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Title	RS Sleep Mode
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Re:	IEEE 802.16j-07/007r2: “Call for Technical Comments and Contributions regarding IEEE Project 802.16j”
Abstract	This contribution proposes RS sleep mode procedure.
Purpose	Text proposal for 802.16j Baseline Document.
Notice	
Release	

	acknowledges and accepts that this contribution may be made public by IEEE 802.16.
Patent Policy and Procedures	The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures <http://ieee802.org/16/ipr/patents/policy.html>, including the statement "IEEE standards may include the known use of patent(s), including patent applications, provided the IEEE receives assurance from the patent holder or applicant with respect to patents essential for compliance with both mandatory and optional portions of the standard." Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <mailto:chair@wirelessman.org> as early as possible, in written or electronic form, if patented technology (or technology under patent application) might be incorporated into a draft standard being developed within the IEEE 802.16 Working Group. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>.

RS Sleep Mode

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1 Introduction

RS Sleep mode is essential for power saving and interference reduction. RS is a relay which is responsible of transferring the traffic sent from MR-BS to MSs and vice versa. On the power saving, the RS may be installed without wired power line in various deployment environment. The fix/nomadic RS may rely on battery or solar power as backup power source, and the mobile RS may only rely on battery power. On the interference reduction, as it is indicated in [1], multihop relay (MR) network current plan on more aggressive resource reuse may result in interference increment. In [2][3], RS amble has been introduced to be transmitted on a known position relative to the beginning of the access preamble. However, the transmission of RS ambles inevitably will introduce additional interference to the MR network.

In this contribution we propose the idea of RS sleep mode and its associated MAC management messages. Our solution makes RS sleep mode not only supports RS power saving, but also reduces the interference and releases the radio resources.

1.1 RS Sleep Mode

This contribution adopts the MR-BS centralized control mechanism and introduces a sleep mode procedure to achieve power saving and interference reduction. The sleep mode feature of RS is useful for providing power efficiency, especially power constrained RS like mobile RS equipped with battery power source, or like low-power fixed RS powered by the solar power or battery. Also, such feature is also applicable to nomadic RS and client owned RS, which are typically installed without power wire. As RS enters the RS sleep mode, its power resource could be conserved, and the radio resources could be utilized for interference reduction.

1.1.1 Broadcast in RS Sleep Mode

Depending on RS type, an RS either relays or generates broadcast messages such as FCH, DCD, UCD, DL_MAP and UL_MAP. If RS relays broadcast messages, then the MR-BS needs to coordinate the broadcast message intervals with the RS, such that the RS stays in the active mode during the broadcast message relay period. If RS generates its own broadcast messages, then there is no need for the coordination.

In order to facilitate network-entry/network-re-entry/handover for the associated MS staying in sleep mode, two RS sleep modes, the Full RS Sleep Mode and the Partial RS Sleep Mode, are defined.

1.1.2 Full RS Sleep Mode

There is no traffic at relay link and access link during RS staying in sleep mode. In this mode, the MR-BS ceases sending traffic to RS, and RS also stops serving all associated downstream RSs and MSs. A RS in full RS sleep mode may support MS enabled-action-triggered actions by leaving its receiver active and monitoring signals on the active receiver from other MSs.

1.1.3 Partial RS Sleep Mode

There is no traffic at relay link or access link except that the DL Start Frame Preamble, FCH, DCD, UCD, DL_MAP, UL_MAP, and broadcast messages periodically sent from the RS at predefined intervals for supporting the message exchanges for the events of MS network entry/re-entry/handover. Attached MSs that stay in sleep mode could send the MOB_SCN-REQ, MOB_MSHO-REQ, and MOB_SCN-REP management messages on the UL location allocated in the UL_MAP if the enabled-action-triggered events are permitted and corresponding events are triggered. The interval of RS broadcasting and allocating the UL bandwidth for bandwidth request messages for exchanging such managements should be less than the time MS searches for decodable UL_MAP.

1.1.4 RS awaking mechanism

When a RS enters sleep mode, it can be awaken by its serving MR-BS or by itself. The MR-BS can uses the existed MOB_TRF-IND to awaken the sleep RS. When the sleep RS receives traffic, it can be awakened by itself directly. When a RS awakens from the sleep mode, it shall activate at least one uplink path and any sleep RS along the path shall be awakened.

1.1.5 RS Sleep Mode in Centralized Scheduling

It is noteworthy that the proposed RS Sleep Mode does not cause any change to the MS sleep mode, it works on top of the MS sleep mode.

In centralized scheduling MR-BS controls all the schedulings and MAP allocations for all MSs and RSs even parts of them are staying in sleep mode. First, the MR-BS informs MS and RS in proper sequences about the listening and sleep windows. Then, the RS could enter the sleep mode with the sleeping pattern which is consistent to the listening and sleep windows of all attached MSs. As all attached MSs are in sleep mode, the RS(s) on the relay path could enter sleep mode for power conservation. The activation of RS sleep mode is fully managed by MR-BS. Alternatively, a RS can request the activation of RS sleep mode (e.g., due to backup power source is activated) by sending RS_SLP-REQ message with MR-BS. RS will obtain the sleep pattern from RS_SLP-RSP message sent from MR-BS.

1.1.6 RS Sleep Mode in Distributed Scheduling

The assumption of the distributed scheduling is that the all RS are capable of performing scheduling functions. For centralized control and distributed scheduling system, the access RS of the access link shall have the information of sleep patterns of associated MSs. After RS is notified the sleep mode information of its subordinate MSs, it will generate the listening and sleep windows for itself and issue an RS_SLP-REQ carrying the sleep parameters to the MR-BS. RS could enter sleep mode after it receives the RS_SLP-RSP message sent from MR-BS. This procedure is optional and independent of the MS sleep mode.

1.1.7 RS Sleep Mode in Reducing Interference

In [2] the current relay frame structure specifies that an RS should use the access zone preamble for initial synchronization when the RS get access into the wireless network. However, after the initial entry is performed, an RS is not able to use the access preamble for synchronization or monitoring the environment because it has to transmit the access preamble synchronously with the MR-BS to which it is attached. Therefore, an RS amble has been introduced to be transmitted on a known symbol offset to the beginning of the access preamble. See Figure 1 for an illustration. However, the transmission of RS ambles inevitably will introduce additional interference to the multihop relay network. If at the same symbol time a relay amble is being transmitted by any RS and there are other "data symbol" being transmitted in neighbouring sectors or cells, the relay amble will cause interference. Note that, 16e preamble comes with a 9dB boost in each active preamble subcarrier (compared with an un-boosted PUSC symbol active subcarrier). It is anticipated that RS amble will be boosted similarly. An overlapping transmission of RS amble and any other “data symbol” result in interference and degradation of performance. To understand the scope of potential RS amble interference, we consider 4 different categories of RS access preamble and RS amble transmission. As shown in Figure 2, there are 4 categories for RS to send or not to send access zone preamble and RS amble.

1.1.7.1 Category 1: MR-BS or RS with both the subordinate RSs and MSs

In this category, MR-BS or RS needs to send access preamble for MSs in every frame (compatible to 802.16e) and RS amble (for subordinate RSs) frequently. The frequency and position of RS ambles are being considered in other contributions [2][3], etc. RS in this category can be deemed to be in active mode.

1.1.7.2 Category 2: RS that do not have any subordinate RS but only MS

In this category, RS does not have any subordinate RS, but only MSs that are gaining access to the multihop relay network through itself. In this case, there is no need to send RS amble to help any subordinate RS to maintain synchronization. However, RS amble transmission can be enabled by the scheduler to assist MRS handover and also help provide interference measurement and link quality/cost information to neighbouring RS. RS in this category is still viewed to be in active mode.

1.1.7.3 Category 3: RS has only subordinate RSs but no MS

In this category, RS needs to send RS amble frequently for subordinate RSs to maintain synchronization and scanning for environment. However, to reduce the interference, there is no need to send the access preamble in every frame for RSs in this category. We recommend reducing the RS access preamble transmission to be every N frames (N>1) for potential MS initial network entry and handover process. If for a prolonged period where there is no active MS in the RSs in this category, the RS can also suspend the access preamble transmission for an indefinite time until some event triggers (e.g., instructed by the MR-BS) to resume access preamble transmission. Reducing the frequency or even suspending the access preamble transmission for RSs in this category can reduce the interference level. Note that RS not sending access preamble may induce a false measurement of SINR for the MSs that are in the scan mode. For this concern, the parameter N should be carefully chosen. Similar to the partial sleep mode in Section 1.1.3, RS in this category can also be viewed to be in partial sleep mode.

1.1.7.4 Category 4: RS has neither subordinate RSs nor active MSs

In this category, the RS is basically idle or inactive for there are simply no subordinate RSs and neither active MSs. In this case, RS should enter Full RS Sleep Mode (Section 1.1.2) by inactivating its transmitted signals.

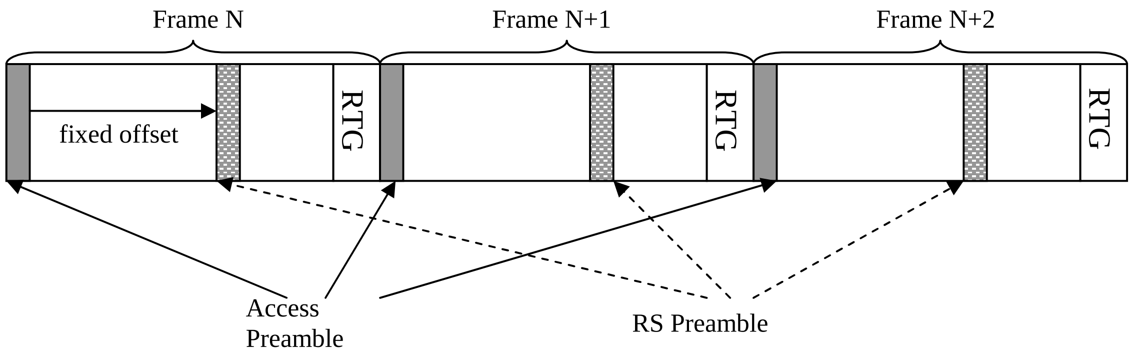

Figure 1. RS Access Preamble and RS amble Illustration

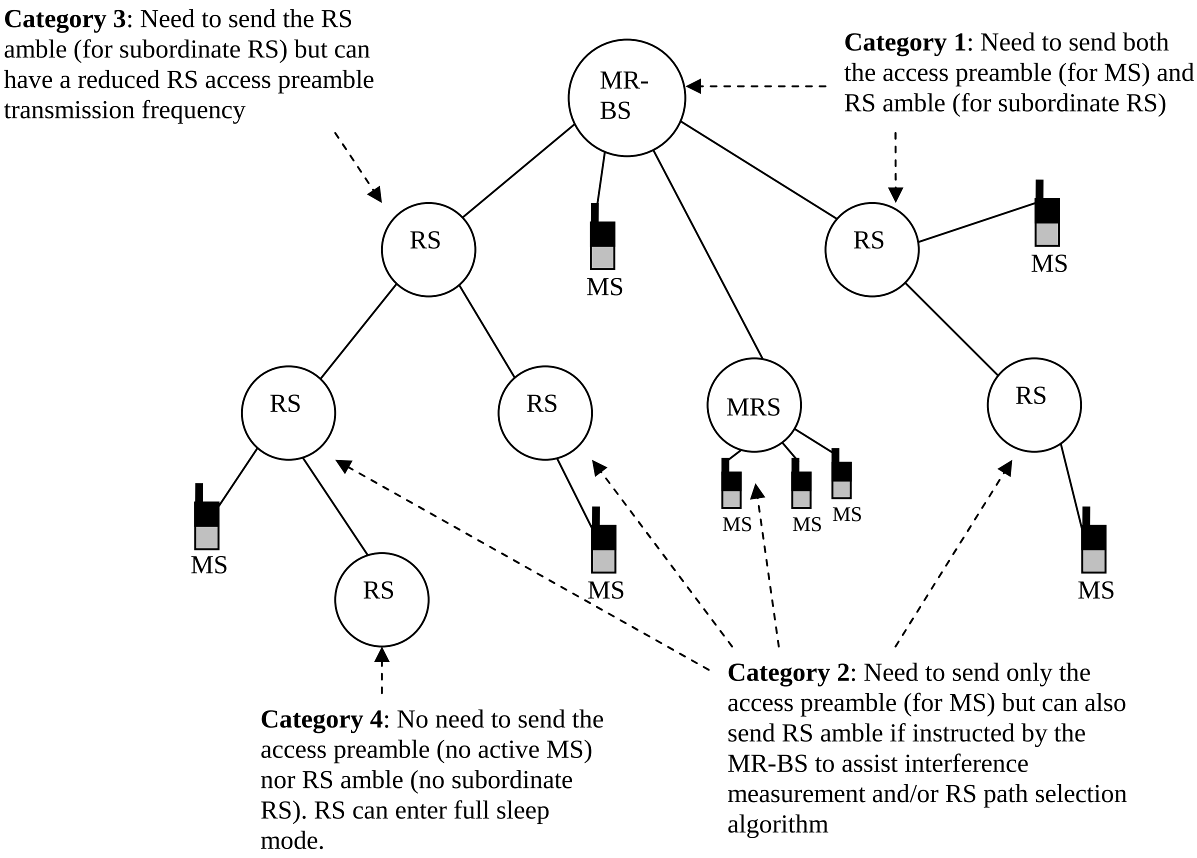

Figure 2. RS Access Preamble and RS Amble Transmission Category

References:
[1] C802.16j-07/019, “Interference Measurement by RS Sounding in MR Network”
[2] C802.16j-07/043, “RS Neighborhood Discovery and Measurement for IEEE 802.16j Multi-hop Relay Network
[3] C802.16j-06/199, “Relay-Station Preamble Segment Assignment/Re-Assignment scheme”

2 Spec Changes

This section contains the suggested text for the 802.16 specification changes.

Change Table 14 as indicated:

Type	Message name	Message description	Connection

~~67–255~~		~~Reserved~~	-
xx	RS_SLP-REQ	RS Sleep Request	Basic
xx	RS_SLP-RSP	RS Sleep Response	Basic
xx-255		Reserved	-

6.3.21.7 Relay sleep mode support for mobility supporting MS

6.3.21.7.2 RS sleep mode

In MR-BS centralized control mechanism, the sleep mode feature of RS is useful for providing power efficiency, especially in the mobile RS with battery power source or low-power fixed/nomadic RS powered by the solar power or battery. Also, such feature can also reducing interference generated by the RS. As RS enters the sleep mode, its power resource could be conserved, the interference from the RS could be reduced, and the air interface resources could be released further.

In centralized control and centralized scheduling system, MR-BS controls all the schedulings and MAP allocations for all MSs and RSs even parts of them are staying in sleep mode. First, the MR-BS informs MS and RS in proper sequences about the listening and sleep windows. Then, the RS could enter the sleep mode with the sleeping pattern which is consistent to the listening and sleep windows of all attached MSs. As all attached MSs are in sleep mode, the RS(s) on the relay path could enter the sleep mode for power conservation and interference reduction. The activation of RS sleep mode is fully managed by MR-BS. Alternatively, a RS can request the activation of RS sleep mode (e.g., due to its backup power source is activated) by sending RS_SLP-REQ message to MR-BS. RS will obtain the sleep pattern from RS_SLP-RSP message sent from MR-BS.

For centralized control and distributed scheduling system, the access RS of the access link shall have the information of sleep patterns of associated MSs. After RS is notified the sleep mode information of its subordinate MSs, it will generate the listening and sleep windows for itself and issue an RS_SLP-REQ carrying the sleep parameters to the MR-BS. RS could enter sleep mode after it receives the RS_SLP-RSP message sent from MR-BS. This procedure is optional and independent of the MS sleep mode.

The RS in sleep mode can leave its receiver active and monitor signals on the active receiver. RS can initiate the awakening procedure in response to the monitored signals. When a RS enters sleep mode, it can be awaken by its serving MR-BS or by itself. The MR-BS can uses the existed MOB_TRF-OND to awaken the sleep RS. If a sleep RS want to transmit data, it can send a bandwidth request header to its serving MR-BS and then could be awakened. When a RS awakens from the sleep mode, at least one uplink path of the RS shall be chosen for the communication to reach the MR-BS. If there exists any sleep RS in the path, it shall be awakened.

6.3.21.7.2.1 Full RS Sleep Mode

There is no traffic at relay link and access link during RS staying in sleep mode. In this mode, the MR-BS ceases sending traffic to the RS which also stops serving all associated downstream RSs and MSs.

6.3.21.7.2.2 Partial RS Sleep Mode

There is no traffic at relay link or access link except that the DL Start Frame Preamble, FCH, DCD, UCD, DL_MAP, UL_MAP, and broadcast messages periodically sent from the RS at predefined intervals for supporting the message exchanges for the events of MS network entry/re-entry/handover. Attached MSs that stay in sleep mode could send the MOB_SCN-REQ, MOB_MSHO-REQ, and MOB_SCN-REP management messages on the UL location allocated in the UL_MAP if the enabled-action-triggered events are permitted and corresponding events are triggered. The interval of RS broadcasting and allocating the UL bandwidth for bandwidth request messages for exchanging such managements should be less than the time MS searches for decodable UL_MAP.

6.3.2.3.65 RS_SLP-REQ message

An RS supporting sleep mode uses the RS_SLP-REQ message to request activation of RS sleep mode. The RS_SLP-REQ message is sent from the RS to the MR-BS on the RS's basic CID. The RS_Sleep_Mode bit indicates what kind of RS sleep mode is requested.

Syntax	Size	Notes
RS_SLP-REQ_Message_format() {	-	-
Management message type = xx	8 bits	-
RS_Sleep_Mode	1 bit	Value=0 – Full RS Sleep Mode Value=1 – Partial RS Sleep Mode
Support_Enabled-Action-Triggered	1 bits	
RS_start_frame_number	6 bits	
RS_initial-sleep_window	8 bits	
RS_listening-window	8 bits	
RS_final-sleep_window_base_	10 bits	
RS_final-sleep_window_exponent	3 bits	
RS_traffic_triggered_wakening_flag	1 bits	
Reserved	2 bits	
}		

Parameters shall be as follows:

RS_Sleep_Mode
0 = Full RS Sleep Mode
1 = Partial RS Sleep Mode
Support_Enabled-Action-Triggered

0 = RS supports MS Enabled-Action-Triggered actions
1 = RS does not support MS Enabled-Action-Triggered actions

RS_start_frame_number
Start frame number for the sleep window.

RS_initial-sleep_window
Assigned Duration of RS listening window (measured in frames).

RS_listening-window
Assigned initial duration for the RS sleep window (measured in frames).

RS_final-sleep_window_base_
Assigned final value for the RS sleep interval (measured in frames).

RS_final-sleep_window_exponent
Assigned factor by which the final-sleep window base is multiplied in order to calculate the RS_final-sleep window. The following formula is used:
RS_final-sleep window = RS_final-sleep window base × $2^{(\text{RS\_final-sleep window exponent})}$

RS_traffic_triggered_wakening_flag
0 = RS shall be activated when it receives traffic.
1 = RS shall be activated only when it receives the MOB_TRF-IND message.

6.3.2.3.66 RS_SLP-RSP message

The RS_SLP-RSP message shall be sent from MR-BS to an RS on the RS's basic CID in response to an RS_SLP-REQ message, or may be sent unsolicited. The RS_Sleep_Mode bit indicates what kind of RS sleep mode is allowed.

Syntax	Size	Notes
RS_SLP-RSP_Message_format() {	-	-
Management message type = xx	8 bits	-
RS_Operation	1 bit	Value=0 – Deactivate. Value=1 – Activate.
if (RS_Operation = 1) {		
RS_Sleep_Mode	1 bit	Value=0 – Full RS Power Sleep Mode Value=1 – Partial RS Power Sleep Mode
RS_start_frame_number	6 bits	
RS_initial-sleep_window	8 bits	
RS_listening-window	8 bits	
RS_final-sleep_window_base_	10 bits	

RS_final-sleep_window_exponent	3 bits	
RS_traffic_triggered_wakening_flag	1 bits	
Support_Enabled-Action-Triggered	1 bits	
Reserved	1 bits	
RS_SLPID	10 bits	
REQ-duration	8 bits	
Reserved	6 bits	
}		
else{		
Reserved	7 bits	
}		
}		

Parameters shall be as follows:

RS_Operation
0= Deactivation of RS Sleep Mode
1= Activation of RS Sleep Mode
RS_Sleep_Mode
0 = Full RS Sleep Mode
1 = Partial RS Sleep Mode
Support_Enabled-Action-Triggered
0 = RS supports MS Enabled-Action-Triggered actions
1 = RS does not support MS Enabled-Action-Triggered actions
RS_start_frame_number
Start frame number for the sleep window.
RS_direction
0b00 = Both
0b01 = Downlink direction only
0b10 = Uplink direction only
0b11 = Reserved
RS_traffic_triggered_wakening_flag
0 = RS shall be activated when it receives traffic.
1 = RS shall be activated only when it receives the MOB_TRF-IND message.
RS_initial-sleep_window
Assigned Duration of RS listening window (measured in frames).
RS_listening-window

Assigned initial duration for the RS sleep window (measured in frames).

RS_final-sleep_window_base_

Assigned final value for the RS sleep interval (measured in frames).

RS_final-sleep_window_exponent

Assigned factor by which the final-sleep window base is multiplied in order to calculate the RS_final-sleep window. The following formula is used:

$RS\_final\text{-}sleep\ window = RS\_final\text{-}sleep\ window\ base \times 2^{(RS\_final\text{-}sleep\ window\ exponent)}$

Scheduling_type

0 = Centralized Scheduling

1 = Distributed Scheduling

RS_SLPID

This is a number assigned by the MR-BS whenever an RS is instructed to enter sleep mode. This number shall be unique in the sense that it is assigned to a single RS that is instructed to enter sleep mode. No other RS shall be assigned the same number while the first RS is still in sleep mode

REQ-duration

Waiting value for the RS_SLP-REQ message re-transmission (measured in MAC frames): the RS may retransmit the RS_SLP-REQ message after the time duration (REQ-duration) provided in the message.

Change Table 14 as indicated:

10.1 Global values

Table 342—Parameters and constants

System	Name	Time reference	Minmum value	Default value	Maximum value
RS/MS	Listening_ Interval	The time duration during which the RS/MS, after waking up and synchronizing with the DL transmissions, can demodulate downlink transmissions and decide whether to stay awake or go back to sleep.	=	=	64 frames

***Change the subclause 11.7.15*:**

11.7.15 Sleep mode recovery time

The 'Sleep mode recovery time' field indicates the time required for an MS or an RS that is in a sleep mode to return to awake-mode. This parameter is optional and may be used by the MR-BS to determine sleep interval window sizes when initiating sleep mode with an MS or an RS.

Type	Length	Value	Scope
32	1	Number of frames required for the MS or the RS to switch from sleep mode to awake-mode	REG-REQ

***Insert new figures in annex D*:**

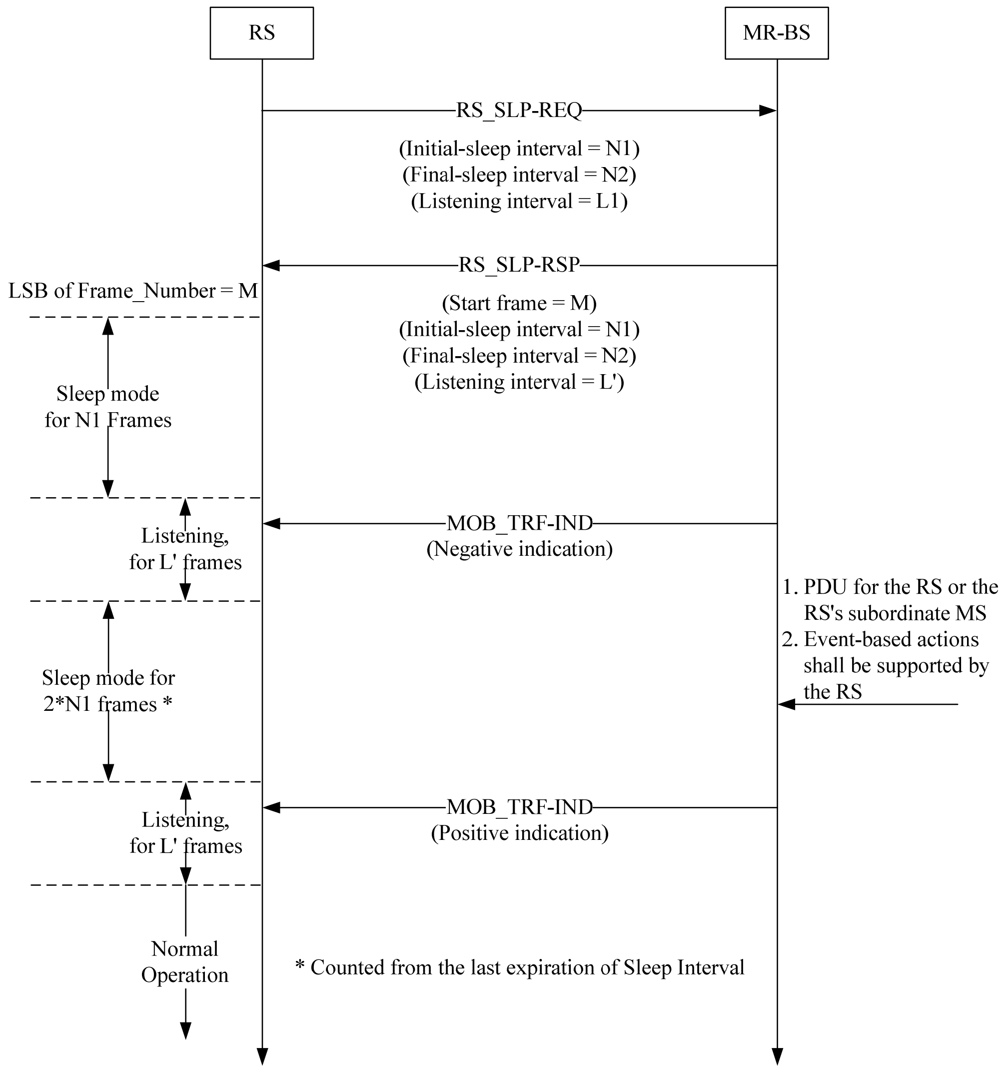

Figure D. 10--Example RS sleep mode — RS initiated

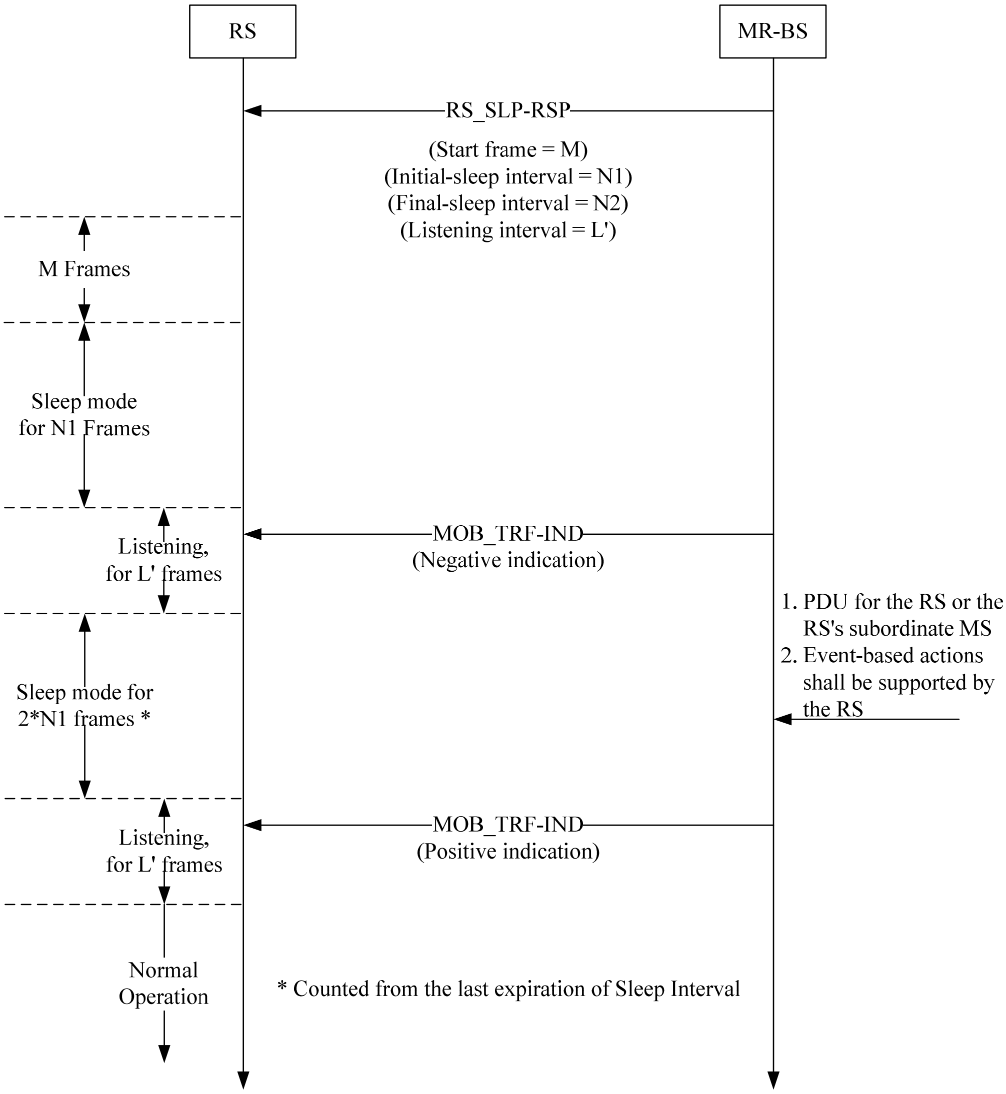

Figure D. 11--Example RS sleep mode — MR-BS initiated

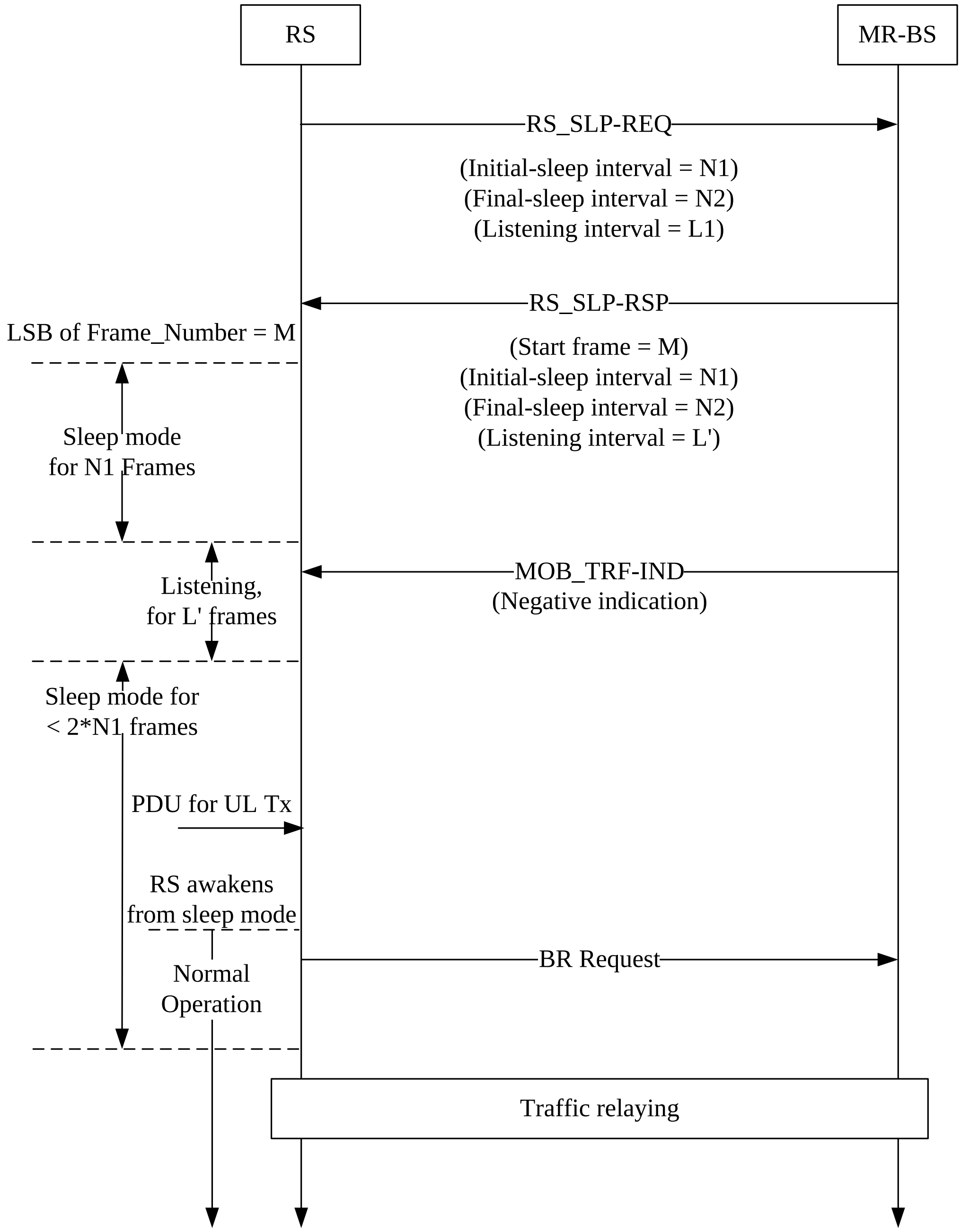

Figure D. 12-- Example RS Sleep mode— RS initiating awakening