Agenda Item: **9.5.1**
Source: **CEWiT**
Title: **Discussion on on-demand SSB Scell operation.**
Document for: **Discussion**

1 Introduction

A Rel. 19 work item for extended work on techniques for NES to common signals/channels was started in RAN1#116 [2]. Based on the WI description in RP-234065 [3], the following objective has been agreed on on-demand SSB SCell operation for NES:

- Specify procedures and signaling method(s) to support on-demand SSB SCell operation for UEs in connected mode configured with CA, for both intra-/inter-band CA. [RAN1/2/3/4]
  - Specify triggering method(s) (select from UE uplink wake-up-signal using an existing signal/channel, cell on/off indication via backhaul, SCell activation/deactivation signaling)
  - Note1: On-demand SSB transmission can be used by UE for at least SCell time/frequency synchronization, L1/L3 measurements and SCell activation, and is supported for FR1 and FR2 in non-shared spectrum.

This contribution discusses techniques to support on-demand SSB and required configurations for the Wake-up-signal (WUS) .

2 Techniques to support on-demand SSB

In NR, the gNB periodically transmits SSBs in all enabled cells to assist a new UE attempting to connect to the network and for link maintenance. However, periodic SSB transmissions in certain cells, particularly SCells, can be unnecessary and consume energy at the gNB, especially when no UE is connected to the SCell or when the gNB is serving connected UEs in another cell, such as the PCell. A connected UE may still require SSB transmissions in SCells for purposes such as L1 measurements or to reactivate a deactivated SCell when access is needed. Furthermore, frequent SSB transmissions by the gNB reduce the SCell's deactivation duration. Therefore, triggering SSB transmissions in SCells on-demand can save power at the gNB. Several agreements have been made for on-demand SSB transmissions based on indications from the gNB, but multiple issues still need to be considered. The following sections address some of these issues.

2.1 Transmissions of on-demand SSB

In RAN1#119[5], the following agreement was made regarding the transmissions of on-demand SSB in SCells. Further study is needed on some of the options and aspects, as specified in the agreement below.

Agreement
For a cell supporting on-demand SSB SCell operation, support at least the following options to deactivate on-demand SSB transmission from a UE perspective.
- Option 1: Explicit indication of deactivation for on-demand SSB via MAC-CE for on-demand SSB transmission indication
  - Deactivation by RRC is up to RAN2
  - FFS: Which scenario Option 1 is used
- Option 2: Configuration/indication of the number N of on-demand SSB bursts to be transmitted after on-demand SSB is indicated
  - FFS: Whether Option 4, 4a is needed in addition to Option 2

FFS: Whether the value of N can be implicitly determined using a timer

A UE requires a minimum number of SSBs to perform measurements before initiating the initial access procedure and to successfully decode the SSB. Therefore, a gNB should transmit the on-demand SSBs multiple times upon receiving a WUS. The UE may assume periodic transmissions of the on-demand SSB

burst for a number of times (N) after time instance A. Hence options 1 and 2 were agreed in RAN#119[5] for indication explicit deactivation command or number N repectively to the UE in DL. However, an FFS for option 4 was proposed to be discussed, option 4 was introduced in RAN1#118b as given below, which supports use of SCell deactivation MAC-CE for the deactivation of OD-SSB if any. However, there can be scenarios where the SCell can be activated for the larger duration of time, whereas the SSB transmission may not be needed for that long duration by the UE. Further option 1 agreed in last meeting already covers the explicit indication for the OD-SSB deactivation whenever needed later or sooner, which is more suitable for the scenarios mentioned above. Hence option 4 is not needed as it cause unnneccary transmissions of OD-SSBs for a longer period.

oOption 4: On-demand SSB transmission, if any, is deactivated when UE receives SCell deactivation MAC-CE for the activated SCell

Observation 1: Option 4 causes unneccasry transmission of SSB when Scell is active for longer period and reduces flexibility at the gNB to deactivate the OD-SSB transmissions.
Proposal 2: Do not support option 4 to use SCell deactivation MAC-CE for deactivation of OD-SSB.

2.2. Enabling of indices of on-demand SSB for a subset of always on SSBs

In RAN1#119[5], the following agreement was made regarding the ithe spatial relation between the always-on SSB and OD-SSB. A discussion is still needed for the case where where SSB indices within on-demand SSB burst can be subset of SSB indices within always-on SSB burst.

Agreement Response to Q4 (What is the spatial relation between the always-on SSB and OD-SSB?) of Obj.1: □SS/PBCH blocks with the same SSB indexes for always-on SSB and on-demand SSB are quasi co-located with respect to Doppler spread, Doppler shift, average gain, average delay, delay spread, and when applicable, spatial RX parameters. oApplies at least for the case when the centre frequency locations of always-on SSB and OD-SSB is same □When a signal/channel is configured to be QCLed with a SSB index, the signal/channel is QCLed with the same SSB index of always-on SSB and on-demand SSB (if transmitted) with the same QCL parameters according to existing specifications oApplies at least for the case when the centre frequency locations of always-on SSB and OD-SSB is same □At least the case where SSB indices within on-demand SSB burst are identical to SSB indices within always-on SSB burst is supported. RAN1 is discussing whether to support the case where SSB indices within on-demand SSB burst can be subset of SSB indices within always-on SSB burst.

An Always on SSB is typically intended to serve all UEs within its beam's coverage area. Therefore SSB indices within always on SSB burst can also be enabled for all coverage beams. On the other hand, an OD-SSB can be indicated for certain UEs in specific scenarios, hence not all OD-SSBs need to be enabled for every beam of an AO-SSB. Enabling indices of OD-SSB for all beams of AO-SSB will cause unecessary transmissions of SSBs in areas with no UEs. Therefore to enable more flexible beam adaptation, the SSB indices within an on-demand SSB burst can be a subset of the SSB indices within an always-on SSB burst.

Observation 2: SSB indices within on-demand SSB equal to SSB indices within always-on SSB burst cause unnecessary SSB transmissions in areas with non uniform UE density.
Proposal 2: Support the SSB indices within on-demand SSB burst as a subset of SSB indices within always-on SSB burst.

2.3. Configuration of parameters supporting on-demand SSB SCell operation

In RAN1#119[5], the following agreement was made regarding the indication of time domain parameters needed for OD-SSB operation to the UE. For case 1, without alwasy on SSB, the time locations for OD-SSB comprises two parameters namely SFN offset and half frame index, which needs to be indicated to the UE.

Agreement □For a cell supporting on-demand SSB SCell operation, support to configure time domain location

of on-demand SSB per on-demand SSB periodicity by RRC for both Case #1 and Case #2.
oFor Case #1 (i.e., No always-on SSB on the cell),
□Based on two parameters, where one is to indicate SFN offset from a reference point and the other is to indicate half frame index
□If SFN offset parameter is NOT configured, UE assumes SFN offset set to 0.
□If half frame index parameter is NOT configured, UE assumes half frame index set to 0.
□The value range of SFN offset is 0 to 15 unless longer periodicity for on-demand SSB than 160 ms is introduced.
oFor Case #2 (i.e., Always-on SSB is periodically transmitted on the cell), down-select one of the following alternatives.
□Alt A: Same as for Case #1
□Alt B: Based on a single parameter which is to indicate the time offset between always-on SSB and on-demand SSB (e.g., similar to ssb-TimeOffset)

The transmissions of an SSB burst in legacy follow the constraint of being confined within a half-frame window. For always on SSB, the index of the half frame in which the SSB are transmitted is indicated in the SSB itself. The transmission of an on-demand SSB burst should also be confined within a half-frame window and both UE and gNB should have a common understanding on the half-frame in which the on-demand SSB will appear after Tmin ends. hence parameters for the location of on-demand SSB burst should be provided to the UE. However, as OD-SSB is independent from always on-SSB, the system frame number (SFN) and half frame index for the location of on-demand SSB burst should be provided independetly to o the UE enabling more flexibilty in adaptation of the OD-SSB transmissions.

Proposal 3: Support the configuration of the SFN offset and half-frame index for the UE in Case 2, similar to Case 1.

2.4. UE behavior for OD-SSB

After receiving the OD-SSB indication from the gNB or transmitting the UL WUS, a UE will monitor for SSBs from the gNB assuming the on-demand SSB operation activated. However, in scenarios where the UE does not receive the OD-SSB, the on-demand SSB operation becomes unreliable, impacting UE performance. For example, the UE may continue monitoring for SSBs even if the gNB is not transmitting them. In RAN1#119[5], the following note was proposed in section 9 of the FL summary regarding UE behavior in cases where the UE cannot receive SSB after the on-demand SSB operation, but it was not addressed due to time constraints:

Issue 3) Whether/how to handle the case where UE cannot receive SSB after on-demand SSB operation

To increase the reliability of the OD-SSB operation, the UE's behavior must be defined in cases where no SSB is received after receiving the OS-SSB indication or after UL WUS transmission for on-demand SSB.

Observation 3: UE not receiving the SSB after on-demand SSB operation leads to unnecessary monitoring by the UE and negative impacts on performance.
Proposal 4: Support handling of the case where the UE cannot receive SSB after the on-demand SSB operation.

2.4 Impacts on RACH procedure

In 5G-NR, the RACH configuration provides a set of RACH occasions (ROs) that repeat periodically based on the RACH configuration period and are mapped to periodically transmitted SSBs according to the SSB-RO mapping rule. These RACH configuration are used for RRC connections by the UE and is transmitted in SIB1 by the gNB. However, in case of on demand SSB, the SSB is transmitted only when triggered or when WUS is received by the gNB. In RAN1#119[5], the following issue was proposed in section 9 of the FL

summary regarding handle the collision issue between SSB and other signals/channels (e.g., RACH occasions), but it was not addressed due to time constraints:

Q#9-1 (Collision): At least 5 companies suggested to handle the collision issue between SSB and other signals/channels (e.g., RACH occasions). Do you agree to handle this issue?

For cells with OD-SSB enabled, the RACH occasions are needed and valid only when SSB transmission occurs. As a result, handling the impact of the on-demand SSB procedure on RACH occasions for RRC connection establishment should be considered.

Observation 4: On-demand SSB impacts the need and validity of periodic RACH occasions and their association with SSBs, requiring adjustments to ensure efficient RRC connection establishment.
Proposal 5: Support handling the impacts of on-demand SSB on RACH occasions for RRC connection establishment.

3 Conclusion

In this contribution, we discussed the techniques required for on-demand SSB SCell operation and following proposals are made,
Observation 1: Option 4 causes unneccasry transmission of SSB when Scell is active for longer period and reduces flexibility at the gNB to deactivate the OD-SSB transmissions.
Proposal 2: Do not support option 4 to use SCell deactivation MAC-CE for deactivation of OD-SSB.
Observation 2: SSB indices within on-demand SSB equal to SSB indices within always-on SSB burst cause unnecessary SSB transmissions in areas with non uniform UE density.
Proposal 2: Support the SSB indices within on-demand SSB burst as a subset of SSB indices within always-on SSB burst.
Proposal 3: Support the configuration of the SFN offset and half-frame index for the UE in Case 2, similar to Case 1.
Observation 3: UE not receiving the SSB after on-demand SSB operation leads to unnecessary monitoring by the UE and negative impacts on performance.
Proposal 4: Support handling of the case where the UE cannot receive SSB after the on-demand SSB operation.
Observation 4: On-demand SSB impacts the need and validity of periodic RACH occasions and their association with SSBs, requiring adjustments to ensure efficient RRC connection establishment.
Proposal 5: Support handling the impacts of on-demand SSB on RACH occasions for RRC connection establishment.

4 References

1 3GPP TR 38.864 V18.1.0, Study on network energy savings for NR.
2 Chairman Notes, RAN1#116, February 26th – March 1st, 2024.
3 RP-234065, “NewWID: Enhancements of network energy savings for NR”, Ericsson, December 2023.
4 Chairman Notes, RAN1#118b, October, 2024
5 Chairman Notes, RAN1#119, November, 2024