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Re:	Response to IEEE 802.16e-03/14 (Call for Contributions on IEEE 802.16e/07r2)
Abstract	Description of alternatives to proposed sleep mode.
Purpose	Stimulate discussion to arrive at a more QoS compatible sleep mode.
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Supporting Material for Comments on Sleep Mode

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Introduction

The sleep mode proposed in IEEE 802.16e-03/07r2 is primarily contained in sections spanning page 17, line 18 through page 19, line 27 and page 24, line 15 through page 26, line 38. As proposed, the sleep mode defines sleep interval and listening intervals, which is well and good. But, the proposal for handling data when transitioning out of the sleep mode and for determining when and for how long to sleep again do not appear to support QoS to the level expected of 802.16. The sleep mode proposal appears to be sub-optimal with regards to bandwidth utilization and with the sole purpose of a sleep mode: power consumption. Additionally, the message definitions appear to be more complicated than what is really necessary.

Goals

There are a handful of goals that a sleep mode for 802.16 should include:

1. Allow an SS to power off for sufficient time to decrease battery consumption in mobile devices.
2. Buffer data to a reasonable extent at the BS while the SS is asleep.
3. Get any such buffered data to the SS when it returns to awake mode.
4. Provide a deterministic mechanism to determine if SS needs UL bandwidth when it returns to awake mode
5. Allow an SS to awaken prematurely if it has data to transmit on the UL.
6. Provide a mechanism for the SS to indicate it has awakened prematurely and needs UL bandwidth.
7. Allow the SS to extend or shorten its listening interval based on current service activity.
8. Minimize the impact on system bandwidth efficiency caused by the sleep mode protocols.
9. Minimize the impact on QoS, both for the SSs services and system wide, caused by the sleep mode protocols.

The sleep mode protocols currently proposed in IEEE 802.16e-03/07r2 are a good starting point for discussion, but they only satisfy a subset of these needs. The sleep mode protocols are more appropriate for a best-effort LAN environment than for a MAN environment with rich QoS.

Discussion of IEEE 802.16e-03/07r2 sleep mode relative to the goals

The concept of sleep request messages from the SS and sleep response messages from the BS which indicate when an SS when sleep and when it will wake up are a good part of the protocol. This part of the protocol enables goal 1 above to be met. Without these messages, the BS would be unsure when to start buffering data, and the SS would be unsure that it was safe to sleep. There are however, some problems with the specification of the sleep interval. The specification of the sleep window appears to be somewhat ambiguous, having

minimum and maximum sizes. This makes it non-deterministic when an SS will awake. This has a number of ramifications.

- The BS does not know when the SSs will wake up so it must periodically broadcast whether any have data pending (TRF-IND). (Tries to solve goal 3, but in a way detrimental to goals 2 and 8)
- Since all SSs are being sent a common TRF-IND periodically getting its period and the awakening time of the SS to overlap while still ensuring QoS above best-effort would require the TRF-IND to be sent in almost every frame. (In order to try to satisfy goal 9, the solution to goal 3 further impacts goal 8)
- The BS does not know for certain when the SSs will wake up, so it doesn't know when to poll SSs to see if they have traffic to send. (Detrimental to goal 4)
- The BS does not know when the SSs will wake up, so it doesn't know when to poll SSs so they can give some sort of acknowledgement to the TRF-IND so the BS can send the buffered data. (Detrimental to goal 3)

These can be solved by simply having the SS sleep for a specified number of frames, starting at a specific frame. Both sides know when the SS is to awake. At that time, or shortly after, the BS can send a TRD-IND if there is data buffered for the SS. This can be sent followed by a UL bandwidth allocation that can be used for a TRF-RSP (need to be certain the SS did awake) and a bandwidth request. If there is no data buffered at the BS for the SS, the BS does not sent a TRF-IND (goal 8 – NAKs are one of the most wasteful protocol elements ever invented), but still should poll the SS to see if it has UL data to send. In fact, since the SS is required to respond to a poll with at least fill bytes, the TRF-IND message is irrelevant and can simply be replaced by polling the SS. If the SS responds, it is awake and the BS can start sending DL data.

Regarding the duration of the sleep interval. There is no reason to specify in the standard that the sleep interval be exponentially increasing. The amount of time an SS can sleep should be a function of the QoS and traffic parameters of its services as well as a function of the BSs buffering capabilities. Exponentially increasing may be OK for best-effort traffic (debatable), but it would clearly not suffice for bursty or on/off real-time traffic such as voice or video. If you have a maximum sleep period that is compatible with the QoS of the activated services, it should always be used to optimize battery life.

That said, there needs to exist a mechanism for the SS to awaken prematurely if it has user data it needs to send. IEEE 802.16e-03/07r2 allows an SS to awaken prematurely (goal 5 met), but provides it no mechanism to let the BS know it has done so (goal 6 not met). Worst case, the SS could be made to wait until it is polled at the expiration of its sleep interval. Alternatively, the BS could periodically allocate (bandwidth permitting) broadcast (or multicast) bandwidth request contention intervals. This would provide a mechanism to short circuit the sleep cycle, leading to better UL responsiveness and decreased delay for services. Whether and how often the BS allocates such contention intervals is a matter of the BS's UL scheduler and is outside the scope of the standard although the standard could recommend the use of such contention based polling in this situation.

The listening interval should not be part of the sleep request message. The decision to sleep should be based on lack of activity of services, not on an arbitrary interval. If the SS has not received DL data or had UL data to send for a QoS determined time, it should request to sleep again (goal 7). The BS should have the capability to refuse based on its knowledge of what data is buffered for the SS.

Proposed changes to IEEE 802.16e-03/07

Replace sections 6.2.2.3.40 through 6.2.2.3.41 with:

6.2.2.3.40 Sleep Request message (MOB_SLP-REQ)

An SS supporting sleep-mode uses the MOB_SLP-REQ message to request permission from the BS to enter sleep-mode. The MOB_SLP-REQ message is sent from the SS to the BS on the SS's basic CID.

Table 56aa – Sleep-Request (MOB_SLP-REQ) message format

Syntax	Size	Notes
SLP-REQ_Message_Format() {		
Management message type = 45	8 bits	
reserved	6 bits	
Sleep interval	10 bits	
}		

Parameters shall be as follows:

Sleep Interval

Requested sleep interval, in frames.

6.2.2.3.41 Sleep Response message (MOB_SLP-RSP)

The MOB_SLP-RSP message shall be sent from the BS to an SS on the SS's basic CID in response to an MOB_SLP-REQ message. It approved, the SS shall enter sleep mode using the parameters indicated in the message.

Table 56ab – Sleep-Response (MOB_SLP-RSP) message format

Syntax	Size	Notes
SLP-RSP_Message_Format() {		
Management message type = 46	8 bits	
Sleep-approved	1 bit	0: sleep mode request denied 1: sleep mode request approved
If (Sleep-approved == 0) {		
reserved	7 bits	
}else{		
reserved	5 bits	
Sleep interval	10 bits	At most as long as the interval requested by the SS.
}		
}		

Parameters shall be as follows:

Sleep approved

Indicates whether or not the request to enter sleep mode has been approved by the BS.

Sleep Interval

Requested sleep interval, in frames.

Section 6.2.2.3.42 should be deleted in favor of simply polling the SS when it is supposed to awaken.

Section 6.2.16 and all its subsections should be replaced with:

6.2.16 Sleep mode for SS power conservation

Sleep mode is a mode in which SS's requiring power conservation (typically mobile) may power down. Sleep mode is intended to enable, in particular, mobility supporting SSs to minimize their energy usage while staying connected to the network and preserving QoS. Implementation of power save is optional for both SS and BS.

An SS that supports sleep mode can be in one of two states:

Awake

Sleep

When an SS is in awake mode, it is receiving and transmitting PDUs in a normal fashion. When the SS is in sleep-mode, it does not send or receive PDUs. In sleep mode the SS may power down but is not required to.

Before entering sleep mode the SS shall inform the BS and shall obtain its approval. The BS may buffer (or it may drop) incoming PDUs addressed to the sleeping SS, and shall send a notification to the SS when it awakes if data is buffered for it.

The SS shall awaken at the expiration of the sleep interval. The BS polls the SS at the expiration of its sleep interval. When the SS responds to the poll, the BS may start transmitting (timing of transmissions is dependant on the overall DL data situation at the BS) downlink data to the SS. If the BS transmits data to the SS, or if the SS has uplink data to transmit it shall remain awake. The SS shall remain awake for a QoS dependant period of time after all its services have been idle. This period is service dependant and is expressed in the TBD TLV of the DSA-REQ message. If after this time period, the services are still idle, the SS may request to sleep again.

The SS may terminate sleep mode prematurely if it has data to send to the BS. If the BS receives a bandwidth request in a bandwidth contention period from an SS that is supposed to be asleep, the BS shall assume the SS is no longer in sleep mode and shall poll the SS.

If the SS does not respond to the poll, the BS shall poll again. After TBD polls, the BS shall assume the SS is non-responsive and shall issue a Reset Command (RES-CMD) message to the SS.

If the SS awakens after expiration of its sleep interval and does not receive a poll within Tn, it shall re-register with the BS. If the SS can no longer hear the BS when it awakens, it shall start scanning for another channel on which to re-enter the network.

Figure 59b1 shows the SDL for the SS in the awake state.

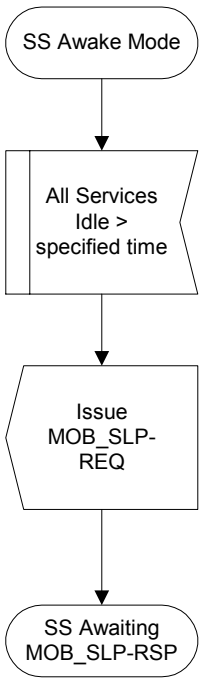

Figure 59b1: SS Awake Mode SDL Diagram

Figure 59b2 shows the SDL for the SS after it has sent an MOB_SLP-REQ message and is awaiting a response.

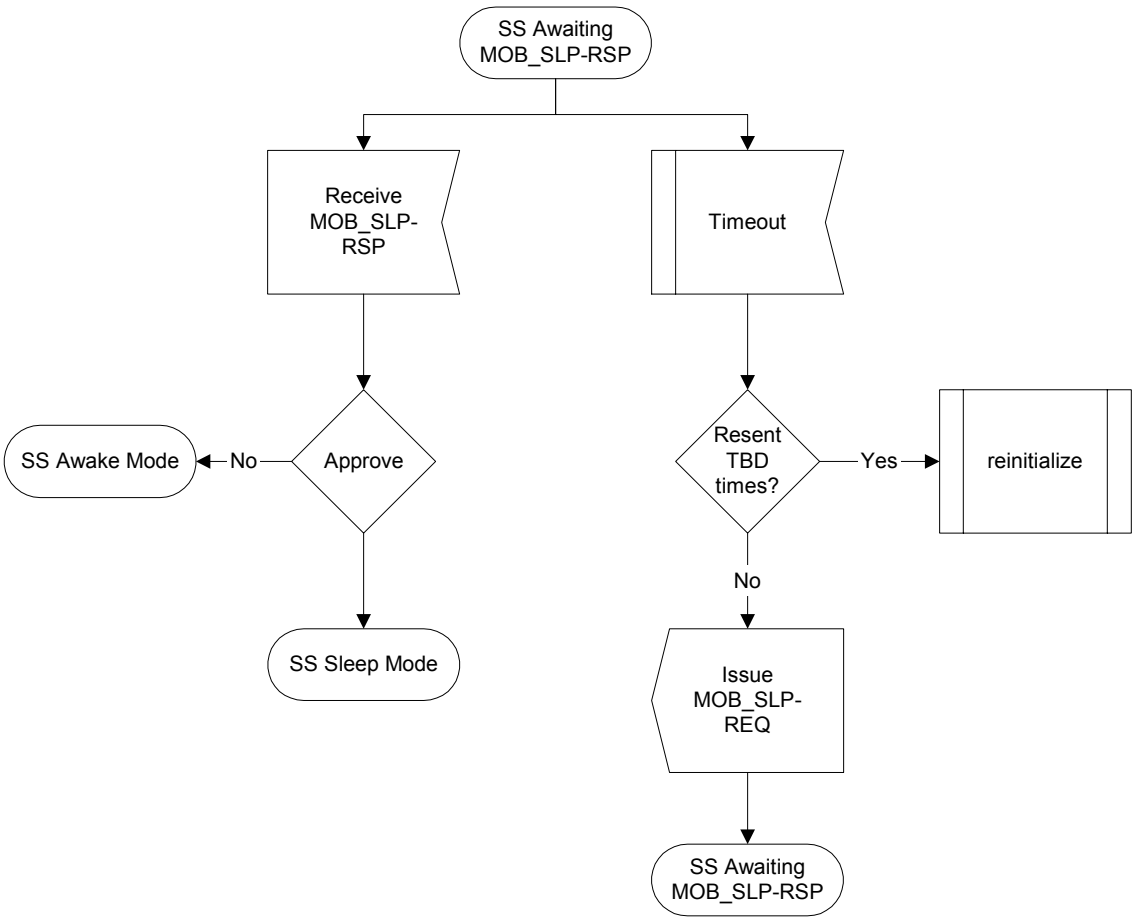

Figure 59b2: SS Awaiting Sleep Response SDL Diagram

Figure 59b3 shows the SDL for the SS while asleep.

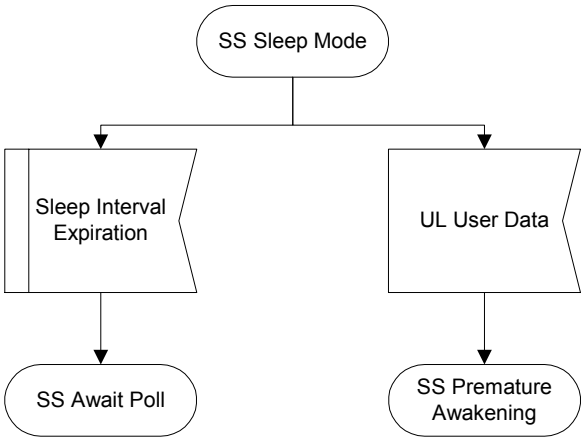

Figure 59b3: SS Sleep Mode SDL Diagram

Figure 59b4 shows the SDL for when the SS is awakening and is expecting to be polled by the BS.

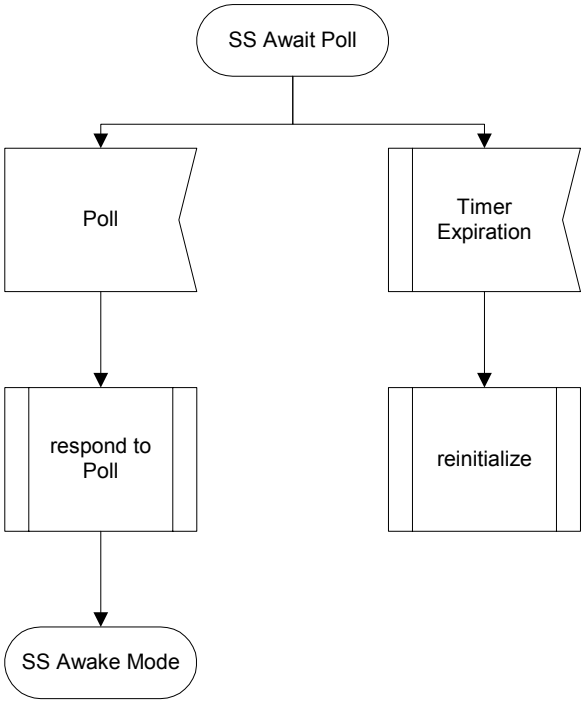

Figure 59b4: SS Await Poll SDL Diagram

Figure 59b5 shows the SDL for when the SS has awakened prematurely.

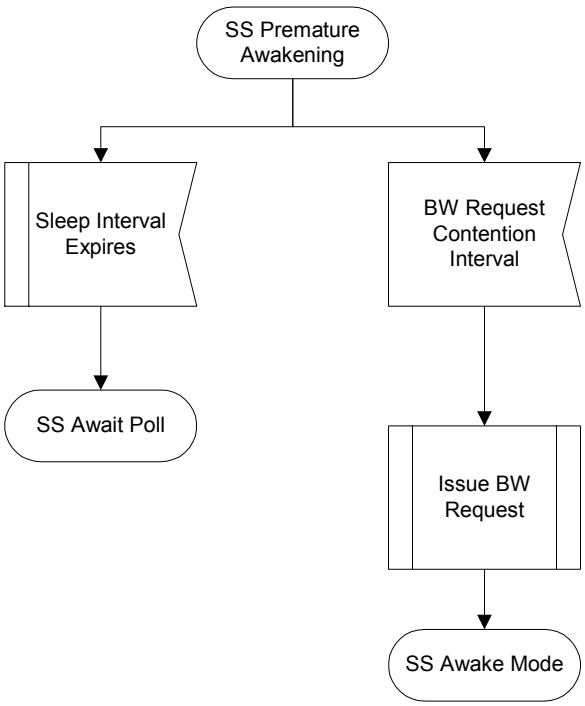

Figure 59b5: SS Premature Awakening SDL Diagram

Figure 59b6 shows the SDL for the BS when an SS is in awake mode.

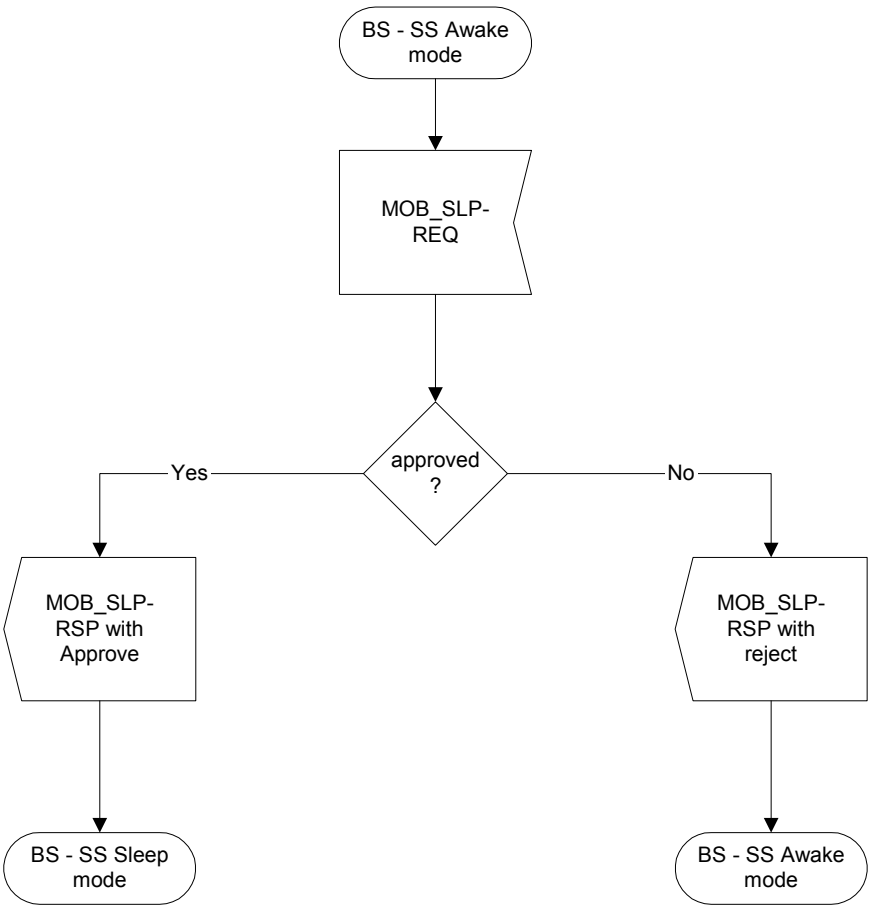

Figure 59b6: BS – SS Awake Mode SDL Diagram

Figure 59b7 shows the SDL for the BS when the SS is in sleep mode.

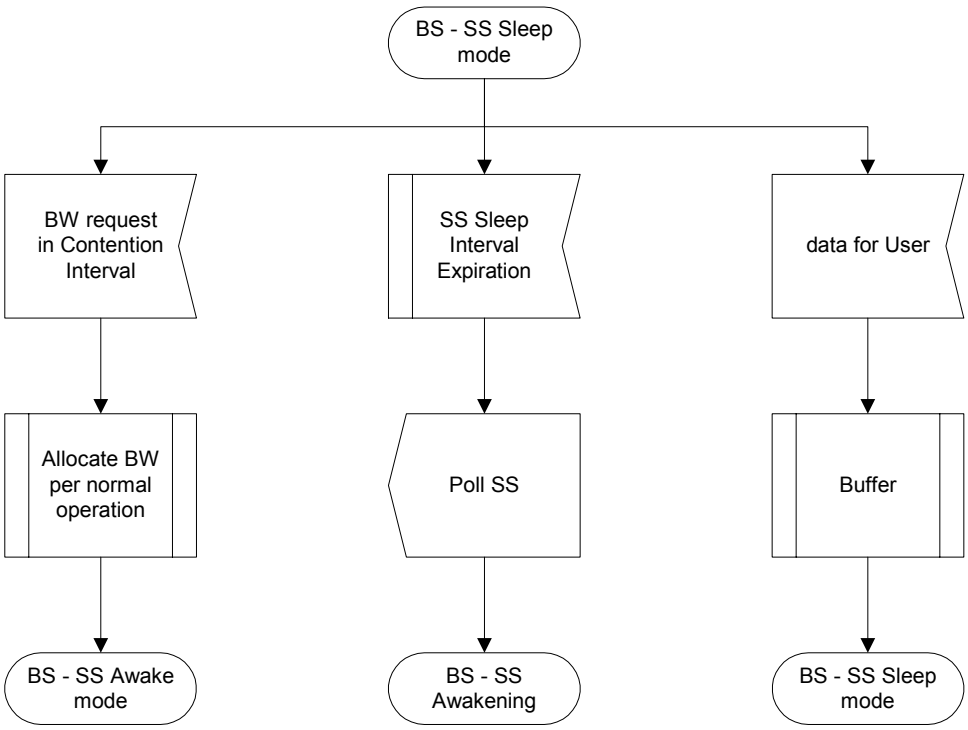

Figure 59b7: BS – SS Sleep Mode SDL Diagram

Figure 59b8 shows the BS SDL for when the SS is awakening.

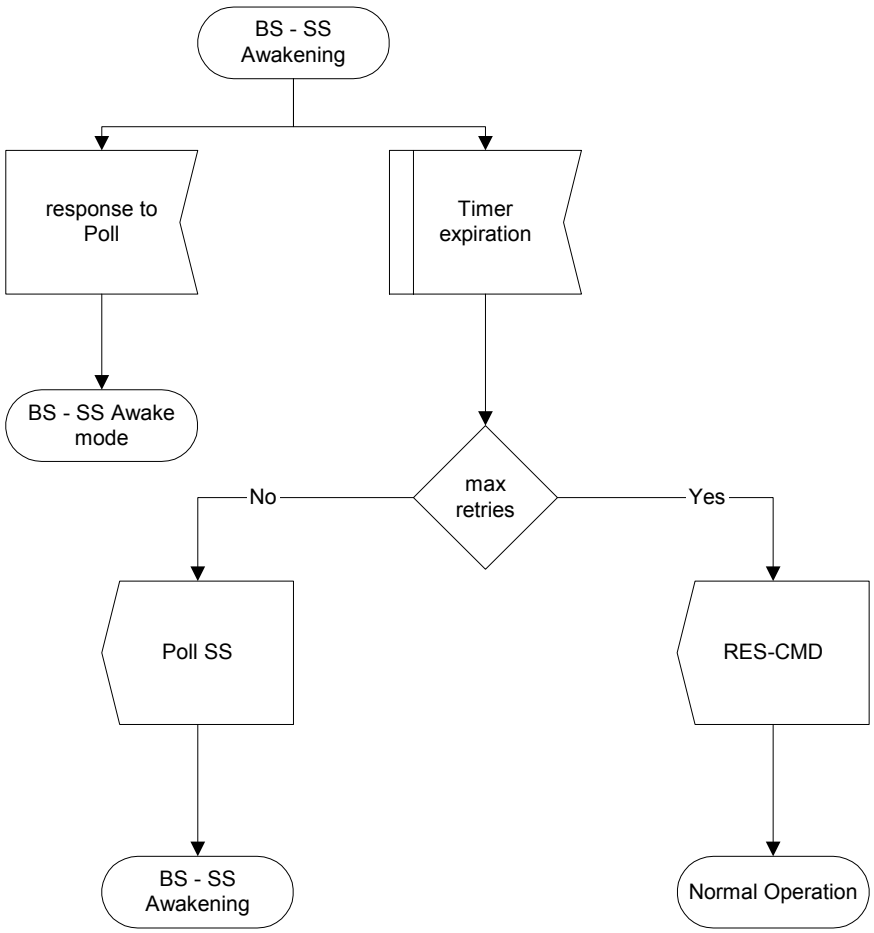

Figure 59b8: BS – SS Awakening SDL Diagram

Incomplete concepts

1. Since the sleep mode is stated as optional, an SS should negotiate that capability during the SBC-REQ/RSP protocol. TLVs supporting this need to be added to chapter 11 and mentioned in the definition of the SBC messages.
2. What to do, i.e., how many times to poll, when an SS fails to awaken needs to be specified. The number of polls and timer should be added to the global constants in chapter 10.
3. What to do, i.e., how long to wait for a poll, when an SS awakens, but the BS does not poll it needs to be specified. The timer should be added to the global constants in chapter 10.
4. We need a traffic parameter TLV for each service (sent in DSA-REQ) that specifies the minimum length of time the service must be idle before the SS is allowed to enter sleep mode.