3GPP TSG RAN WG1 #120 **R1-2500525**
Athens, Greece, Feb 17th – 21st, 2025

Agenda Item: **9.5.1**

Source: **InterDigital Inc.**

Title: **Discussion on on-demand SSB SCell operation**

Document for: **Discussion**

1 Introduction

The Rel-19 Revised WID on Network Energy Savings for NR has the following objective on on-demand SSB SCell [1]:

1. 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.

The agreements made in the RAN1#119 [2] meeting are provided in the appendix. In this contribution, we discuss the remaining issues for enabling on-demand SSB SCell operation.

2 Discussion

For CA deployments, intra-band CA with SSB-less SCell has been supported since Rel-15 for both FR1 and FR2. In Rel-18 the support for SSB-less SCell is extended for collocated cells in FR1 that are in inter-band CA (e.g. within max receive time, frequency and power difference). In the inter-band CA case, the NW signals to the UE which cell is the reference cell (e.g. a PCell or another SCell), where the reference cell acts as the timing reference and AGC source of the SSB-less Scell.

Supporting inter-band CA for FR2 comes with challenges, e.g. achieving synchronization, L1/L3 measurements and beam management, especially when the cells are non-collocated and only the SCells operate in FR2 while other cells in FR1. For energy saving purposes in both intra- and inter-band CA, it is important for the SCells to operate in NES mode as long as possible (e.g. before and after SCell activation) with limited SSB transmission.

2.1 Scenarios where OD-SSB is applicable

The following scenarios/cases agreed in RAN1#116bis [6] were discussed in previous meetings but no related agreements were made.

Agreement

For the identified scenarios and cases (as per RAN1#116 agreement), on-demand SSB can be triggered by gNB at least for the following scenarios/cases:

- Scenario #2 and Case #1
- Scenario #2 and Case #2
- Scenario #2A and Case #1

- Scenario #2A and Case #2
- FFS: Scenario #3A and Case #1
- FFS: Scenario #3A and Case #2
- FFS: Scenario #3B and Case #1
- FFS: Scenario #3B and Case #2
- For Case #1, once on-demand SSB is triggered, its transmission is in a periodic manner.
    - Note: This does not imply periodic on-demand SSB is transmitted indefinitely after triggered.
- Notes:
    - Scenario #2A refers to
        - "When UE receives SCell activation command (e.g., as defined in TS 38.321)"
    - Scenario #3A refers to
        - "After UE receives SCell activation command (e.g., as defined in TS 38.321) until SCell activation is completed"
    - Scenario #3B refers to
        - "When SCell activation is completed and SCell is activated" or
        - "After SCell activation is completed and SCell is activated"
    - For discussion purpose under AI 9.5.1, always-on SSB is SSB supported in Rel-18 specifications.
    - Timing for on-demand SSB transmission (e.g. when the triggered SSB starts and ends) will be separately discussed.

In Scenario #3B, it is possible that the SCell can be transitioned to an NES mode after SCell activation is completed. At this stage, both Case #1 (operate completely SSB-less) and Case #2 (AO-SSBs are transmitted with long periodicity) can still apply at the SCell, assuming that the SCell is not configured as PCell for other UEs. Scenario #3B is reasonable as it provides more opportunities for the SCell for energy savings, especially during low load conditions. Triggering OD-SSB transmisison in Scenario #3B can also be beneficial to improve sycnchronization, timing reference and AGC at the UE, especially in Case #2 when the last transmission of AO-SSB burst may be outdated.

Observation 1: **Since the SCell can be transitioned to NES mode after SCell activation is completed, triggering OD-SSB transmission can be beneficial to improve synchronization, timing reference and AGC at the UE, especially when last AO-SSB transmission is outdated.**

In addition, such benefits for using OD-SSBs can apply in the cases outside of the SCell activation procedure where the UE can be triggered to perform RRM measurements, CSI measurements/reporting and PDCCH decoding. The spec impacts for supporting OD-SSB (e.g. in terms of signaling for indicating OD-SSB) are similar regardless of its applicability for Scenarios 2/2A and Scenarios 3B. As such, we see no reason to restrict OD-SSB transmission to only scenarios/cases during SCell activation. In general, not supporting such scenario may be an artificial limitation, given that the procedures and signalling will anyways be designed more generically. Thus far, there is no need to restrict such network implementation from sending the OD-SSB indication MAC CE at any point. Given the overall benefits, we propose the following:

Proposal 1: **Support on-demand SSB transmission in Scenario #3B at least for Case #2**

2.2 Assumption on cell supporting OD-SSB transmission

In RAN1#118 [4], the following agreement was made on the SSB types supported for OD-SSB:

Agreement

For a cell supporting on-demand SSB SCell operation, at least the following is supported
- On-demand SSB on the cell is not located on synchronization raster.
- On-demand SSB on the cell is non-cell-defining SSB

FFS: Additional support of OD-SSB for CD-SSB located on sync-raster

Based on the agreement above, since the OD-SSB transmitted (e.g. off sync raster and as NCD-SSB) does not allow initial access on the SCell, any adverse impacts to legacy and R19 idle/inactive UEs can be avoided. However, limiting the OD-SSB

to such SSBs can result in only limited NES gains if any. In this regard, it is preferable to also support OD-SSB to be configured as CD-SSB located on sync raster.

For an SCell that supports OD-SSB, it is possible that such cell is configured as PCell for other UEs, in which case it is likely to impact any legacy UEs when the OD-SSB is a CD-SSB. To address this, any impacts to idle/inactive UEs can be avoided by using legacy MIB-based barring or by proper deployment/dimensioning of the CD-SSBs. It can anyways be up to the gNB implementation to decide on the type of SSBs to use for OD-SSB rather than restricting them to only a subset of SSBs with no clear NES benefits.

***Proposal 2*: Support CD-SSB located on sync-raster for a cell supporting OD-SSB SCell operation**

2.3 Time domain parameters for OD-SSB

In RAN1#119, the following agreement was made:

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.
  - For 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
      - The reference point is SFN which satisfies (SFN index *10) modulo (OD-SSB periodicity) = 0
      - 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.
      - The value range of half frame index is 0 or 1.
  - For 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*)

Regarding Case #2, there are 2 alternatives that were considered for the time domain parameters in the last meeting. In Alt A, the same set of parameters for SFN offset and half frame index as those used for Case #1 are applied for Case #2. One implication of this for Case #2 is the possibility where AO-SSB and OD-SSB may fully overlap in time domain. Since the periodicity of AO-SSB is expected to be longer (e.g. 160ms), such overlap in time domain is not expected to be frequent. Even when there is an overlap, any impact at the UE can be addressed (e.g. during L1/L3 measurements) when the same configuration parameters for ss-PBCH-BlockPower and ssb-PositionsInBurst are applied for both AO-SSB and OD-SSB.

In contrast, Alt-B introduces a time offset between AO-SSB and OD-SSB primarily to avoid any overlap in time domain. The benefit of avoiding such overlap is not significant, compared to the additional spec impact and introducing unnecessary dependency between AO-SSB and OD-SSB. Based on this reasoning, we propose the following:

***Proposal 3:* For cell supporting OD-SSB SCell operation, support configuring the same time domain location parameters (i.e. reference point, SFN offset, half frame index) for Case #2 as that of Case #1**

2.4 Frequency location relation between AO-SSB and OD-SSB

In RAN1#119, the following agreement was made regarding the frequency location relation

Agreement

Down-select at least one of the following alternatives.

- Alt 1: If always-on SSB is CD-SSB on a synchronization raster, the frequency location of on-demand SSB is different from the frequency location of always-on SSB.
- Alt 2: If always-on SSB is CD-SSB on a synchronization raster, the frequency location of on-demand SSB is the same as the frequency location of always-on SSB
- Alt 3: Do not support the case where always-on SSB is CD-SSB on a synchronization raster.

Down-select at least one of the following alternatives.

- Alt A: If always-on SSB is CD-SSB and not on a synchronization raster, the frequency location of on-demand SSB can be same or different from the frequency location of always-on SSB, subject to its configuration.
- Alt B: If always-on SSB is CD-SSB and not on a synchronization raster, the frequency location of on-demand SSB is the same as the frequency location of always-on SSB
- Alt C: Do not support the case where always-on SSB is CD-SSB and not on a synchronization raster.

The first set of alternatives in the agreement above are related to the scenario where AO-SSB is configured as CD-SSB on the sync-raster. Such scenario is valid in some SCell deployments and also in the case when the SCell may be configured as PCell for other UEs. With Alt-1, it would be possible to allow NW flexibility and address some impacts to legacy UEs by configuring the OD-SSB off sync-raster. However, from NW perspective a larger frequency footprint is incurred to transmit the both AO-SSB and OD-SSB over a wider set of frequency resources. Alt-2 on the other hand, avoids any issues related to UE complexity for tracking multiple frequencies during measurements. Alt-2 can also avoid impacts to legacy UE by configuring the OD-SSB on sync raster as NCD-SSB, e.g. to prevent triggering initial access with OD-SSB.

Proposal 4: **For AO-SSB configured as CD-SSB on a sync raster, support the frequency location of OD-SSB to be the same or different as the frequency location of AO-SSB (Alt-1 or Alt-2)**

The second set of alternatives in the agreement above are related to the scenario where AO-SSB is configured as CD-SSB and not on the sync raster. Although a likely NW deployment may configure the AO-SSB off GSCN sync-raster as NCD-SSB, it is possible that in some deployments the AO-SSBs off sync raster are configured as CD-SSB. In this case, having OD-SSB configured on different frequency locations without being constrained by the AO-SSB frequency locations can be beneficial for enabling measurements for faster SCell activation. To allow adequate NW flexibliblity when transmitting OD-SSB, it is preferable for the frequency location of OD-SSB to be the same or different from that of AO-SSB as indicated in Alt-A.

Proposal 5: **For AO-SSB configured as CD-SSB and not on sync raster, support the frequency location of OD-SSB to be the same or different from the frequency location of AO-SSB (Alt-A)**

2.5 Overlap between AO-SSB and OD-SSB

In RAN1#118bis [3] meeting, the following agreement was made on multiplexing cases:

Agreement

For a cell supporting on-demand SSB SCell operation and for Case #2 (i.e., Always-on SSB is periodically transmitted on the cell), study at least the following Mux-Cases.

- Mux-Case #1: No time-domain overlap between always-on SSB and on-demand SSB
- Mux-Case #2: Always-on SSB and on-demand SSB overlap at least in time or frequency domain

In relation to the agreement above, the benefits of having both AO-SSB and OD-SSB overlap in the same frequency location were discussed in a previous section. In some scenarios, overlap in frequency domain can at least help to reduce usage of frequency resources for SSBs and avoid UE complexity for tracking multiple frequencies during L1/L3 measurements.

On the question of whether AO-SSB and OD-SSB can overlap in time domain (i.e. the same time offset is used for both AO-SSB and OD-SSB), at least from the NW perspective it makes sense to minimize the time domain resources allocated for the SSBs when both SSB types overlap. In fact, avoiding the overlap can make the design more complicated, as the periodicities of AO-SSB and OD-SSB need to be offset from each other. Also, to strive for a common design for OD-SSB and SSB adaptation in Scell, the periodicity of OD-SSB can be configured to be a period multiple of the AO-SSB, such that overlap in the TD can happen in some occasions.

Even from UE perspective, having both AO-SSB and OD-SSB in the same time locations mitigates further complexity to account for multiple SSB parameters. For example, when both SSBs overlap in the time domain the UE can make measurements on either SSBs provided the same SSB Tx power and SSB positions in burst are configured for both. Also, such overlap is anyways not expected to happen frequently since a longer periodicity is expected to be configured for AO-SSB compared to OD-SSB (e.g. in Case 2). Based on this reasoning, we propose the following:

Proposal 6: **For multiplexing of AO-SSB and OD-SSB in SCell, support overlap in time domain and/or frequency domain**

2.6 Deactivation of OD-SSB transmission

In RAN1#119, the following agreement was made on the deactivation of OD-SSB

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

Regarding the FFS under Option 1 in the agreement above, the OD-SSB deactivation indication via MAC CE can be received by UE in multiple scenarios. In Scenario 2 (SCell is configured but before the UE receives SCell activation command), both the OD-SSB activation and deactivation indications can be received before the Scell activation indication, e.g. for indicating start/end of measurements on the OD-SSB transmitted by the SCell. In Scenario 2A (when UE receives SCell activation command), the OD-SSB activation indication itself can be received before the the SCell activation indication, e.g. to initite measurements. The OD-SSB deactivation indication can then be received at the same time when receiving the Scell activation indication, in a different MAC CE. In Scenario 3B, it is possible that OD-SSB can be activated and deactivated even after the SCell activation is complete, e.g. when the SCell transitions into an NES/dormant mode. Having a common design for indicating OD-SSB deactivation via MAC CE in all scenarios is preferable not only from spec effort perspective but also to avoid imposing any restrictions at NW. Based on the analysis above, we propose the following:

Proposal 7: **Support explicit indication of deactivation for OD-SSB via MAC-CE for all supported scenarios**

The first FFS under Option 2 in the agreement above corresponds to implicit deactivation of OD-SSB, e.g. when SCell is deactivated and the SCell deactivation timer expires. Although such implicit deactivation may be possible in some scenarios, any overhead savings for not having to send a OD-SSB deactivation indication is negligible, especially when the NW anyways sends the SCell deactivation indication. Additionally, having an explicit OD-SSB deactivation indication provides NW flexibility to decouple the OD-SSB deactivation with that of SCell activation procedure. Given this, we propose the following:

Proposal 8: **Deactivation of OD-SSB when the UE received SCell deactivation (Option 4) or expiry of SCell deactivation timer (Option 4A) are not supported**

Regarding the second FFS under Option 2 in the agreement above, configuring the number N of OD-SSB bursts in RRC can provide some benefit at gNB for limiting the OD-SSB transmisisons to a fixed number. Since the same OD-SSB transmissions can be used for multiple UEs, to enable sufficient flexibility at NW it is important to configure a proper value for N in RRC. For example, the N value can be configured per OD-SSB periodicity. Since Option 1 already supports indicating deactivation of OD-SSB, there is no motivation to dynamically indicate the N value, and that RRC configuration of N is sufficient. Also, given the ongoing discussion on the N value, it makes sense to not introduce an additional timer for achieving the same outcome.

Proposal 9: **An additional timer for implicitly determining the value of N for the number of OD-SSB bursts is not introduced**

2.7 Signaling additional parameters for OD-SSB

In RAN1#118 [4], the following agreement was made on the parameter than can be indicated in the MAC CE on OD-SSB transmission:

Agreement

For a cell supporting on-demand SSB SCell operation, at least for the following parameter(s), multiple candidate values can be configured by RRC and the applicable value can be indicated by MAC CE for on-demand SSB transmission indication for the cell.

- Periodicity of the on-demand SSB
- FFS: Any other relevant parameters

The agreement above on signalling the periodicity value of OD-SSB in MAC CE already provides sufficient flexibility to the NW, e.g. to enable OD-SSB with different periodicity in different scenarios. In this case, the different candidate periodicity values can be configured under the same OD-SSB configuration and a specific periodicity can be signalled to the UE when needed.

Regarding the FFS, aside from periodicity, there is no further motivation to dynamically signal other parameters (e.g. number N of OD-SSB bursts) in the MAC CE that can justify the additional overhead and spec impact. As described in previous section, other parameters of OD-SSB can anyways be included in the RRC configuration for OD-SSB. Also, since explicit deactivation of OD-SSB is supported via the MAC CE (previous agreement), there is no need to indicate the number N of OD-SSB bursts in the MAC CE. In light of this and in the interest of keeping the spec effort manageable, we propose the following:

Proposal 10: **Indication of the number N of OD-SSB bursts is not supported in the MAC CE for OD-SSB**

2.8 DCI for indicating OD-SSB

In RAN1#117 [5], the following agreement was made on the signaling to indicate OD-SSB transmission:

Agreement

- For a cell supporting on-demand SSB SCell operation,
  - Support RRC based signaling to indicate on-demand SSB transmission on the cell.
  - Support MAC CE based signaling to indicate on-demand SSB transmission on the cell.
  - FFS: Whether to support DCI based signaling to indicate on-demand SSB transmission on the cell.
    - This DCI signaling does not provide SCell activation/deactivation.
    - If supported, details on DCI including UE-specific or group-common DCI, DCI contents, etc.
  - FFS: Scenarios where the above signalings are applicable

On the FFS in the agreement, supporting DCI provides another means to indicate the OD-SSB transmission, which is cell-specific, with relatively low latency and low overhead using a group-common signaling. On the other hand, in view of the existing support for both RRC and MAC CE based signaling, there is no further motivation to introduce DCI based signaling to indicate the same info on OD-SSB. The RRC and MAC CE based signaling also provides higher reliability and are similar to the legacy signalling used for SCell activation/deactivation, hence the corresponding UE behavior when receiving the indication on OD-SSB in such signaling is reuseable. Given the reasoning, we propose the following:

Proposal 11: **DCI based signalling to indicate OD-SSB transmission is not introduced in Rel-19**

2.9 L1 measurements on OD-SSB

In RAN1#118 [4], the following agreement was made for supporting L1 measurements on OD-SSB:

Agreement

For a cell supporting on-demand SSB SCell operation and for Case #2 (i.e., Always-on SSB is periodically transmitted on the cell), consider only one or both of the following options for UE to perform L1 measurement based on on-demand SSB.

- Option 1: A CSI report configuration is associated with both of on-demand SSB and always-on SSB
- Option 2: A CSI report configuration is associated with one of always-on SSB and on-demand SSB
- FFS: Whether OD-SSB and always on SSB have same beam or not

In relation to the agreement above, one of the issues discussed in previous meeting is on whether the UE measures AO-SSB and OD-SSB separately or jointly for deriving CSI. When both AO-SSB and OD-SSB resources are configured to be within the same BWP, it should be possible for the CSI report configuration to be associated with both SSB resources.

In Case #2, OD-SSB may be transmitted with shorter periodicity compared to AO-SSB. In this case, although CSI may be derived predominantly based on measurements of denser OD-SSB resources, configuring both AO-SSB and OD-SSB resources can be useful from CSI accuracy perspective. In this regard, Option 1 can be supported, provided that both SSB resources are configured in the same BWP with same set of parameters (e.g. same SSB Tx power, same beam). Alternatively, if the BWP is configured with only one of AO-SSB and OD-SSB resources (e.g. OD-SSB is configured in a different frequency location than AO-SSB), then Option 2 can be supported where the CSI report configuration is associated with either AO-SSB or OD-SSB resources. Based on this, we propose the following:

Proposal 12: **Support a CSI report configuration that is associated with**

- **one of OD-SSB and AO-SSB (Option 1) when the SSB resources are in different BWPs, or**
- **both OD-SSB and AO-SSB (Option 2) when the SSB resources are within the same BWP**

Regarding the FFS in the agreement above, configuring OD-SSB beams (e.g. via the *ssb-PositionsInBurst* parameter) that are different than those of AO-SSB may provide some flexibility and opportunities for NES at the gNB given the potential to optimize the usable beams during SCell activation. However, having to configure different sets of beams with different properties adds complexity not only at the NW but also at the UE. For example, when configured with different beams for OD-SSBs and AO-SSBs, the UE needs to switch between different Rx spatial filters during L1 measurements. Such switching and complexity is unnecessary when the purpose of the measurements is mainly to facilitate T/F sync and CSI derivation during SCell activation. For simplicity and practicality, it is preferred for the OD-SSB and AO-SSB to have the same beams.

Proposal 13: **Support configuring the same set of beams when both OD-SSB and AO-SSB are configured for L1 measurements**

3 Conclusion

In this contribution, the following observations are made:

Observation 1: **Since the SCell can be transitioned to NES mode after SCell activation is completed, triggering OD-SSB transmission can be beneficial to improve synchronization, timing reference and AGC at the UE, especially when last AO-SSB transmission is outdated.**

The following proposals are made:

Proposal 1: **Support on-demand SSB transmission in Scenario #3B at least for Case #2**

Proposal 2**: Support CD-SSB located on sync-raster for a cell supporting OD-SSB SCell operation**

Proposal 3: **For cell supporting OD-SSB SCell operation, support configuring the same time domain location parameters (i.e. reference point, SFN offset, half frame index) for Case #2 as that of Case #1**

Proposal 4: **For AO-SSB configured as CD-SSB on a sync raster, support the frequency location of OD-SSB to be the same or different as the frequency location of AO-SSB (Alt-1 or Alt-2)**

Proposal 5: **For AO-SSB configured as CD-SSB and not on sync raster, support the frequency location of OD-SSB to be the same or different from the frequency location of AO-SSB (Alt-A)**

Proposal 6: **For multiplexing of AO-SSB and OD-SSB in SCell, support overlap in time domain and/or frequency domain**

Proposal 7: **Support explicit indication of deactivation for OD-SSB via MAC-CE for all supported scenarios**

Proposal 8: **Deactivation of OD-SSB when the UE received SCell deactivation (Option 4) or expiry of SCell deactivation timer (Option 4A) are not supported**

Proposal 9: **An additional timer for implicitly determining the value of N for the number of OD-SSB bursts is not introduced**

Proposal 10: **Indication of the number N of OD-SSB bursts is not supported in the MAC CE for OD-SSB**

Proposal 11: **DCI based signalling to indicate OD-SSB transmission is not introduced in Rel-19**

Proposal 12: **Support a CSI report configuration that is associated with**

- **one of OD-SSB and AO-SSB (Option 1) when the SSB resources are in different BWPs, or**
- **both OD-SSB and AO-SSB (Option 2) when the SSB resources are within the same BWP**

Proposal 13: **Support configuring the same set of beams when both OD-SSB and AO-SSB are configured for L1 measurements**

---

4 Appendix: Agreements on OD-SSB SCell operation

RAN1#119 Agreements

Agreement

Response to Q1 (What is the relation in terms of periodicity between always-on SSB and OD-SSB?) of Obj.1:

- The periodicity of on-demand SSB is one of 5 ms, 10 ms, 20 ms, 40 ms, 80 ms, or 160 ms.
- The periodicity of on-demand SSB can be configured separately from the periodicity of always-on SSB.
- RAN1 is discussing what is the relation between periodicity of always-on SSB and periodicity of on-demand SSB and it has been identified that the main use case is that the periodicity of on-demand SSB is equal to or smaller than that of always-on SSB.

Further update to be made based on RAN1#119 progress.

Agreement

Response to Q3 (What is the relation in terms of frequency location between the always-on SSB and OD-SSB?) of Obj.1:

- The frequency location of on-demand SSB is the same as the frequency location of always-on SSB at least for the case where always-on SSB is not CD-SSB. RAN1 is discussing the frequency location of OD-SSB for the case where always-on SSB is CD-SSB.

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.
    - Applies 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
    - Applies 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.

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.
    - For 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
            - The reference point is SFN which satisfies (SFN index *10) modulo (OD-SSB periodicity) = 0
            - 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.
            - The value range of half frame index is 0 or 1.
    - For 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*)

Agreement

- New periodicity value for on-demand SSB other than the legacy values (i.e., 5 ms, 10 ms, 20 ms, 40 ms, 80 ms, or 160 ms) is NOT introduced in Rel-19.

Agreement

Down-select at least one of the following alternatives.

- Alt 1: If always-on SSB is CD-SSB on a synchronization raster, the frequency location of on-demand SSB is different from the frequency location of always-on SSB.
- Alt 2: If always-on SSB is CD-SSB on a synchronization raster, the frequency location of on-demand SSB is the same as the frequency location of always-on SSB
- Alt 3: Do not support the case where always-on SSB is CD-SSB on a synchronization raster.

Down-select at least one of the following alternatives.

- Alt A: If always-on SSB is CD-SSB and not on a synchronization raster, the frequency location of on-demand SSB can be same or different from the frequency location of always-on SSB, subject to its configuration.
- Alt B: If always-on SSB is CD-SSB and not on a synchronization raster, the frequency location of on-demand SSB is the same as the frequency location of always-on SSB
- Alt C: Do not support the case where always-on SSB is CD-SSB and not on a synchronization raster.

Agreement

Response to Q2 (What is the relation in terms of time location between always-on SSB and OD-SSB?) of Obj.1:

- RAN1 understands the time location of OD-SSB in Q2 refers to the time location of possible OD-SSB burst
- RAN1 is still discussing the relation in terms of time location between always-on SSB and OD-SSB

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

RAN1#118bis Agreements

Agreement

For a cell supporting on-demand SSB SCell operation, deactivation of on-demand SSB transmission is supported. In order to deactivate on-demand SSB transmission from a UE perspective, support at least one of the following options.

- Option 1: Explicit indication of deactivation for on-demand SSB via MAC-CE for on-demand SSB transmission indication
- Option 1A: Explicit indication of deactivation for on-demand SSB via RRC for on-demand SSB transmission indication
- Option 2: Configuration/indication of the number N of on-demand SSB bursts to be transmitted after on-demand SSB is indicated
- Option 3: Configuration/indication of the duration of on-demand SSB transmission window
- Option 4: On-demand SSB transmission, if any, is deactivated when UE receives SCell deactivation MAC-CE for the activated SCell
- Option 4A: On-demand SSB transmission, if any, is deactivated when the timer for SCell deactivation is expired
- Option 5: On-demand SSB transmission, if any, is deactivated when SCell activation is completed
- Option 6: Explicit indication of deactivation for on-demand SSB via [group-common] DCI
- FFS: Each option is applicable to which Cases or Scenarios
- FFS: Details related to each of the above options

Agreement

For a cell supporting on-demand SSB SCell operation, support to provide at least the following parameters for on-demand SSB configuration by RRC at least for Case #1.

- Sub-carrier spacing of the on-demand SSB
  - FFS if this can be absent
- Physical Cell ID of the on-demand SSB
- FFS: Time domain location of on-demand SSB burst such as SFN offset and half frame index
- Downlink transmit power of on-demand SSB
- FFS: The number N of on-demand SSB bursts to be transmitted after on-demand SSB is indicated

- FFS whether the above parameters are configured by reusing legacy RRC parameters or new RRC parameters

Agreement

For a cell supporting on-demand SSB SCell operation and for Case #2 (i.e., Always-on SSB is periodically transmitted on the cell), consider only one or both of the following options for UE to perform L1 measurement based on on-demand SSB.

- Option 1: A CSI report configuration is associated with both of on-demand SSB and always-on SSB
- Option 2: A CSI report configuration is associated with one of always-on SSB and on-demand SSB
- FFS: Whether OD-SSB and always on SSB have same beam or not

Conclusion

No consensus on the support of on-demand SSB SCell operation triggered by UE.

Agreement

The previous RAN1 agreement is partly confirmed and further revised as follows.

- For SSB burst(s) indicated by on-demand SSB SCell operation via a MAC CE, UE expects that on-demand SSB ~~burst(s)~~ is transmitted from time instance A which is determined as follows.
  - Alt 3-1: Time instance A is the beginning of the first slot containing ~~[candidate SSB index 0 or~~ the first actually transmitted SSB index~~]~~ ~~of~~within the first "possible" on-demand SSB burst which is at least T slots after the slot where UE receives a signalling from gNB to indicate on-demand SSB transmission
    - The SSB time domain positions of on-demand SSB burst are configured by gNB.
      - The location(s) (e.g., SFN offset, half frame index) in the time domain of "possible" on-demand SSB burst and SSB position within the burst should be configured by the gNB
  - Note: The value of T is not less than existing timeline required for UE's MAC CE processing for SCell activation
  - (Working assumption): T is not less than T_min=$m + 3N_{slot}^{subframe,\mu}$+1 where slot n+m is a slot indicated for PUCCH transmission with HARQ-QCK information when the UE receives MAC CE signaling to indicate on-demand SSB transmission ending in slot n, and $N_{slot}^{subframe,\mu}$ is as defined in current specification.
    - RAN4 to confirm that T_min can be equal to $m + 3N_{slot}^{subframe,\mu}$+1
  - (Working assumption) T=T_min
- Above applies at least for the case where SCell with on demand SSB transmission and cell with signalling transmission have the same numerology.

Agreement

For a cell supporting on-demand SSB SCell operation and for Case #2 (i.e., Always-on SSB is periodically transmitted on the cell), study at least the following Mux-Cases.

- Mux-Case #1: No time-domain overlap between always-on SSB and on-demand SSB
- Mux-Case #2: Always-on SSB and on-demand SSB overlap at least in time or frequency domain

RAN1#118 Agreements

Agreement

- Update the previous RAN1 agreement as follows.
  - At least support L1 measurement based on on-demand SSB
    - For L1 measurement based on on-demand SSB, periodic, semi-persistent, ~~[~~and aperiodic~~]~~ L1 measurement reports based on existing CSI framework are supported.

- FFS on potential enhancements of CSI report configuration and/or triggering/activation mechanisms for L1 measurement based on on-demand SSB
- The support of LTM is a separate discussion point

Agreement

For a cell supporting on-demand SSB SCell operation,

- Support RRC based signaling to indicate on-demand SSB transmission on the cell at least for the case where this RRC also configures the SCell, activates the SCell, and provides on-demand SSB configuration.
  - FFS: Whether to support RRC based signaling for other cases.
- Support MAC CE based signaling to indicate on-demand SSB transmission on the cell for Scenarios #2 and #2A.

Note: Deactivation and adaptation of on-demand SSB transmission can be separately discussed.

Agreement

For a cell supporting on-demand SSB SCell operation, at least for the following parameter(s), multiple candidate values can be configured by RRC and the applicable value can be indicated by MAC CE for on-demand SSB transmission indication for the cell.

- Periodicity of the on-demand SSB
- FFS: Any other relevant parameters

Agreement

For a cell supporting on-demand SSB SCell operation, at least the following is supported

- On-demand SSB on the cell is not located on synchronization raster.
- On-demand SSB on the cell is non-cell-defining SSB

FFS: Additional support of OD-SSB for CD-SSB located on sync-raster

Agreement

Support L3 measurement based on on-demand SSB

- Further work on L3 measurement is up to RAN2/RAN4

Agreement

LS to RAN2 for on-demand SSB SCell operation is agreed. Final LS in R1-2407438.

Agreement

The previous RAN1 agreement made in RAN1#117 is revised as follows.

- For SSB burst(s) indicated by on-demand SSB SCell operation via MAC CE, UE expects that on-demand SSB burst(s) is transmitted from time instance A which is determined as follows.
  - Alt 3-1: Time instance A is the beginning of the first slot containing [candidate SSB index 0 or the first actually transmitted SSB index] of on-demand SSB burst ~~[the slot boundary of] the first SSB time domain position [of actually transmitted on-demand SSB burst]~~ which is at least T ~~[~~slots ~~or symbols]~~ after the ~~[~~slot ~~or symbol]~~ where UE receives a signalling from gNB to indicate on-demand SSB transmission
    - The SSB time domain positions of on-demand SSB burst are configured by gNB.
  - ~~FFS: Details of the value of T (≥ 0) including possibility of T comprising of multiple components~~
  - Note: The value of T is not less than existing timeline required for UE's MAC CE processing for SCell activation
  - (Working assumption): T is not less than T_min=$m + 3N_{slot}^{subframe,\mu}$+1 where slot n+m is a slot indicated for PUCCH transmission with HARQ-QCK information when the UE receives MAC CE signaling to indicate on-demand SSB transmission ending in slot n, and $N_{slot}^{subframe,\mu}$ is as defined in current specification.
    - RAN4 to confirm that T_min can be equal to $m + 3N_{slot}^{subframe,\mu}$+1
  - ~~FFS: Whether the value of T is predefined or indicated/configured by gNB~~
  - (Working assumption) T=T_min

- ~~FFS: Details of "the [slot or symbol] where UE receives a signalling from gNB" or "the [slot or symbol] where UE transmits HARQ-ACK corresponding to a signalling from gNB to trigger on-demand SSB"~~
- Above applies at least for the case where SCell with on demand SSB transmission and cell with signalling transmission have the same numerology.

Agreement

LS on timeline for On-demand SSB operation on SCell is agreed in R1-2407565.

RAN1#117 Agreements

Agreement

- For a cell supporting on-demand SSB SCell operation,
  - Support RRC based signaling to indicate on-demand SSB transmission on the cell.
  - Support MAC CE based signaling to indicate on-demand SSB transmission on the cell.
  - FFS: Whether to support DCI based signaling to indicate on-demand SSB transmission on the cell.
    - This DCI signaling does not provide SCell activation/deactivation.
    - If supported, details on DCI including UE-specific or group-common DCI, DCI contents, etc.
  - FFS: Scenarios where the above signalings are applicable

Agreement

- For a cell supporting on-demand SSB SCell operation, at least the following for on-demand SSB via higher layer RRC signaling is supported.
  - Frequency of the on-demand SSB
  - SSB positions within an on-demand SSB burst by using signaling similar to *ssb-PositionsInBurst*
  - Periodicity of the on-demand SSB
  - FFS: Whether more than one on-demand SSB configurations can be configured for the cell to UE
  - FFS: Whether the RRC is newly introduced or existing RRC is reused

Agreement

- At least support L1 measurement based on on-demand SSB
  - For L1 measurement based on on-demand SSB, periodic, semi-persistent, [and aperiodic] L1 measurement reports based on existing CSI framework are supported.
    - FFS on potential enhancements of CSI report configuration and/or triggering/activation mechanisms for L1 measurement based on on-demand SSB

Agreement

For SSB burst(s) indicated by on-demand SSB SCell operation via MAC CE, UE expects that on-demand SSB burst(s) is transmitted from time instance A which is determined as follows.

- Alt 3-1: Time instance A is [the slot boundary of] the first SSB time domain position [of actually transmitted on-demand SSB burst] which is T [slots or symbols] after the [slot or symbol] where UE receives a signalling from gNB to indicate on-demand SSB transmission
  - The SSB time domain positions of on-demand SSB burst are configured by gNB.
- FFS: Details of the value of T (≥ 0) including possibility of T comprising of multiple components
- Note: The value of T is not less than existing timeline required for UE's MAC CE processing for SCell activation
- FFS: Whether the value of T is predefined or indicated/configured by gNB
- FFS: Details of "the [slot or symbol] where UE receives a signalling from gNB" or "the [slot or symbol] where UE transmits HARQ-ACK corresponding to a signalling from gNB to trigger on-demand SSB"

Above applies at least for the case where SCell with on demand SSB transmission and cell with signalling transmission have the same numerology.

Agreement

- For a cell supporting on-demand SSB SCell operation, at least the followings for on-demand SSB are known to UE.
  - Sub-carrier spacing of the on-demand SSB
  - Physical Cell ID of the on-demand SSB
  - Location of on-demand SSB burst
  - Downlink transmit power of on-demand SSB
  - FFS: Other parameters
  - FFS: Whether each of above parameters is configured/indicated explicitly or not

RAN1#116bis Agreements

Agreement

For the identified scenarios and cases (as per RAN1#116 agreement), on-demand SSB can be triggered by gNB at least for the following scenarios/cases:

- Scenario #2 and Case #1
- Scenario #2 and Case #2
- Scenario #2A and Case #1
- Scenario #2A and Case #2
- FFS: Scenario #3A and Case #1
- FFS: Scenario #3A and Case #2
- FFS: Scenario #3B and Case #1
- FFS: Scenario #3B and Case #2
- For Case #1, once on-demand SSB is triggered, its transmission is in a periodic manner.
  - Note: This does not imply periodic on-demand SSB is transmitted indefinitely after triggered.
- Notes:
  - Scenario #2A refers to
    - "When UE receives SCell activation command (e.g., as defined in TS 38.321)"
  - Scenario #3A refers to
    - "After UE receives SCell activation command (e.g., as defined in TS 38.321) until SCell activation is completed"
  - Scenario #3B refers to
    - "When SCell activation is completed and SCell is activated" or
    - "After SCell activation is completed and SCell is activated"
  - For discussion purpose under AI 9.5.1, always-on SSB is SSB supported in Rel-18 specifications. Timing for on-demand SSB transmission (e.g. when the triggered SSB starts and ends) will be separately discussed.

Agreement

- For a cell supporting on-demand SSB SCell operation,
  - Note: It is up to gNB implementation whether always-on SSB (if transmitted) on the cell is cell-defining SSB or not.
  - For on-demand SSB on the cell, downselect between the following alternatives
    - Alt-1: It is up to gNB implementation whether on-demand SSB is cell-defining SSB or not.
    - Alt-2: On-demand SSB is limited to non-cell-defining SSB.
      - FFS: Further limitations to on-demand SSB

Agreement

- For a cell supporting on-demand SSB SCell operation,
  - L1 and/or L3 measurement based on on-demand SSB is supported for the cell.
    - FFS further details on L1 and/or L3 measurement

Agreement

The following agreement from RAN1#116 is modified (in red)

- For SSB burst(s) ~~triggered~~indicated by on-demand SSB SCell operation, study at least the following options.
  - Option 1: UE expects that on-demand SSB burst(s) is periodically transmitted from time instance A.
  - Option 1A: UE expects that on-demand SSB burst(s) is periodically transmitted from time instance A until gNB turns OFF the on demand SSB
  - Option 2: UE expects that on-demand SSB burst(s) is transmitted from time instance A to time instance B and not transmitted after time instance B.
  - Option 3: UE expects that on-demand SSB burst(s) is transmitted N times after time instance A and not transmitted after N on-demand SSB bursts are transmitted.
  - Option 4: UE expects that on-demand SSB burst(s) is transmitted with a periodicity from time instance A to time instance B and with the other periodicity after time instance B.
  - FFS: The combination of above options
  - FFS: How to define time instance A/B and the value of N per option
  - FFS: Each option is applicable to which Cases or Scenarios (as per the previous agreement)

Agreement

For a cell supporting on-demand SSB SCell operation, further study the following options.

- Option 1: Separate signaling between legacy/existing signaling (e.g., RRC, MAC CE) providing SCell activation/deactivation and signaling providing On-demand SSB transmission indication.
- Option 2: A single signaling in which both SCell activation/deactivation and On-demand SSB transmission indication are provided.
  - FFS: Details of the signaling
- Other options are not precluded.
- FFS: Details on On-demand SSB transmission indication

RAN1#116 Agreements

Agreement

Regarding the UE assumption on SSB transmission on a cell supporting on-demand SSB SCell operation, the following cases are identified for further study:

- Case #1: No always-on SSB on the cell
- Case #2: Always-on SSB is periodically transmitted on the cell
- FFS: Whether always-on SSB and on-demand SSB are not cell-defining SSB if transmitted.

FFS: Which scenario the above applies for

Agreement

RAN1 to strive for a common design for on-demand SSB operation considering all applicable CA configurations.

Agreement

For the following identified scenarios for on-demand SSB SCell operation, focus future RAN1 discussion to down-select (both may be selected) between the two scenarios.

- Scenario #2: SCell is configured to a UE but before the UE receives SCell activation command (e.g., as defined in TS 38.321)
- Scenario #3: After UE receives SCell activation command (e.g., as defined in TS 38.321)
  - This does not preclude SCell for which activation is completed
  - FFS: The case where SCell activation is completed

FFS: Application timing between NW triggering message and on demand SSB transmission

Agreement

Support on-demand SSB SCell operation triggered by gNB.

- FFS Details of associated signaling/indication/configuration provided to UE

Agreement

- For SSB burst(s) triggered by on-demand SSB SCell operation, study at least the following options.
  - Option 1: UE expects that on-demand SSB burst(s) is periodically transmitted from time instance A.
  - Option 1A: UE expects that on-demand SSB burst(s) is periodically transmitted from time instance A until gNB turns OFF the on demand SSB
  - Option 2: UE expects that on-demand SSB burst(s) is transmitted from time instance A to time instance B and not transmitted after time instance B.
  - Option 3: UE expects that on-demand SSB burst(s) is transmitted N times after time instance A and not transmitted after N on-demand SSB bursts are transmitted.
  - Option 4: UE expects that on-demand SSB burst(s) is transmitted with a periodicity from time instance A to time instance B and with the other periodicity after time instance B.
  - FFS: The combination of above options
  - FFS: How to define time instance A/B and the value of N per option
  - FFS: Each option is applicable to which Cases or Scenarios (as per the previous agreement)

5 References

[1] RP-242354, Revised WID: Enhancements of network energy savings for NR, Sep 2024

[2] Chair notes, RAN1#119, Nov 2024

[3] Chair notes, RAN1#118bis, Oct 2024

[4] Chair notes, RAN1#118, Aug 2024

[5] Chair notes, RAN1#117, May 2024

[6] Chair notes, RAN1#116bis, April 2024

[7] 3GPP TR 38.864, Study on network energy savings for NR (Release 18), V18.1.0, Mar 2023

[8] 3GPP TS 38.213, Physical layer procedures for control (Release 18), V18.1.0, Dec 2023