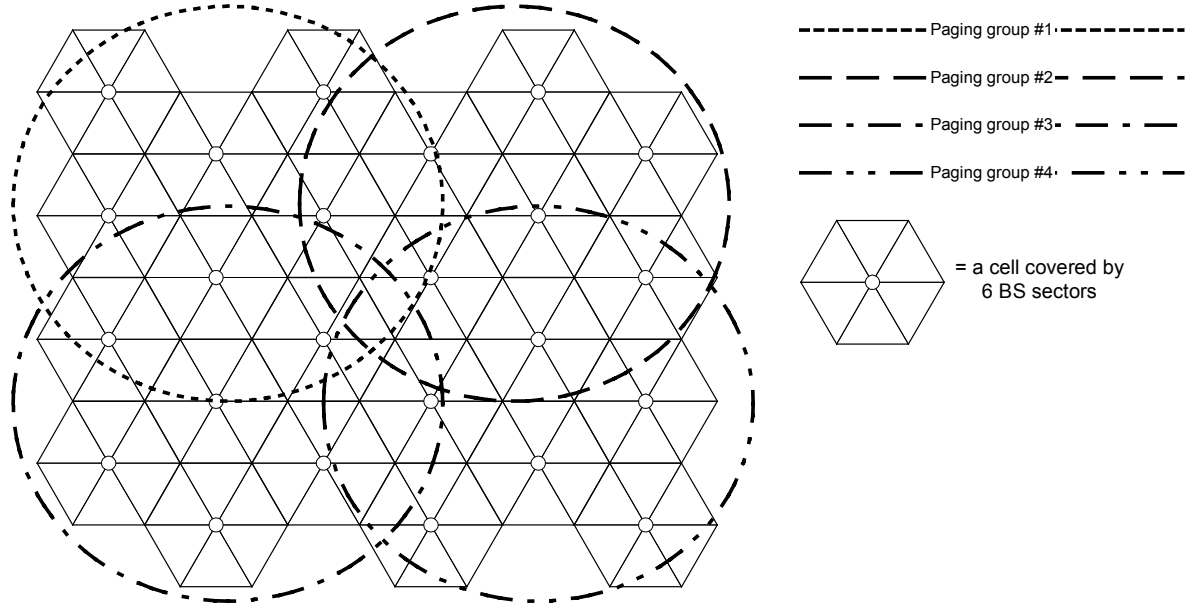

Figure 2: Paging-groups example

The paging-groups are be defined the management system. One possible method of definition is by using the **paging-group-action** backbone message. Another backbone message, **paging-announce**, is used to initiate paging of the MSS on all BS belonging to the paging group.

6.4.18.2 Entry to hibernate-mode

An HBRN-REQ message may be transmitted by a MSS to request entry to hibernate-mode. The BS shall respond with an HBRN-RSP message that will assign the MSS to a paging group, and a paging cycle. The HBRN-RSP message may also be sent unsolicited by the BS.

6.4.18.3 Paging in hibernate-mode

When in hibernate mode, and as long as the MSS remains in the same paging-group, all that is required of the MSS is to listen to the paging message. The paging message includes the paging group ID, so as long as the MSS receives the paging message, it can determine whether or not it can continue to remain in hibernate mode. The paging message shall be transmitted by all BS that belong to the same paging group with the same transmission cycle, and therefore at the same frame. The paging message shall be transmitted regardless of the number of MSS that need paging. The MSS may listen to any BS that belongs to the paging group.

6.4.18.4 Exit from hibernate-mode and network re-entry

6.4.18.4.1 MSS side

The MSS shall exit hibernate-mode if either of the following conditions is met,

- The MSS has traffic to send
- The MSS has detected a hash value matching its 48-bit MAC address in the paging message
- The MSS has lost synchronization with the paging message

- The MSS has detected crossing of a paging-group boundary

In all the above situations the MSS should re-enter the network, and may use the short network re-entry sequence similar to the behavior after HO or drop event. When re-entering the network, to prevent collisions from multiple MSS trying to wake from hibernate mode at the same time, the MSS shall use special initial-ranging back-off values that will be advertised in the UCD message.

6.4.18.4.2 BS side

The BS at which the MSS entered the network shall report to the BS that initiated the paging about the MSS network re-entry, using the **MSS-info-request** backbone message. If the BS that has initiated the paging does is not informed about MSS reentry into the network, it shall initiate another paging sequence for the MSS. The **MSS-info-request** backbone message will also be used to inform the BS where the MSS has entered hibernate mode that the MSS has transitioned to a different paging group.

Modify Table C3 in section C.2.1. as shown below

Field	Size	Notes
Global header	152-bit	
Num Records	4-bit	Number of paging-group-ID records
For (j=0; j<Num Records; j++) {		
MSS unique identifier	48-bit	48-bit unique identifier used by MSS on initial network entry
Action flag	8-bit	0 – Request information 1 – MSS arrived from hibernate mode 2 – MSS has transitioned to another paging group
}		
Security field	TBD	A means to authenticate this message
CRC field	32-bit	IEEE CRC-32

Add new sections C.2.8, C.2.9 and rename the existing C.2.8. The sections will include the following text

C.2.8 Paging-group-action message

This message is sent from BS to BS (or the ASA server) to indicate that the recipient BS is either added or removed from a paging group. The message can also be used to query whether the recipient BS is part of a paging group, or inform that the sender BS is part of a paging group.

The message contains the following information,

Field	Size	Notes
Message Type = ?	8-bit	
Sender BS-ID	48-bit	Base station unique identifier (Same number as that broadcasted on the DL-MAP message)
Target BS-ID	48-bit	Base station unique identifier (Same number as that broadcasted on the DL-MAP message)
Time Stamp	32-bit	Number of milliseconds since midnight GMT (set to 0xffffffff to ignore)
Action	4-bit	0 – Assign target BS to paging groups 1 – Remove target BS from paging groups 2 – Query (which paging groups target BS belongs to?) 3 – Information (paging groups sender BS belongs to)
Num Records	4-bit	Number of paging-group-ID records
For (j=0; j<Num Records; j++) {		
Reserved	1-bit	-
Paging-group-ID	15-bit	Paging-group-ID
Paging-group-Cycle	16-bit	Cycle in which the paging message is transmitted within the paging group
Paging-group-Cycle-Base	16-bit	16 LS-bits of the frame number closest to the time in which the message is sent, in which the paging message is transmitted within the paging group
}		
Security field	TBD	A means to authenticate this message
CRC field	32-bit	IEEE CRC-32

Table xxx: Paging-group-action message

C.2.9 Paging-announce message

This message is sent from BS to BS (or the ASA server) to announce that the recipient BS should page the provided list of MSS at a certain frame.

The message contains the following information,

Field	Size	Notes
Message Type = ?	8-bit	
Sender BS-ID	48-bit	Base station unique identifier (Same number as that broadcasted on the DL-MAP message)
Target BS-ID	48-bit	Set to 0xffffff to indicate broadcast
Time Stamp	32-bit	Number of milliseconds since midnight GMT (set to 0xffffffff to ignore)
Frame number where to page	32-bit	Frame number, where the MSS should be paged. The frame number that should be consistent with the paging group cycle, and should allow enough time for all BS to process this message
Num MSS	8-bit	Number MSS to page
For (j=0; j<Num MSS; j++) {		
MSS 48-bit MAC address	48-bit	-
}		
Security field	TBD	A means to authenticate this message
CRC field	32-bit	IEEE CRC-32

Table yyy: Paging-announce message