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Re:	The document supports a comment at Sponsor Ballot on 802.16e/D5 document
Abstract	The documents suggests text changes to incorporate different cases of Sleep Mode operations into a single scheme
Purpose	The document is for consideration during Sponsor Ballot comments resolution
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Sleep Mode Generic Mechanism

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1. Problem Description

In 802.16e standard the Sleep Mode is defined for the purpose of power efficient operations. The Sleep Mode procedure includes listening window of constant size and doubling sleep window. Such behavior perfectly fits the behavior of demand created by "random" ("bursty") IP traffic, like WEB browsing. Such traffic typically is carried in NRT-VR or BE connections.

But demand created by UGS and in some cases RT-VR connections may have different pattern. In the case of UGS, the demand for transmission of N bytes appears each M milliseconds, so it would be natural for the MSS to have listening window of constant size around time instances where demand is expected with sleep windows in-between. *As opposite to existing definition of Sleep Mode, data transmission within listening window should be allowed without interruption of sleep state*. Note that under current Sleep Mode scheme, each time UGS demand appears, the BS must terminate Sleep Mode, arrange data transfer and restart Sleep Mode. The cost of Sleep Mode interruption is that the BS and the MSS exchange MOB_SLP-REQ/RSP messages *after each transferred packet*.

Specific problem with multicast / broadcast services is that MSS may have both multicast connection(s) and unicast connections with different demand patterns, so synchronization of sleep/listening cycles between different MSSs is nearly impossible. Under current Sleep Mode scheme, the only reasonable solution is to interrupt Sleep Mode for all involved MSSs and to arrange data transfer. The cost of Sleep Mode interruption is time for getting out of Sleep Mode and air interface overhead. Additionally, as defined in current version, initial value of sleep-window is 6 bits only, therefore maximum 63 frames, which is far from reasonable maximum value that might be achieved previously. So restarting sleep mode is inefficient also from the point of view of MSS power consumption.

Another problem is combining Sleep Mode operations with management procedures like Periodic Ranging, SNMP operations etc. Suppose that MSS is in Sleep Mode as there is no demand at existing traffic connections and there is a need for SNMP operations or other management procedure, then BS has to keep the MSS available for SNMP transaction. Existing traffic connections still have no demand, so there is no reason to interrupt their Sleep state. But existing procedure prescribes to terminate Sleep Mode (by "Traffic Indication" message though there is no traffic) perform SNMP procedure and restart Sleep.

Periodic Ranging procedure as described in the standard, appears as an exceptional case handled by special arrangement. Seems profitable to include it into general scheme as a particular case.

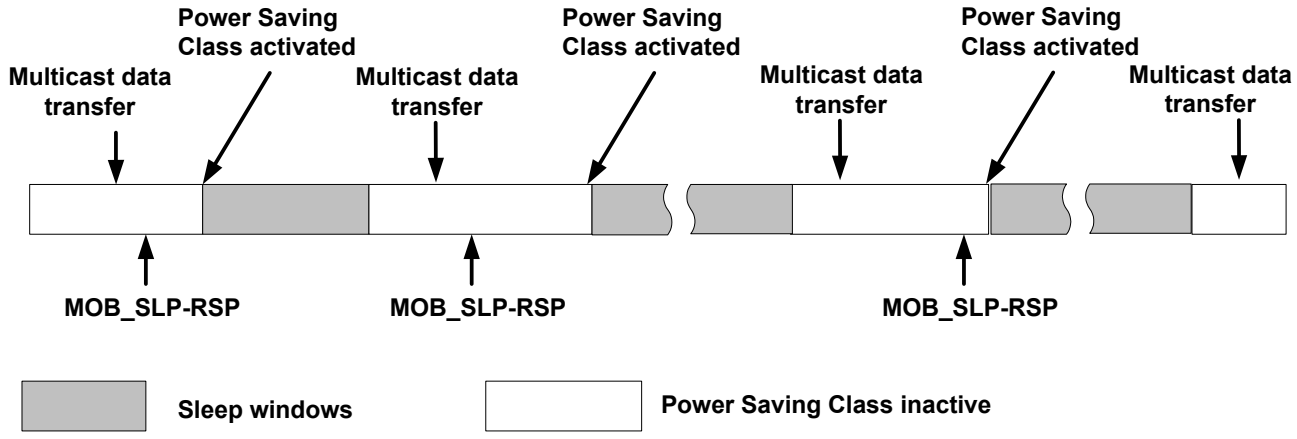
2. Idea of Solution

Definition of Sleep Mode for MSS should be extended. If the MSS has several services of different types (or for UGS, RT-VR with different parameters), then for each service type a separated Sleep Mode context must be created. Sleep Mode entrance/termination for each state machine depends on presence of demand at

corresponding connections, so they are independent of each other. Each of these independent Sleep Mode state machines provides certain sequence of sleep/listening windows. The MSS is supposed to sleep in intervals at which ALL state machines show “sleep” state.

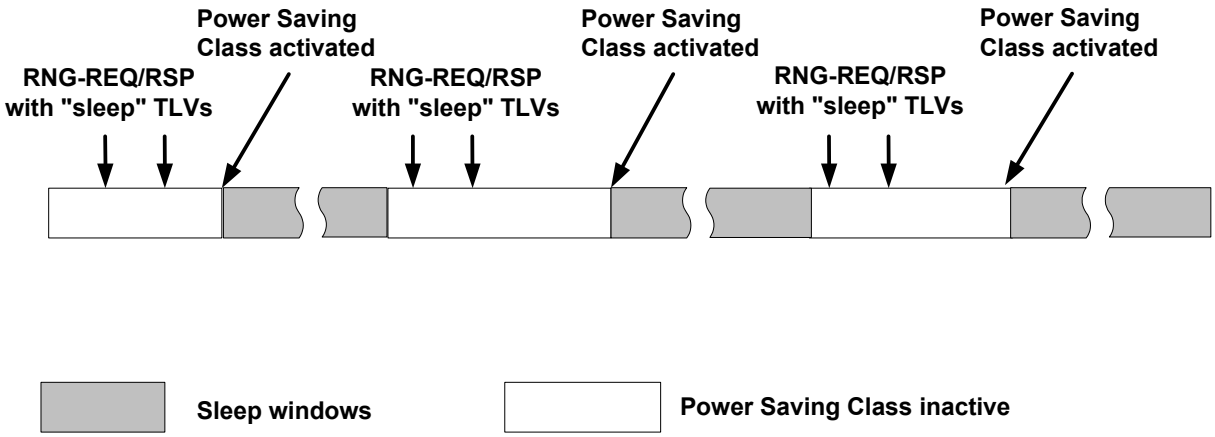
For example, let’s assume that a MSS has two Power Saving Classes: Class A contains several connections of BE and NRT-VR type, Class B contains a single connection of UGS type (see Figure NNN below). Then for Class A the BS allocates sequence of listening window of constant size and doubling sleep window. For Class B the BS allocates sequence of listening window of constant size and sleep window of constant size. The MSS is considered unavailable (and may power down) within intersections of sleep windows of A and B. Now, let’s consider one of listening windows for Class B. Supposedly there is a transmission demand of UGS connection at the window, so the BS allocates certain capacity to transfer the data; after transfer the connection returns to “sleep” state. If during all this activity NRT-VR connection has no demand, it stays in “sleep” state and there is no need in re-starting Sleep Mode with already achieved maximum sleep window size.

The following picture illustrates suggested Sleep implementation for multicast connection. The corresponding Power Saving Class is associated with the corresponding multicast connection. When activated (by MOB-SLP-RSP from BS), the class of this type provides a single sleep window. After expiration of sleep window, the MSS is awake and if multicast data is already available, it may be transferred, otherwise Power Saving Class is re-activated and the MSS enters sleep window.



Power Saving Class for multicast connection

Next picture describes suggested Sleep implementation for Periodic Ranging procedure. The corresponding Power Saving Class is associated with Basic connection of the MSS. At initial point MSS and BS perform Periodic Ranging transaction using RNG-REQ/RSP messages that contain TLVs to configure and activate Power Saving Class of same type as for multicast connections. A listening window of this class is used again for exchange of RNG-REQ/RSP messages, which again may activate Power Saving Class etc.



Power Saving Class Usage for Periodic Ranging

Suggested changes in 802.16e have the following advantages

- Set of parameters and behavior of MSS with a single Power Saving Class of certain type (Type 1 specified below) is exactly the same as in currently defined Sleep Mode procedure
- Universal set of parameters and universal structure of MOB-SLP-REQ/RSP messages defined
- New Sleep Mode option added for UGS/RT-VR support: Power Saving Classes of type 2
- New Sleep Mode option added to support broadcast / multicast connections and management procedures (Periodic Ranging, DSx, broadcast management messages like NBR-ADV etc.): Power Saving Classes of type 3 BS may decide to use this procedure also to keep certain MSSs awake up to arrival of nearest DCD or UCD messages.

3. Specific Changes in 802.16e/D5

[Replace sections 6.3.19.1- 6.3.19.3 starting from p. 102, line 53, with the following text]

6.3.19.1 Introduction

Sleep Mode is a state in which an MSS conducts pre-negotiated periods of absence from the Serving BS air interface. These periods are characterized by the unavailability of the MSS, as observed from the Serving BS, to DL or UL traffic. Sleep Mode is intended to minimize MSS power usage and decrease usage of Serving BS air interface resources. Implementation of sleep-mode is optional for the MSS and mandatory for the BS.

For each involved MSS the BS keeps one or several contexts, each one related to certain Power Saving Class. Power Saving Class is a group of connections, which have common demand properties. For example, all BE and NRT-VR connections may be marked as belonging to a single class which means that they will have same sleep/listening windows. Two UGS connections may belong to two different classes in case they have different intervals between consequent allocations. MSS shall be capable of supporting at least 4 Power Saving Classes simultaneously. Activation of certain Power Saving Class means starting sleep/listening windows sequence associated with this class. Algorithm of choosing Power Saving Class type for certain connections is outside of the scope of the standard.

There are three types of Power Saving Classes, which differ by their parameter sets, procedures of activation/deactivation and policies of MSS availability for data transmission.

Unavailability interval is a time interval that does not overlap with any listening window of any active Power Saving Class

Availability interval is a time interval that does not overlap with any Unavailability interval

During Unavailability interval the BS shall not transmit to the MSS and shall not provide unicast transmission opportunities to the MSS, so the MSS may power down one or more physical operation components or perform another activities that do not require communication with the BS: scanning neighbor BSs, associating with neighbor BSs etc.

If there is a connection at the MSS, which is not associated with any active Power Saving Class, the MSS shall be considered available on permanent basis.

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, the MSS shall continue reception until receiving the corresponding updated message.

Figure NNN describes example of behavior of MSS with two Power Saving Classes: Class A contains several connections of BE and NRT-VR type, Class B contains a single connection of UGS type. Then for Class A the BS allocates sequence of listening window of constant size and doubling sleep window. For Class B the BS allocates sequence of listening window of constant size and sleep window of constant size. The MSS is considered unavailable (and may power down) within windows of unavailability, which are intersections of sleep windows of A and B.

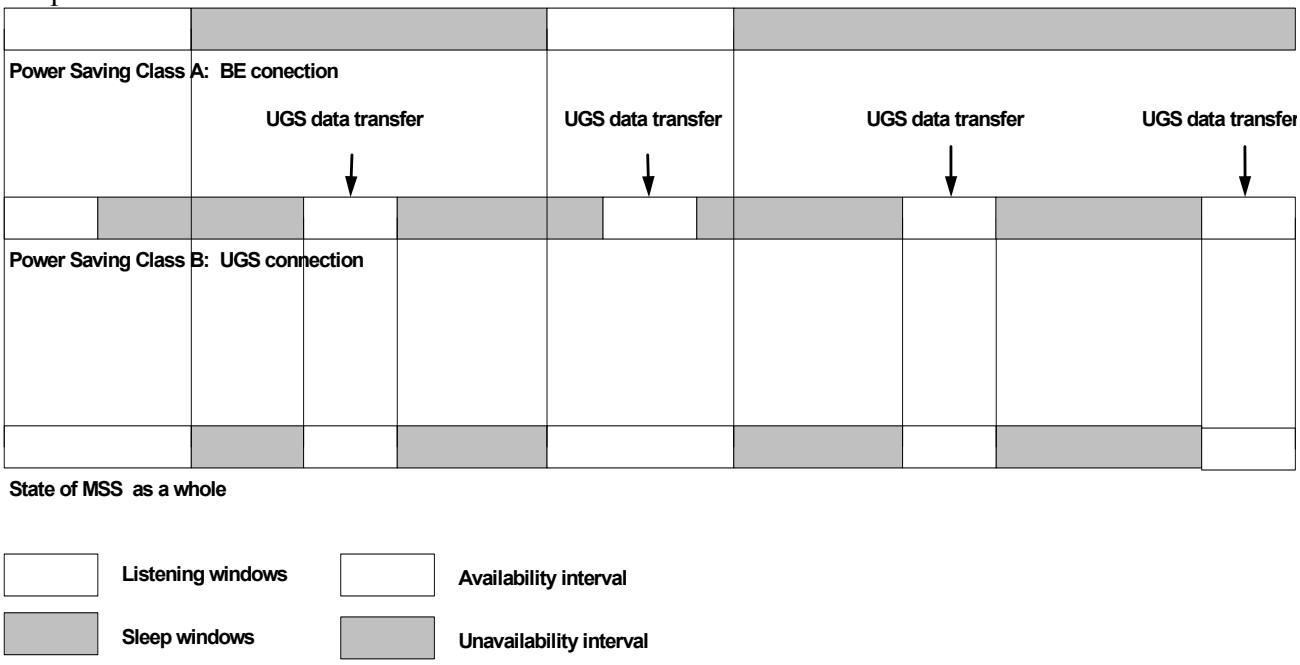


Figure NNN. Example of Sleep Mode Operations with two Power Saving Classes

6.3.19.2 Power Saving Classes of type 1

Power Saving Class of this type is recommended for connections of BE, NRT-VR type.

For definition and/or activation of one or several Power Saving Classes of Type 1 the MSS shall send MOB_SLP-REQ; the BS shall respond with an MOB-SLP_RSP message. The BS may send an unsolicited MOB-SLP-RSP to the MSS to activate one or several Power Saving Classes.
Alternatively Power Saving Class may be defined/activated /deactivated by TBD TLVs transmitted in RNG-RSP or DBPC-RSP messages.

The following are relevant parameters

- Initial-sleep window
- Final-sleep window base
- Listening window
- Final-sleep window exponent
- Start frame number for first sleep window

Power Saving Class becomes active at the frame specified as Start frame number for first sleep window. Each next sleep window is twice of size comparatively to previous one, but not greater than specified final value

Sleep window = min (2(Previous sleep window), Final-sleep window base * 2 ^ (Final-sleep window exponent))*

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. A traffic indication (MOB_TRF-IND) message shall be sent by the BS during each 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, 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 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 indicating presence of buffered traffic addressed to the MSS
- Assuming TRF-IND_Required bit was set in MOB_SLP-REQ, MSS failed to receive MOB_TRF-IND message during availability window.

During listening windows the MSS is expected to receive all DL transmissions same way as in the state of normal operations (no sleep).

6.3.19.3 Power Saving Classes of type 2

Power Saving Class of this type is recommended for connections of UGS, RT-VR type. The following are relevant parameters

- Initial-sleep window
- Listening window
- Start frame number for first sleep window

Power Saving Class becomes active at the frame specified as "Start frame number for first sleep window". All sleep windows are of the same as initial window. Sleep windows are interleaved with listening windows of fixed duration. Power Saving Classes of this type are defined/activated/deactivated by MOB_SLP-REQ/ MOB_SLP-RSP transaction. The BS may send unsolicited MOB_SLP-RSP to initiate activation of Power Saving Class. Once started, the active state continues until explicit termination by MOB_SLP-REQ/MOB_SLP-RSP messages. BS may send unsolicited MOB_SLP-RSP message to deactivate Power Saving Class. Alternatively Power Saving Class of type 2 may be activated /deactivated by TLVs transmitted in TBD messages (see section MMM).

As opposite to Power Saving Class Type 1, during listening windows of Power Saving Class Type 2 the MSS may send or receive any MAC SDUs or their fragments at connections comprising the Power Saving Class as well as acknowledgements to them. The MSS shall not receive or transmit MAC SDUs during sleep windows.

6.3.19.4. Power Saving Classes of type 3

Power Saving Class of this type is recommended for multicast connections as well as for management operations, for example, Periodic Ranging, DSx operations, MOB_ NBR-ADV etc. Power Saving Classes of this type are defined/activated by MOB_SLP-REQ/MOB_SLP-RSP transaction. The BS may send unsolicited MOB_SLP-RSP to initiate activation of Power Saving Class. Deactivation of Power Saving Class occurs automatically after expiration of sleep window.

Alternatively Power Saving Class of type 3 may be defined/activated by TLVs (see section MMM).

The following are relevant parameters:

- Final-sleep window base
- Final-sleep window exponent
- Start frame number for sleep window

Power Saving Class becomes active at the frame specified as "Start frame number for first sleep window". Duration of sleep window is specified as base / exponent. After the expiration of the listening window Power Saving Class automatically becomes inactive.

For multicast service Base Station may guess when the next portion of data will appear. Then the BS allocates sleep interval for all time when it does not expect the multicast traffic to arrive. During listening

window multicast data may be transmitted to relevant MSSs. After the end of the listening window the BS may decide to re-activate Power Saving Class.

Power Saving Class of type 3 that includes Basic connection may be used also to serve needs of Periodic Ranging. In this case duration (base / exponent) of sleep window shall be equal to time interval needed before next Periodic ranging transaction. Then the MSS, after the specified time interval, shall be available to DL transmission and BS may either allocate an UL transmission opportunity for RNG-REQ or send unsolicited RNG-RSP. Re-activation of the Power Saving Class may be achieved using, for example, TLVs included into RNG-REQ/RSP

Alternatively Power Saving Class of type 3 may be activated /deactivated by TBD TLVs transmitted in RNG-RSP or DBPC-RSP messages.

Power Saving Class of type 3 is deactivated after all involved connections closed.

[Replace section 6.3.2.3.44, page 56 line53.]
6.3.2.3.44 Sleep Request message (MOB_SLP-REQ)

MSS supporting sleep-mode uses the MOB-SLP-REQ message to request definition and/or activation of certain Power Save Classes of types 1 and 2. The MOB-SLP-REQ message is sent from the MSS to the BS on the MSS's Basic CID

Table 106a—Sleep-Request (MOB-SLP-REQ) message format

Syntax	Size	Notes
MOB_SLP-REQ_Message_Format() {		
Management message type = 51	8 bits	
for (i = 0; i < Number_of_Classes; i++) {		
Operation	1 bits	
Power_Saving_Class_ID	6 bits	
if (Operation = 1) {		
Start_frame_number	6 bits	
TRF-IND_Required	1 bit	
Reserved	2 bit	
}		
if (Definition = 1) {		
Power_Saving_Class_Type	2 bits	
Direction	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_CIDs	3 bits	
for (i = 0; i < Number_of_CIDs; i++) {		
CID	16 bits	
}		

}		
}		

Parameters shall be as follows:

Definition

1 = Definition of Power Saving Class present

Operation

1 = Activation of Power Saving Class

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

Power_Saving_Class_ID

Assigned Power Saving Class identifier. The ID shall be unique within the group of Power Saving Classes associated with the MSS. 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

Direction

Defined the directions of the class's CIDs.

00 = Un-specified. Each CID has its own direction assign in its connection creation. Can be either DL, UL or both.

10 = Uplink direction only

01 = Downlink direction only

11 = Reserved

Listening window

Assigned Duration of MSS listening interval (measured in frames). For Power Saving Class type 3 it is not relevant and shall be encoded as 0

Initial-sleep window

Assigned initial duration for the sleep window (measured in frames). For Power Saving Class type 3 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 2 it is not relevant and must be encoded as 0. For Power Saving Class type 2 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:

final-sleep window = final-sleep window base × 2^(final-sleep window exponent)

For Power Saving Class type 2 it is the exponent for the duration of single sleep window requested by the message

Number_of_CIDs

If Number_of_CIDs = 0, it means that all unicast CIDs associated with the MSS are requested for addition to the class.

CID

CIDs of unicast connections comprising the Power Saving Class.

CID = 0 denotes set of all management connections associated with the MSS.

[Replace section 6.3.2.3.45, page 57 line 1]

6.3.2.3.45 Sleep Response message (MOB_SLP-RSP)

The MOB-SLP_RSP message shall be sent from BS to a MSS on Broadcast CID or on the MSS's Basic CID in response to an MOB-SLP_REQ message, or may be sent unsolicited. The MSS shall assemble connections in Power Saving Classes and optionally activate them as described in the message. If for certain class activation is deferred (Activation ='0'), the BS may signal activation at later time in another unsolicited MOB-SLP_RSP message.

Table 106b—Sleep-Response (MOB-SLP-RSP) message format

Syntax	Size	Notes
MOB_SLP-RSP_Message_Format() {		
Management message type = 51	8 bits	
for (i = 0; i < Number_of_Classes; i++) {		
Definition	1 bit	
Operation	1 bits	
Power_Saving_Class_ID	6 bits	
If (Operation = 1) {		
Start_frame_number	6 bits	
TRF-IND_Required	1 bits	
Reserved	1 bits	
}		
If (Definition = 1) {		
Power_Saving_Class_Type	2 bits	
Direction	2 bits	
initial-sleep window	8 bits	
listening window	8 bits	
final-sleep window base	10 bits	
final-sleep window exponent	3 bits	
SLPID	10 bits	
Reserved	2 bits	
Number_of_CIDs	3 bits	
for (i = 0; i < Number_of_CIDs; i++) {		
CID	16 bits	
}		
}		
If (SHO or FBSS capability enabled) {	1 bit	
Maintain Active Set and Anchor BS ID		
If (Active Set and Anchor BS ID maintained) {	3 bits	
SHO/FBSS duration (s)		
}		
}		
Padding	Variable	If needed
}		

Parameters shall be as follows:

Power_Saving_Class_Type
Requested Power Saving Class type
Definition
1 = Definition of Power Saving Class present
Operation
1 = Activation of Power Saving Class
0 = Deactivation of Power Saving Class (for types 1 and 2 only)
TRF-IND_Required
For Power Saving Class Type 1 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 another types
Power_Saving_Class_ID
Assigned Power Saving Class identifier. The ID shall be unique within the group of Power Saving Classes associated with the MSS. 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
Direction
Defined the directions of the class's CIDs.
00 = Un-specified. Each CID has its own direction assign in its connection creation. Can be either DL, UL or both.
10 = Uplink direction only
01 = Downlink direction only
11 = Reserved
Listening interval
Assigned Duration of MSS listening interval (measured in frames). For Power Saving Class type 3 it is not relevant and must be encoded as 0
Initial-sleep window
Assigned initial duration for the sleep window (measured in frames). For Power Saving Class type 3 it is not relevant and must be encoded as 0
Final-sleep window base
Assigned final value for the sleep interval (measured in frames).). For Power Saving Class type 2 it is not relevant and must be encoded as 0. For Power Saving Class type 3 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:
final-sleep window = final-sleep window base × 2^(final-sleep window exponent)
For Power Saving Class type 2 it is the exponent for the duration of single sleep window requested by the message
SLPID
This is a number assigned by the BS whenever an MSS is instructed to enter sleep-mode. This number shall be unique in the sense that it is assigned to a single MSS that is instructed to enter sleep-mode. No other MSS shall be assigned the same number while the first MSS is still in sleep-mode.

Number_of_CIDs

In case the message is sent on Basic connection of certain MSS, Number_of_CIDs = 0 means that all CIDs associated with the MSS are included into the class

CID

CIDs of all connections comprising the Power Saving Class. This list shall contain either unicast connections or multicast connections or management connections, but not combination of connections of different types. If Basic CID is encoded, it means that all MSS connections are included in a single class. CID = 0 is reserved for management operations. In case the message is sent on Basic connection of certain MSS, CID = 0 denotes set of all management connections associated with the MSS

[Change in Table 365a—RNG-RSP Message Encodings]

Name	Type (1 byte)	Length	Value (Variable-length)
Power_Saving_Class_Parameters	21	Variable	Compound TLV to specify Power Saving Class operation

[Add after Table 365a]

Power_Saving_Class_Parameters Value field is composed from a number of encapsulated TLV fields as specified in Table NNN.

Table NNN.

Name	Type (1 byte)	Length	Value (Variable-length)
Flags		1	Bit 0: Definition 1 = Definition of Power Saving Class present Bit 1: Operation 1 = Activation of Power Saving Class 0 = Deactivation of Power Saving Class (for types 1 and 2 only) Bit 2: TRF-IND_Required For Power Saving Class Type 1 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 another types Bits 3-7: reserved
Power_Saving_Class_ID		1	Assigned Power Saving Class identifier
Power_Saving_Class_Type		1	Power Saving Class Type as specified in 6.3.2.3
Start_frame_number			Start frame number for first sleep window
initial-sleep window		1	initial-sleep window
listening window		1	Assigned Duration of MSS listening interval (measured in frames)
final-sleep window base		1	Assigned final value for the sleep interval (measured in frames) - base

Name	Type (1 byte)	Length	Value (Variable-length)
final-sleep window exponent		1	Assigned final value for the sleep interval (measured in frames) - exponent
SLPID		1	A number assigned by the BS whenever an MSS is instructed to enter sleep-mode
CID			CID of connection to be included into the Power Saving Class. There may be several TLVs of this type in a single compound Power_Saving_Class_Parameters TLV
Direction		1	Direction for management connection which is added to Power Saving Class