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Title	Short Data Burst Support for MSS in Sleep Mode	
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Re:	IEEE P802.16e/D4-2004	
Abstract	This contribution proposes to support short data burst transmissions to/from MSS in Sleep Mode	
Purpose	Review and Adopt the suggested changes into P802.16e/D4	
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1 Introduction

Problem Description

In p802.16e/D4, the Sleep Mode is introduced in Section 6.3.19 for the purpose of power efficient operation. Based on the current standard, any UL/DL traffic transmission will result in a mode transition from Sleep Mode back to Normal Operation. Switching back to Sleep Mode involves some overhead (SLP-REQ – SLP-RSP transactions, see figure 1 below). This overhead spoils the efficiency of the Sleep Mode mechanism.
Furthermore, there's no solution in the standard for maintaining active non Best-Effort (BE) connections for MSS in Sleep Mode, or any other method for supporting MSS power down between data transmissions on such connections.
Though it is not clearly state so in the standard, implicitly all non BE connections must be closed (non active) before MSS initiates Sleep Mode.
The last issue missing from the standard, which this contribution deals with, is the transmission of broadcast and multicast messages to MSS in Sleep Mode.

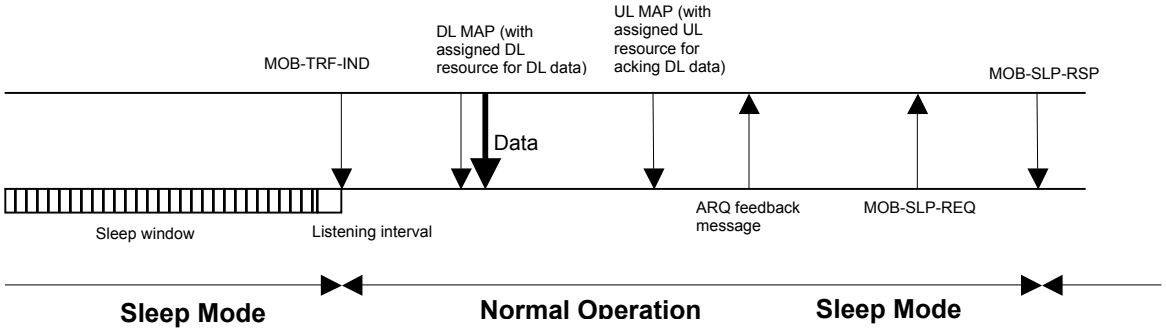

Fig. 1. Current operation for a small amount of DL data transmission to an MSS in Sleep Mode.

Contribution Objectives

This proposed contribution has several objectives for improving Sleep Mode as it is defined in the standard:

1. Provide a method for MSS to transmit and receive bursts of data (typically short ones) while in Sleep Mode, without the overhead of switching to Normal Operation mode and back to Sleep Mode.
2. Provide a method for the BS to schedule in advance broadcasts/multicasts to numerous MSSs in Sleep Mode.
3. Provide a method for the BS to inform MSS in advance of transmission schedule. This may be particularly useful for non BE connections (UGS, rtPS and nrtPS). In this method MSS can use the information to power down and save power on the period until next scheduled transmission. This can also permit keeping non BE connections open and active, for MSS in Sleep Mode.

Generally, the motivation is to allow MSS to sleep (power down and save power) as much as possible and wake up only when it was scheduled to receive DL data, or in case it has pending UL data to transmit.

General Description

According to the proposed contribution, described in this document, infrequent bursts of (typically small amount of) data may be transmitted by the MSS or to the MSS, while the MSS remains in Sleep Mode, without bringing the MSS back to Normal Operation before the data transmission.
This goal is achieved by using the following methods:

- Renewed definition of the Sleep Mode termination – not each data transaction requires Sleep Mode termination.
- Allowed UL transmissions by MSS, while remaining in Sleep Mode (using a new type of BW-REQ).
- Allowed DL transmissions by BS during Sleep Mode Listening Interval
- Definition of Scheduled Data Burst (SDB) Window. BS provides MSS with the offset to the beginning of the SDB Window,

for a specific CID. The SDB Window (or duration) is the period in which MSS should expect DL traffic and UL allocation for the specified CID.

- SDB Windows may be used for MSS in Sleep Mode, in which case non BE connections may remain active. BS may keep providing UL allocations for such connections. MSS may choose to use them in case of pending UL data or ignore them (remain asleep).
- BS may schedule broadcast and multicast transmissions also using the SDB Window mechanism. This may be especially useful for MSSs in Sleep Mode (schedule all relevant MSS to wake simultaneously to receive the data).

2 Proposed Enhancements

Highlights

In this contribution, the method of enabling data burst transmission to and from an MSS in Sleep Mode is proposed. The proposal includes the followings:

- Enabling MSS to receive data while in Sleep Mode (no termination required), in Listening Interval and in additional special scheduled windows (SDB Windows).
- Enabling MSS to transmit data while in Sleep Mode (no termination required), at any time using a special new type of BW request (DBDS-BW-REQ).
- DL and UL traffic for a particular CID may be scheduled to special windows (SDB Windows). BS sends this scheduling information to the MSS, which may choose to power down until the beginning of the window (as long as it doesn't have other active connections). This is especially useful for non-BE connections, that may remain active during Sleep Mode.
- Enabling a method for the BS to schedule broadcast and multicast messages in advance, and inform all (relevant) MSSs, so MSS in Sleep Mode can wake up and receive those transmissions. The SDB Window scheduling mechanism is used for this purpose.

Scheduled Data Bursts (SDB) Operation

- SDB Window:
  - Scheduled Data Burst (SDB) Window is a period (defined in full frames), in which MSS should be listening for DL bursts (unicast/multicast/broadcasts) and look for UL allocations.
  - First frame of next SDB Window for a specific CID is defined using SDB-Offset IE in DL-MAP.
  - During SDB Duration MSS will remain awake and listen for DL traffic and UL allocations. MSS will resume sleep (SDB-Offset termination) after receiving a new SDB-Offset IE. Sleep will be resumed in the following frame.
  - In frames with broadcast DL traffic, BS may use SDB-Offset, in order not to impose on the DL-MAP with the IE.
  - For each CID there may be only one pending SDB-Offset. A new SDB-Offset IE for a specific CID replaces any previous SDB-Offset defined for this CID.
  - See figure 2.
- SDB Offset Information Element (SDB-Offset IE):
  - BS may include in the DL-MAP this information element, which includes offsets to the first frame of next SDB Window for various CID (for unicast, multicast and broadcast).
  - The SDB-Offset IE may be included in one or more of the frames that the MSS should be listening to – in case of an MSS in Sleep Mode, SDB-Offset IE may be transmitted during Listening Interval, or during previously defined SDB Window.
  - The last option will allow a periodic DL transmission of data during Sleep Mode, which is more frequent than the Listening Intervals.

MSS DL Data While in Sleep Mode

- BS may transmit short bursts of data during the Listening Interval
  - MSS is required to process DL-MAP and the corresponding DL burst allocation, during the whole Listening Interval, and look for DL bursts which are targeted to it.
  - If ARQ is in use, MSS will remain awake, even if the Listening Interval is over, until it finished receiving all the blocks (and ACKing them), or until ARQ timeouts expire.
  - See figure 3.

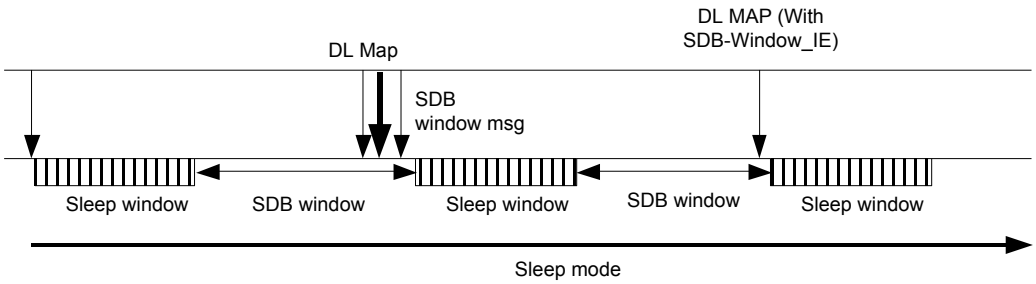

Fig. 2. DL data burst transmission to an MSS in Sleep Mode during SDB Window.

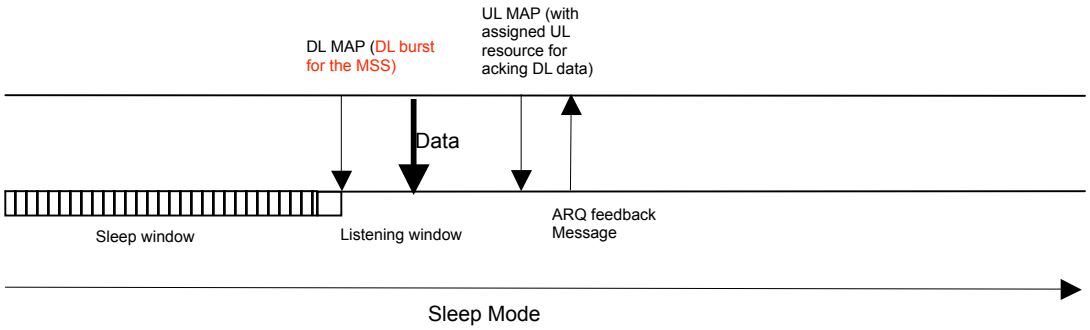

Fig. 3. DL data burst transmission to an MSS in Sleep Mode during Listening Interval.

MSS UL Data While in Sleep Mode

- Data Burst During Sleep BW Request (DBDS-BW-REQ):
  - Add a new type of BW-REQ, which means MSS has UL data to transmit (typically a small amount), and requires BW allocation to do so, without terminating Sleep Mode.
  - When BS receives a DBDS-BW-REQ it allocates UL allocations to the MSS, but the MSS is still considered to be in Sleep Mode (PDUs are buffered by BS etc.)
  - See figure 4.

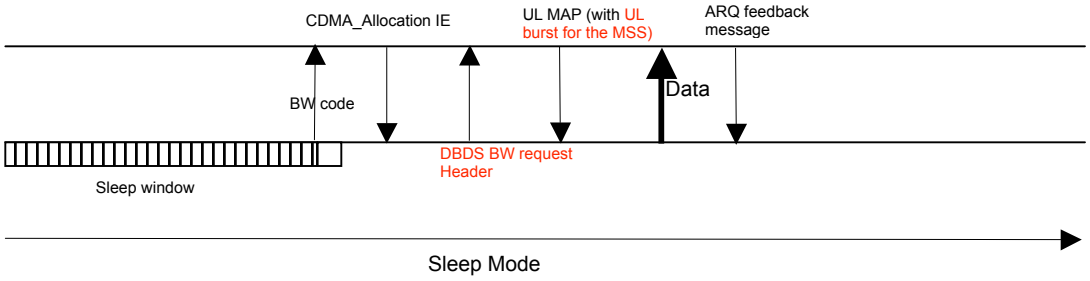

Fig. 4. UL data burst transmission from an MSS in Sleep Mode.

Non Best Effort Connections While in Sleep Mode

- UGS/rtPS/nrtPS connections and Sleep Mode:
  - Existing connections will maintain their states and parameters when MSS goes to Sleep Mode.
  - BS may maintain and keep providing to MSS periodic UL allocations for such connections.
  - BS may use SDB Windows to schedule DL transmissions and UL allocations for such connections.

- MSS may power down / sleep until SDB Window, and then awake, receive DL transmissions and use UL allocations for UL traffic.
- If ARQ is in use, MSS will remain awake, and keep transmitting until all blocks are ACKed or max number of retries was reached.
- DL/UL transmissions to MSS on such connections should be done during SDB Windows, but may also be done during Listening Intervals.
- SDB Window scheduling can be used for connections of MSSs that are not in Sleep Mode. Such an MSS may be able to identify opportunities to power down, during periods that no connection has scheduled traffic, to save power.
- See figure 5 for UGS example

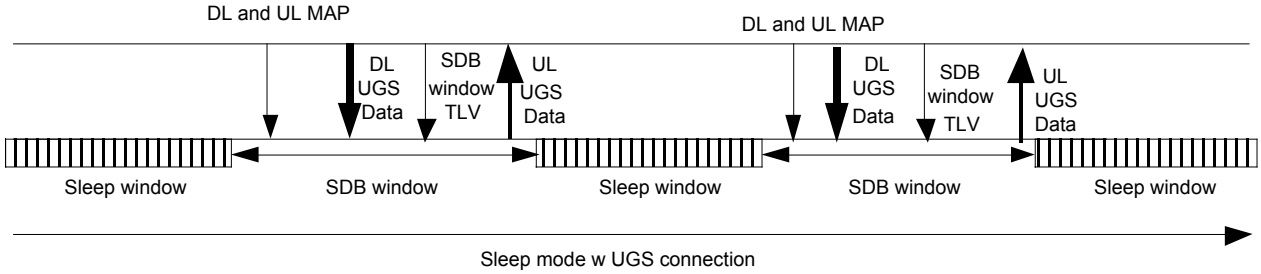

Fig. 5. DL/UL data burst transmissions to/from an MSS in Sleep Mode, for UGS connection.

Broadcast and Multicast Transmissions While In Sleep Mode

- Broadcast/Multicast
  - MSS must receive all broadcasts/multicasts that are transmitted during it's Listening Interval and SDB Window.
  - BS may use the SDB-Offset to schedule broadcast/multicast transmission to numerous MSS in Sleep Mode (or in Normal Operation mode), by using the broadcast CID in the SDB-Offset IE..

General Enhancements

- Redefinition of Sleep Mode termination:
  - Sleep Mode will be terminated by MSS initiative only when BS receives a standard (non-DBDS) BW-REQ from MSS.
  - See figure 6 for Sleep Mode termination by MSS initiative.
  - Sleep Mode will be terminated by BS initiative only when MSS receives a positive traffic indication in MOB-TRF-IND message (pending traffic indication and not Ranging opportunity).
  - Even after sending positive traffic indication, BS will assume MSS is still in Sleep Mode (and not send the pending data) until receiving a standard (non-DBDS) BW-REQ from the MSS, as an acknowledgment to the MOB-TRF-IND.
  - For any other type of PDU sent by MSS on UL or by BS on DL, Sleep Mode will be maintained.
  - See figure 7 for Sleep Mode termination by BS initiative.
- Sleep Window and Listening Interval
  - The Listening Interval length value and the Sleep Window initial and final values that were defined by BS at SLP-RSP message, and the Sleep Window length algorithm will be maintained as long as the MSS remains in Sleep Mode, independent of the use of SDB mechanism or UGS/rtPS/nrtPS connections transmissions.
  - When Sleep Window ends and Listening Interval begins, MSS must listen for MOB-TRF-IND message and for DL traffic bursts, no matter if it is in the middle of DBDS, SDB or UGS/rtPS/nrtPS transactions.
  - When Listening Interval ends, MSS may remain awake if in the middle of reception or transmission.
  - BS may send MOB-TRF-IND with positive traffic indication in SDB Window (not only in listening interval) in order to wake the MSS out of Sleep Mode.

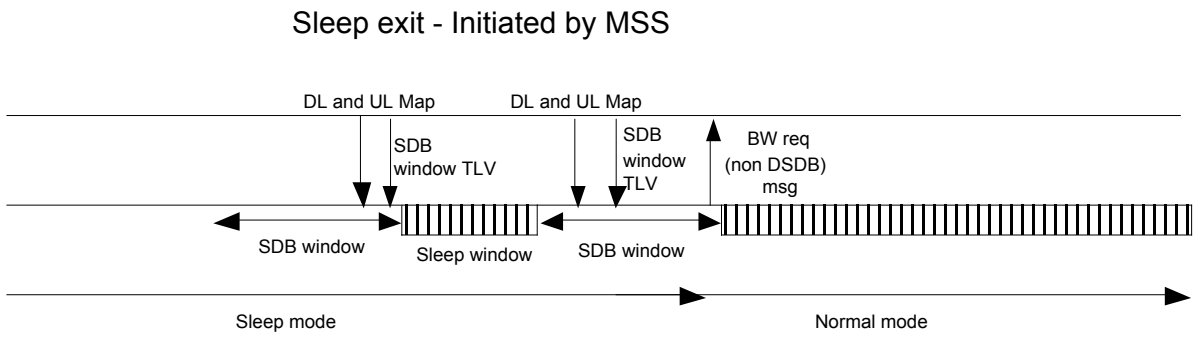

Fig. 6. Sleep Mode termination, initiated by MSS

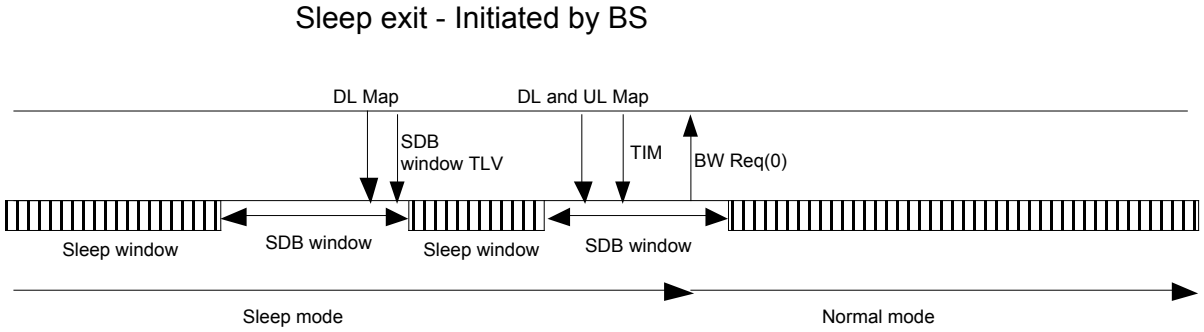

Fig. 7. Sleep Mode termination, initiated by BS

3 Proposed Text Changes

The following modification is based on p802.16e/D4.

[Modify the Section 6.3.19.1]

[……]

An MSS in sleep-mode shall engage in a sleep-interval, defined as a time duration, measured in whole frames, where the MSS is in sleep-mode. The sleep-interval is constructed of one or more variable-length, consecutive sleep-windows, with interleaved listening-windows and possibly SDB-Offsets. During a sleep-window, an MSS does not ~~send or~~ receive PDUs, and may power down one or more physical operation components, or may awaken for periodic ranging, data burst transmissions or during SDB-Offset. During a listening-interval, an MSS shall synchronize with the Serving BS downlink~~, and~~ listen for an appropriate MOB-TRF-IND traffic indication message and receive broadcast/multicast/unicast traffic. Similarly, during a SDB-Offset, an MSS shall synchronize with the Serving BS downlink, receive broadcast/multicast/unicast traffic and listen for an appropriate MOB-TRF-IND traffic indication message. The MSS shall decide whether to stay awake or go back to sleep based on the either value of its own 2-bit indicator in the SLPID bitmap or the basic CID of the MSS in a MOB-TRF-IND from the Serving BS. During consecutive sleep-windows and listening-windows, comprising a single sleep-interval, sleep-window shall be updated using the algorithm as defined in 6.3.19.2 Sleep-window update algorithm.

[……]

An MSS may terminate sleep-mode and return to Normal Operation anytime, by sending a standard (non-DBDS type) BW request header (i.e. there is no need to wait until the sleep-interval is over). If a Serving BS receives a non-DBDS type BW-REQ header ~~a PDU~~ from an MSS that is supposed to be in Sleep Mode, the BS shall assume that the MSS is no longer in sleep-mode~~, except for RNG-REQ or DBPC-REQ~~. An MSS ~~which~~ shall send~~s~~ the RNG-REQ or DBPC-REQ message using unsolicited grant or using DBDS type BW request header to the BS, and remain~~s~~ in awake mode during the operation of downlink burst profile management and then return~~s~~ to Sleep Mode after the operation. An MSS which sends DBDS-BW-REQ header to the BS remains in awake mode during the UL data burst transmission procedure and then returns to sleep-mode, maintaining the original sleep-window and listening-window.
Any other UL message from the MSS to the Serving BS shall not interrupt the sleep-interval, shall signal the Serving BS that the MSS is still ~~active~~ in Sleep Mode and connected and has not dropped connection during its sleep-interval.

The BS may send a positive traffic indication to terminate sleep-mode and order the MSS back to Normal Operation, by using the MOB-TRF-IND message, during Listening Interval or during SDB Window (see section 6.3.19.4.1). After receiving a positive traffic indication in the MOB-TRF-IND message, the MSS shall respond with a non-DBDS type BW-REQ.

The BS shall consider the MSS to be out of sleep-mode, only after receiving a non-DBDS type BW request header ~~any MAC PDU (except RNGREQ or DBPC-REQ)~~ from any of the MSS connections.....

The BS may maintain existing connections states and parameters when MSS enters Sleep Mode. Specifically, BS may keep UGS and n/rtPS Polling grants or uplink transmissions allocations in the uplink for an MSS in Sleep Mode, as it does for MSS in Normal Operation. This is to allow the MSS to have the resources required to keep the quality of the connections during Sleep Mode.
BS may use SDB-Offset IE to inform the MSS of next DL/UL transmission opportunity for the connection, in order for MSS in Sleep Mode to be able to schedule awake period.

MSS in Sleep Mode shall become awake during the SDB Window, searches for UL bursts allocation and for DL transmissions for the relevant connection. If ARQ is in use, MSS should ACK the received data appropriately, before going back to sleep.
Connections status and parameters may be updated using DSx management messages by BS during Listening Intervals and SDB Windows and by MSS at any time.

[……]

[Add a new section 6.3.19.4. Short data burst operation]

6.3.19.4 Data Burst Transmission to/from an MSS in Sleep Mode

6.3.19.4.1 DL Data Burst to an MSS in Sleep Mode

BS may send short bursts of DL data to the MSS during listening-interval, without bringing the MSS back to Normal Operation. MSS is required to process DL-MAP and DL sub-frame, during the whole Listening Interval, and look for DL bursts which are targeted to it. If the ARQ function is enabled, the MSS shall send ARQ ACK message to the BS. The ARQ ACK message can be sent on the UL resource assigned by the BS. Alternatively, if UL resource is not assigned, the MSS shall follow the procedure of UL data burst transmission as described in section 6.3.19.4.2 to send the ARQ ACK message.

The BS may send a SDB-Offset IE to the MSS to specify an offset to the next SDB duration, in which the MSS shall stay awake regardless of its predefined sleep state. This feature can be used to synchronize Multicast or Broadcast DL intervals across different MSSs and also provide the BS flexibility to schedule future DL/UL unicast traffic to and from the MSS in Sleep Mode when resources become available.

The SDB-Offset IE may be included in one or more frames that the MSS should be listening to. For MSS in Sleep Mode, it means during Listening Interval, or during previously defined SDB Window. For each CID there may be only one pending SDB-Offset. A new SDB-Offset IE for a specific CID replaces any previous SDB-Offset offset defined for this CID.
BS may send MOB-TRF-IND with positive traffic indication in SDB Window (not only in listening interval) in order to wake the MSS out of Sleep Mode

6.3.19.4.2 UL Data Burst Transmission from an MSS in Sleep Mode

Upon arrival of UL PDUs, the MSS may become awake to receive unsolicited UL BW allocation from the BS. Alternatively, MSS in

Sleep Mode can send DBDS-BW-REQ to inform the BS of required BW for uplink data burst transmission while in Sleep Mode. After receiving the request, the BS may allocate UL resource for the MSS to transmit the data burst. If the ARQ function is enabled, the BS shall send ARQ ACK message to the MSS. The MSS shall resume Sleep Mode operation after either ACK is received or the number of retrials has reached the maximum value. If ARQ function is not enabled, the MSS may resume Sleep Mode operation after the UL data burst transmission. MSS may terminate Sleep Mode and go back to Normal Operation only by sending non-DBDS BW request header.

The BS may schedule SDB windows to assign UL resource to the MSS. In case of a non Best Effort (BE) connection (UGS, rtPS or nrtPS), the BS may schedule regular SDB windows for the connection. UL PDUs are transmitted during the appropriate SDB Windows, in which UL allocations should be provided.

[Add a new section 6.3.2.1.4 UL Short Data Burst Bandwidth request header]

6.3.2.1.4 Data Burst During Sleep Bandwidth Request (DBDS-BW-REQ) Header

The Data Burst During Sleep Bandwidth Request (DBDS-BW-REQ) Header is used by an MSS in Sleep Mode to send an UL resource request for data-burst transmission.

PDU shall consist of DBDS-BW-REQ Header alone and shall not contain a payload. The DBDS-BW-REQ header is illustrated in Fig. xxx.

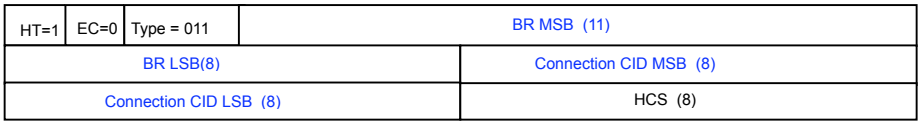

Fig. XXX. DBDS-BW-REQ header.

The DBDS-BW-REQ header shall have the following properties:

a) The length of the header shall always be 6 bytes
b) The EC field shall be set 0, indicating no encryption
c) The CID shall indicate the connection CID for which the UL bandwidth is requested
d) The Type field shall be '011'
e) The BR field shall indicate the number of bytes requested (in unit of 1-byte)

The fields of the DBDS-BW-REQ header are defined in Table xx.

Table xx. DBDS-BW-REQ fieds

Name	Length (bits)	Description
BR	19 bits	Number of bytes requested (in unit of 1-byte)
Connection CID	16 bits	Connection CID for which the UL bandwidth is requested
HT	1 bit	Header Type = 1
EC	1 bit	Always set to 0
Type	3 bits	Type = 011
HCS	8 bits	Header Check Sequence (same usage as HCS entry in Table 5)

[Add a new section 8.4.5.3.19 DL-SDB-in-Sleep Information Element format]

8.4.5.3.19 SDB-Offset Information Element format

The SDB-Offset Information Element is used by a BS to specify a frame offset for potential scheduled data burst, during which the MSS shall stay awake regardless of its predefined Sleep, Normal or Idle mode. This feature can be used to synchronize Multicast or Broadcast DL intervals across different MSSs in Sleep, Normal or Idle mode and also provide the BS flexibility to schedule future UL/DL unicast traffic to the MSS in Sleep or Normal mode, when resources become available.

The awake duration following the SDB-Offset is dynamic, and determined only by the presence of a new SDB-Offset IE. When receiving such an IE the MSS may resume its sleep, Idle or normal power save operation as of the following frame.

BS may choose not to schedule the next SDB-Offset. In such case it should send a SDB-Offset IE with Next wakeup period offset offset to 0.

Table XXX. SDB-Offset IE format

Syntax	Size	Notes
SDB-Offset_IE() {		
_Extended DIUC	4 bits	0x0F
_Length	4 bits	
_Num_assignment	8 bits	
_For (i=0;i< Num_assignment;i++) {		
__CID	16 bits	Unicast, broadcast and multicast CID
__Next SDB offset	10 bits	Offset_in_units_of_frames_from_the_current frame, at which the next SDB offset will start
_}		
Reserved	*variable*	Padding bits to ensure octet aligned
}		