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Re:	Response to the P802.16e/D5a Ballot Resolution Committee Recirculation Announcement IEEE 802.16-04/79
Abstract	This contribution recommends adding a broadcast Universal Downlink Notification message to be used, and optionally placed at the early part of DL MAP to allow fast paging, traffic allocation and broadcast update indications to the mobile terminals in the Idle and Sleep Modes.
Purpose	To be discussed and considered in preparation of new text for idle and sleep mode sections.
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Universal Downlink Notification Message

Kamran Etemad et al
Nextel

Problem:
The current draft of IEEE802.16e provides definitions and procedures for mobile stations operation in sleep and idle modes. The two modes share in common periods of programmed/scheduled unavailability or absence from the DL/UL traffic of the base station.

While "inactive" in idle or sleep mode the Mobile Stations need to "wake up" from time to time and listen to downlink messages over a listening interval to check for any paging notification MAC management message, DL traffic allocation for a sleep mode MSS, notification of instruction to exit sleep mode, or broadcast update information. The schedule for listening vs. unavailability intervals are determined and set by the system according to the procedure already defined in the IEEE802.16e specification.

As the mobiles spend a large majority, e.g. > %90, of their times in the idle and sleep modes their power consumption during these states has a major impact on their overall standby and talk time if they are battery powered--as most mobile devices are assumed to be. Therefore any reduction in the PHY and MAC layer processing of mobiles during Idle and Sleep time is of great interest for power efficiency. Adjustment may also yield MAC overhead savings as well.

Remedy:
This contribution proposes that a common notification mechanism may be appropriate for both 'intermittent unavailable' modes in the mobility standard, and that such a generalized method can provide MSS substantial power conservation savings, and may alleviate MAC overhead as well. Specifically, the proposal presents an extended DUIC IE format, Universal DL Notification IE, to be incorporated as a broadcast control MAC message to the DL-MAP. Additional appropriate language changes in the Sleep Mode and Idle Mode sections supporting the introduction of this DL-MAP extended IE are given.

Using the DL-MAP extended IE to perform this notification function conveys a number of benefits. First, it moves the notification activity much earlier in the frame, in this case to very near the beginning of the DL-MAP. Early presence of the notification message allows Idle Mode and Sleep Mode devices to quickly determine the need to interpret the remainder of the DL-MAP, and possibly to remain awake, active and decode the remainder of the frame, or discontinue decoding of the current frame.

Of course it is important to remain sensitive to adding excessive overhead. So the proposed mechanism uses a scalable, single- bit flag table to which MSS index through a hash of their MAC Address. A single Universal DL Notification IE can support over 100 flag bits, and do it within a 128 bit total IE package. This compares favorably to a PAG-ADV or TRF-IND message of 168 bit MAC header plus payload; figure the current MAC messages weighing in at around 200 bits, minimum. While the proposed mechanism does not replace PAG-ADV, it may be used to replace TRF-IND if the proposed feature is selected to be mandatory instead of only optional. Replacing TRF-IND is also desirable in that adoption of recent changes to Sleep Mode have made TRF-IND obsolete, especially SLPID component. TRF-IND is no longer the primary means of extricating MSS from Sleep Mode. So continued use of the large and cumbersome TRF-IND message is no longer warranted.

For Idle Mode MSS, provided that Paging Group ID is included in the IE so they may detect transition out of their serving paging zone, absence of a positive notification allows them to immediately return to MSS Paging Unavailable Interval—minimizing powered activity. A positive indication informs the Idle Mode MSS that the PAG-ADV message will contain an instruction for activity and the MSS should continue decoding the frame and perform the directed operation.

Sleep Mode MSS use the bit flags to alert them to the presence of pending DL allocation as detailed in the DL-MAP and/or BS interest in MSS terminating operation of one or more Power Saving Classes, once again by including a DL allocation in the DL-MAP pointing to a Sleep Header message. At the time of Sleep Mode MSS decoding a positive indication flag in the Universal DL Notification IE, the MSS does not know if it will be just receiving a normal DL traffic allocation or will receive other instruction, but does know that it should continue decoding the frame and perform the directed operation. Of benefit, the absence of a positive indication in the IE permits the Sleep Mode MSS to discontinue decoding the current frame; if the last frame of its listening interval, the MSS may immediately return to its sleep interval; if not the last frame of its listening interval, the MSS will again begin decoding at the beginning of the next frame.

While the hashing method employed and the shared use of the indexed flags by devices in two modes can yield a very small number of false positive indications, the probability of false positives is extremely small and the outcome very minor: the MSS would continue to decode the DL-MAP and possibly the PAG-ADV, whereby it would learn that, in fact, no action was required, and would return to its mode function without impediment to its current operation. That is to say that no state changes are affected through the proposed IE, only direction of MSS to ‘pay attention’ and continue decoding the current frame at least through the remainder of the DL-MAP.

Of more severity would be false negatives, which are not possible with the current design.

Another issue that can be conveniently addressed through the proposed remedy mechanics is the problem of changes in DCD and/or UCD. Sleep Mode, and especially Idle Mode MSS can waste substantial frames decoding the beginning of each and every frame looking for the updated DCD/UCD to regain burst mode synch, upon detecting a change in the Configuration Change Counter of the DL-MAP. Increasing the spacing between DCD/UCD changes and/or transmission is hardly helpful as it only increases the duration of this constant decoding period. Decreasing the spacing between DCD/UCD changes and/or transmissions beyond what is desirable for optimal system performance unnecessarily increases overhead. A method to remove MSS obligation to search each frame for updated DCD/UCD is to include the frame number of the next DCD/UCD transmission. With the frame number in hand, MSS could continue their mode operation without the burden of unnecessarily decoding the beginning of frames outside of their listening interval, awakening when the proscribed DCD/UCD transmission frame time arrives, decoding the transmission, and becoming again immediately available to return to normal operation with minimal synchronization; minimized call setup latency. With this method, MSS in both Idle and Sleep Mode remain constantly updated to DCD/UCD changes with the minimum of frame decoding requirements.

The contribution suggests including support for other change notification and frame mapping for some other configuration change and emergency notification purposes. Specifically, the contribution makes allowance for changes to some as yet undefined configuration items and/or allowance for scheduled receipt of emergency services multicast bulletins (e.g. location specific emergency advisories like avalanche, flash flood, tornado, Amber alert, etc…). These additions can be extremely beneficial in that they allow for the

timely dispersal of timing critical information/updates while not requiring a massed network re/entry with resumption of normal operations by all MSS in sleep and idle modes.

While the remedy method proposed in the contribution is for the OFDMA PHY, the mechanism is equally valid for all PHY types.

Revision Editorial Notes:

[Phil Barber: 2005/1/13] Language revision to several locations of proposed text to remove obscure language indicating it may be possible to discontinue decoding of DL-MAP in some instances. Because of CRC on DL-MAP, not currently possible to discontinue decoding of message. Must decode entire DL-MAP, but not necessary to interpret entire message in some cases.

[Phil Barber: 2005/1/13] Moved 'Padding bits' in Table xxxa to end of message.

[Phil Barber: 2005/1/13] Changed legacy references in proposed text from 'Page 1 of 2' to 'Multi-part IE' in several places.

[Phil Barber: 2005/1/13] Corrected equation for 'N' in proposed text for 6.3.19.1 and 6.3.21.5

[Phil Barber: 2005/1/13] Removed 'mandatory' language from new section 8.4.5.3.20.

[Phil Barber: 2005/1/13] Removed 'If MSS supports…' language in proposed text for 2nd paragraph of 6.3.19.1 and 6.3.21.5.

[Phil Barber: 2005/1/25] Removed language excising TRF-IND and SLPID material.

[Phil Barber: 2005/1/25] Adjusted invoking language for Sleep Control Headers and TRF-IND to clarify optional usage.

[Phil Barber: 2005/1/25] Modified Sleep Mode section language to accommodate optional sleep mode indication mechanisms: Universal DL Notification IE, Sleep Control Headers, TRF-IND.

The following sections specify text changes to the D5a draft:

Remedy 1:
[In 6.3.2.1.6 Sleep Control Headers, page 19, line 33, modify paragraphs as]:
Bandwidth request and Sleep Control Header is sent by the MSS to request activation / deactivation of certain Power Saving Class. The message also indicates total transmission demand at the MSS that may be used by the BS for the purpose of scheduling. Sleep Control Header is optional.

[In 6.3.2.3.46 Traffic Indication message (MOB-_TRF-IND), page 72, line 10, modify paragraphs as]:
TRF-IND is an optional notification message. This message is sent from BS to MSS on the broadcast CID. The message is intended for MSSs that are in Sleep Mode, and is sent during those MSS's listening-intervals. The message indicates whether there has been traffic addressed to each MSS that is in Sleep. For an MSS that is in Sleep Mode, during its listening window the MSS shall decode this message to seek an indication addressed to itself.

When an MSS awakens, it will check the frame number to ensure that it did not lose frame synchronization with the BS and read the message, when present, including the SLPID-Group Indication bit-map or Traffic Indication bit-map assigned to it and decide whether to continue in Sleep Mode or return to Normal Operation.

[In 6.3.19.1 Introduction, page 122, line 33, modify paragraphs as]:
During Availability interval the MSS is expected to receive all DL transmissions same way as in the state of normal operations (no sleep). In addition, the MSS shall examine the DCD and UCD change counts and the frame number of the DL-MAP PHY Synchronization Field to verify synchronization with the BS. Upon detecting a changed DCD and/or UCD count in the DL MAP, unless using the Universal DL Notification IE method for tracking and updating DCD and/or UCD changes, the MSS shall continue reception until receiving the corresponding updated message.

If the BS transmits the Universal DL Notification IE, the MSS shall read and react to this message before any further action according to the following:

- The MSS shall read the Skip Traffic Indication flag in the message. If the flag is set to '1', the MSS shall discontinue acting on the remainder of the Universal DL Notification IE and continue to decode the frame as in listening interval of Sleep Mode. If the flag is set to '0', the MSS shall:
  - hash to and read one of the binary flags in the Binary Notification Flags field. The hashing is based on (MSS MAC Address) modulo N where N is the number of bits in the Binary Notification Flags field, additive if both Universal_DL_Notification_IE and Universal_DL_Extension_IE are transmitted. For hashing purposes, Binary Notification Flags in Universal_DL_Extension_IE is an extension, adds to the end of Binary Notification Flags from Universal_DL_Notification_IE. The value of N shall be calculated based on the following:

    N={Length of Binary Notification Flags x 8 + (Multi-part IE x (Length of Universal_DL_Extension_IE x 8 - 9))}

  - If the Binary Notification Flag hash value read is '0', indicating no DL or UL transmission activity scheduled for the MSS this frame, the MSS may discontinue decoding the remainder of the frame after the DL-MAP. If the value read is '1', the MSS shall continue decoding the frame as in listening interval of sleep mode.
- If the DCD_UCD Configuration Change Counter has changed since MSS last decoding of this IE, even if scheduled to be in a sleep interval the MSS shall awaken at DCD_UCD Transmission Frame in time to synchronize to the DL and decode the DCD and UCD message in the frame, if present. If the MSS fails to decode one or both of DCD and UCD, or no DCD or UCD was transmitted by the BS, the MSS shall continue decoding all subsequent frames until it has acquired both updated DCD and UCD. Upon successful completion of DCD and UCD decoding, the MSS shall immediately return to regular Sleep Mode operation.
- If Skip Broadcast_System_Update is set to '0', even if scheduled to be in a sleep interval, the MSS shall awaken at Broadcast_System_Update_Transmission_Frame in time to synchronize to the DL and decode and read the DL-MAP and any message, if present. Upon completion, the MSS shall immediately return to regular Sleep Mode operation.

During Unavailability intervals for MSS the BS may buffer (or it may drop) MAC SDUs addressed to unicast connections bound to an MSS. The BS may choose to delay transmission of SDUs addressed to multicast connections until to following Availability Interval, common for all MSSs participating in the multicast connection.

An MSS performing handover may include Power_Saving_Class_Parameters in RNG-REQ message to indicate its preference to enter Sleep Mode after the handover. In this case, the BS shall transmit unsolicited MOB_SLP-RSP message to the MSS after handover.

In MOB-TRF-IND message with negative indication for the MSS, the BS may include an updated SLPID for a MSS by appending SLPID_Update TLV in the MOB-TRF-IND message. When the received MOB-TRF-IND message includes a SLPID_Update TLV, the MSS shall decode the TLV and, if addressed, update its SLPID to the new one. The MSS shall identify if the SLPID_Update TLV addresses it by searching through the SLPID_Update TLV and determining if the MSS's current SLPID matches the Old_SLPID in the SLPID_Update TLV. If they match, then the MSS shall set its SLPID to the New_SLPID provided in the SLPID_Update TLV. For an example of sleep mode operation, see Annex E.

MSS in Sleep Mode may participate in periodic ranging. The procedure includes Serving BS allocation of UL transmission opportunity for periodic ranging in which the MSS shall transmit RNG-REQ message. After transmittal of the RNG-REQ, the MSS shall wait for the RNG-RSP message. Participation in the periodic ranging procedure does not change state of Power Saving Classes not associated with Ranging procedure.

The Serving BS may verify MSS exit from Sleep Mode by making a UL allocation for MSS at any time subsequent to supposed wakening event (for example, positive indication in MOB_TRF-IND message or Binary Notification Flag hash value read in a Universal DL Notification IE is '1') by transmitting at least BR message (if there is no data to transmit, BR field of the BR PDU shall be set to 0).

[In 6.3.19.2 Power Saving Classes of type 1, page 124, line 14, modify paragraphs as]:
Sleep windows are interleaved with listening windows of fixed duration. The BS terminates active state of Power Saving Class by sending MOB-TRF_IND message or a Binary Notification Flag hash value read in a Universal DL Notification IE with a value '1'. The BS shall send a~~A~~ traffic indication (MOB_TRF-IND) message ~~shall be sent by the BS~~ on broadcast CID or Universal DL Notification IE with a Binary Notification Flag hash value of '1'during listening window to alert MSS of appearance of DL traffic demand at the corresponding connections.

When an MSS receives an UL allocation after receiving a positive MOB_TRF-IND message indication or Binary Notification Flag hash value read in a Universal DL Notification IE of '1', the MSS shall transmit at least BR message (if there is no data to transmit, BR field of the BR PDU shall be set to 0).

During active state of Power Saving Class of Type 1 the MSS is not expected to send or receive any MAC SDUs or their fragments or to send bandwidth requests at connections that belong to the Power Saving Class.

Power Saving Class is deactivated either by MOB_SLP-REQ or MOB_SLP-RSP messages or (if Traffic triggered wakening flag = 1) after one of following events:

- BS transmits (during availability window) a MAC SDU or fragment thereof over connection belonging to the Power Saving Class
- MSS transmits a bandwidth request with respect to connection belonging to the Power Saving Class
- MSS receives MOB_TRF-IND message or Binary Notification Flag hash value read in a Universal DL Notification IE indicating presence of buffered traffic addressed to the MSS

Assuming TRF-IND_Required flag was set in MOB_SLP-REQ, Power Saving Class shall be deactivated if MSS failed to receive MOB_TRF-IND or Universal DL Notification IE message during availability window.

[In 6.3.21.5 MSS Paging Listening Interval, page 147, line 4, modify as]:

6.3.21.5 MSS Paging Listening Interval

The MSS shall scan, decode the DCD and DL-MAP, and synchronize on the DL for the Preferred BS in time for the MSS to begin decoding any BS Broadcast Paging message during the entire BS Paging Interval. At the end of MSS Paging Listening Interval, providing that the MSS does not elect to terminate the MSS Idle Mode, the MSS may return to MSS Paging Unavailable Interval.

If the BS transmits the Universal DL Notification IE, the MSS shall read and react to this message before any further action according to the following:

- If this is the first listening interval for the MSS for this Preferred BS, the MSS shall decode the Universal DL Notification IE, however the MSS shall continue to decode the frame as in paging listening interval of Idle Mode as if the Universal DL Notification IE had not been transmitted.
- The MSS shall read the Skip Paging Flags flag in the message. If the flag is set to '1', the MSS shall discontinue acting on the remainder of the Universal DL Notification IE and continue to decode the frame as in paging listening interval of Idle Mode. If the flag is set to '0', the MSS shall:
  - hash to and read one of the binary flags in the Binary Notification Flags field. The hashing is based on (MSS MAC Address) modulo N where N is the number of bits in the Binary Notification Flags field, additive if both Universal_DL_Notification_IE and Universal_DL_Extension_IE are transmitted. For hashing purposes, Binary Notification Flags in Universal_DL_Extension_IE is an extension, adds to the end of Binary Notification Flags from Universal_DL_Notification_IE. The value of N shall be calculated based on the following:

    N={Length of Binary Notification Flags x 8 + (Multi-part IE x (Length of Universal_DL_Extension_IE x 8 - 9))}

  - If the Binary Notification Flag hash value read is '0', indicating no DL or UL transmission activity scheduled for the MSS this frame, the MSS may discontinue decoding the remainder of the frame after the DL-MAP and infer that Paging Group ID is valid and matches MSS Paging Group ID (i.e. no paging group zone change). If the value read is '1', the MSS shall continue decoding the frame as in paging listening interval of idle mode.
- If the DCD_UCD Configuration Change Counter has changed since MSS last decoding of this IE, even if scheduled to be in a paging unavailable interval the MSS shall awaken at DCD_UCD Transmission Frame in time to synchronize to the DL and decode the DCD and UCD message in the frame, if present. If the MSS fails to decode one or both of DCD and UCD, or no DCD or UCD was transmitted by the BS, the MSS shall continue decoding all subsequent frames until it has acquired both updated DCD and UCD. Upon successful completion of DCD and UCD decoding, the MSS shall immediately return to regular Idle Mode operation.
- If Skip Broadcast_System_Update is set to '0', even if scheduled to be in a paging unavailable interval, the MSS shall awaken at Broadcast_System_Update_Transmission_Frame in time to synchronize to the DL and decode the DL-MAP and any message, if present. Upon completion, the MSS shall immediately return to regular Idle Mode operation.

[In 6.3.21.7 BS Broadcast Paging message, page 147, line 49, modify paragraphs as]:

MSS are identified in the BS Broadcast Paging message by their MSS MAC Address hash. A single BS Broadcast Paging message may include multiple MAC Addresses. For a given BS Broadcast Paging message in a specific BS Paging Interval, the BS shall include only those MSS MAC Address hash particular to the PAGING_CYCLE and which require notification of required action.

00: ~~no action required~~reserved
01: perform Ranging to establish location and acknowledge message
10: perform initial network entry
11: reserved

[In 6.3.21.9.1.1 Paging Group Update, page 149, line 18, modify paragraph as]:
The MSS shall perform Location Update process when the MSS detects a change in paging group. The MSS shall detect the change of paging group by monitoring the paging group identifier, ~~PG_ID~~Paging Group ID, which is transmitted by the Preferred BS in the MOB_PAG-ADV broadcast message during the Transmission Interval. If the ~~PG_ID~~Paging Group ID detected does not match the Paging Group to which the MSS belongs, or if the MSS fails to detect a MOB-PAG-ADV message at the appropriate interval, the MSS shall determine that paging group has changed.

[In 8.4.5.3 DL-MAP IE format, page 235, line 4, append new section as]:
8.4.5.3.20 Universal DL Notification IE
When transmitted, this IE broadcast control MAC message shall be placed at the earliest possible part of DL MAP, e.g. right after the critical broadcast control messages, to provide a fast and efficient delivery of binary notification flags to MSS in idle and sleep modes, triggering various actions. The structure of this IE and its extension are captured in Tables xxxa and xxxb respectively. Support for Universal DL Notification IE is optional.

Table xxxa— Universal_DL_Notification_IE Format

Syntax	Size	Notes
Universal_DL_Notification_IE{		
Extended DIUC	4 bits	FDN = 0x0A
Length	4 bits	Length of IE in Bytes
IE Identifier	1 bit	This bit is set to '0' to indicate that this IE is the Universal_DL_Notification_IE
Multi-part IE	1 bit	This bit is set to '1' if there is a Universal_DL_Extension_IE following this message.
DCD_UCD Configuration Change Counter	3 bits	A composite configuration change counter incremented for each change in either DCD or UCD
DCD_UCD Transmission Frame	8 bits	The least significant eight bits of the frame number of the next DCD and/or UCD transmission.
Skip Broadcast_System_Update	1 bit	
If (Skip Broadcast_System_Update == 0) {		
Broadcast_System_Update_Type	3 bits	Shows the type of Broadcast_System_Update

		000 For NBR_ADV Update 001 For Emergency Services Message 010 – 111 Reserved
Broadcast_System_Update_Transmission_Frame	8 bits	The least significant eight bits of the frame number of the next Broadcast_System_Update transmission.
}		
Skip Traffic Indication	1 bit	If set to '1', MSS in Sleep Mode can skip the remainder of this message; this message contains no additional information for MSS in Sleep Mode.
Skip Paging Flags	1 bit	If set to '1', MSS in Idle Mode can skip the remainder of this message; this message contains no additional information for MSS in Idle Mode.
Length of Binary Notification Flags	4 bits	Length of Binary Notification Flags in Bytes
Binary Notification Flags	*variable*	Used for both sleep mode and idle mode notification. Individual Binary values shall be set to '1' if any MSS that would hash to that flag index location is intended to be notified of pending DL or UL traffic allocation in the current frame, or BS instruction to Sleep Mode MSS with an operating Power Savings Class 1 to discontinue Sleep Mode for that Power Savings Class.
Padding	*variable*	The padding bits are used to ensure the IE size is integer number of bytes
}		

The size of Binary Notification field can optionally be expanded by appending another DL-MAP extended IE to this message, if indicated by Multi-part IE flag in this message. In that case, the Universal DL Extension IE shall be included and shall only contain additional binary notification flags.

Table xxxb—Universal_DL_Extension_IE Format

Syntax	Size	Notes
Universal_DL_Extension_IE{		
Extended DIUC	4 bits	FDN = 0x0A
Length	4 bits	Length of IE in Bytes
IE Identifier	1 bit	This bit is set to '1' to indicate that this IE is the Universal_DL_Extension_IE
Binary Notification Flags	*variable*	Used for both sleep mode and idle mode notification. Individual Binary values shall be set to '1' if any MSS that would hash to that flag index

		location is intended to be notified of pending DL or UL traffic allocation in the current frame, or BS instruction to Sleep Mode MSS with an operating Power Savings Class 1 to discontinue Sleep Mode for that Power Savings Class.
}		