3GPP TSG RAN WG1 #120 **R1-2500228**
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Source: **CATT**
Title: **Discussion on on-demand SSB SCell operation**
Agenda Item: **9.5.1**
Document for: **Discussion and Decision**

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1 Introduction

In RAN1#119 meeting, several agreements were achieved related to on-demand SSB SCell operation [1].

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

This contribution discusses on-demand SSB SCell operation. Section 2 discusses the scenarios and cases of on-demand SSB SCell operation. Section 3 discusses signalling methods for on-demand SSB TX indication. Section 4 discusses contents of on-demand SSB configuration/indication. Section 5 discusses TX behavior of on-demand SSB burst. Section 6 discusses L1 measurement based on on-demand SSB. Section 7 discusses SSB multiplexing. Section 8 discusses further details of on-demand SSB operation. Finally, section 9 summarizes the observation and proposals with conclusions.

2 General aspects

2.1 Scenarios and Cases

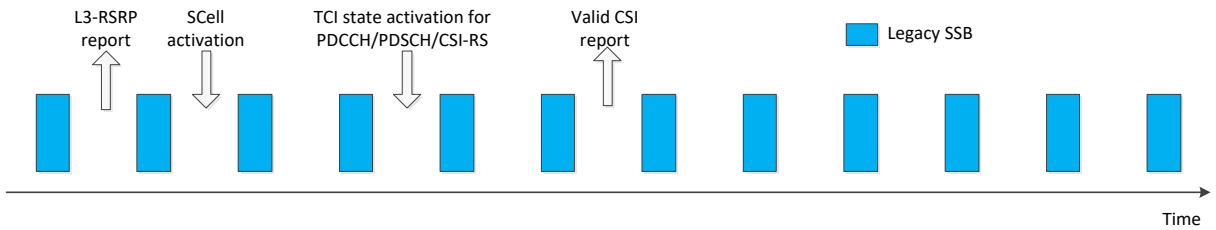
In RAN1#116-bis meeting, one agreement was achieved related to the scenarios and cases of on-demand SSB SCell operation [4].

Agreement

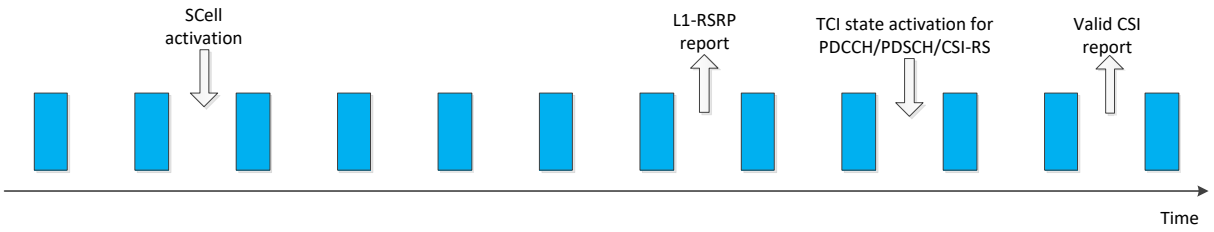
For the identified scenarios and cases (as per RAN1#116 agreement), on-demand SSB can be triggered by gNB at least for the following scenarios/cases:

- 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.

Before going to the discussion of use cases and scenarios, we need to first investigate the role of SSB during legacy SCell activation. Figure 1 shows the procedure of current SCell activation for both known SCell case and unknown SCell case. According to [5], SCell activation completes after UE reports a valid CSI. If L3-RSRP has been reported before SCell activation command within a certain period, gNB would acquire UE's measurement result in advance. When UE receives SCell activation command, it is feasible for gNB to quickly determine the TCI state used for further data transmission. Such SCell is defined as known SCell, which is shown in Figure 1 (a). In this case, after receiving SCell activation command, UE would use SSB for fine time tracking. On the other hand, if there is no L3-RSRP report before SCell activation, the SCell is regarded as unknown SCell, as shown in Figure 1 (b). After SCell activation command, UE has to perform AGC, synchronization and L1 measurement/report based on SSB. Then gNB actives TCI state for data transmission according to UE's report. Therefore, larger activation delay is required for the unknown SCell.



(a) Known SCell



(b) Unknown SCell

Figure 1: Procedure of current SCell activation

Observation 1: In the current system, after UE receives SCell activation command, for a known SCell, UE acquires SSB for fine time tracking. For an unknown SCell, UE acquires SSB to perform AGC, synchronization and L1 measurement report.

According to the above 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

And the following combinations of scenarios/cases should be further studied:

- FFS: Scenario #3A and Case #1
- FFS: Scenario #3A and Case #2
- FFS: Scenario #3B and Case #1
- FFS: Scenario #3B and Case #2

According to the agreement above, the definitions of scenario #3A and scenario #3B are listed as follows:

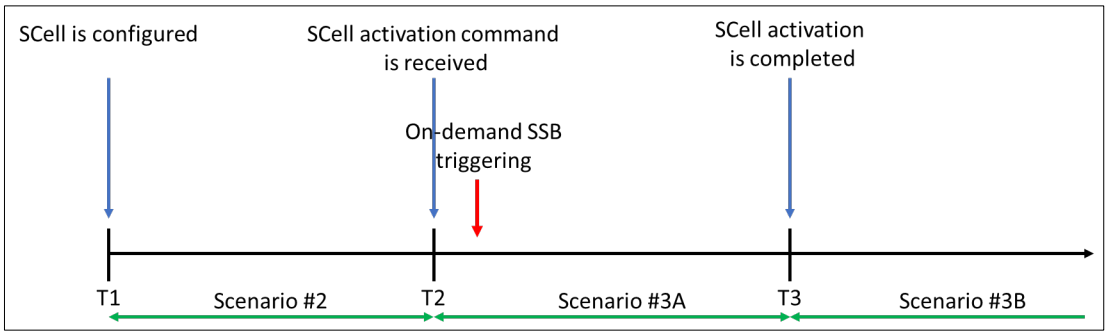
- Scenario #3A refers to
  - "After UE receives SCell activation command (e.g., as defined in TS 38.321) until SCell activation is completed"
- Scenario #3B refers to
  - "When SCell activation is completed and SCell is activated" or
  - "After SCell activation is completed and SCell is activated"

According to the agreement in RAN1#116, the definitions of case #1 and case #2 are listed as follows:

- Case #1: There is no always-on SSB on the cell.
- Case #2: Always-on SSB is periodically transmitted on the cell.

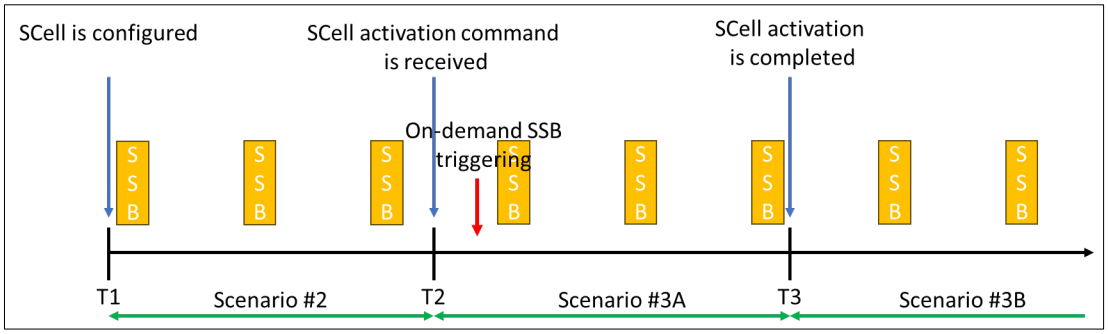
The combinations of scenario #3A/3B and case #1/2 are shown in the following Figure 2:

- Scenario #3A and Case #1:



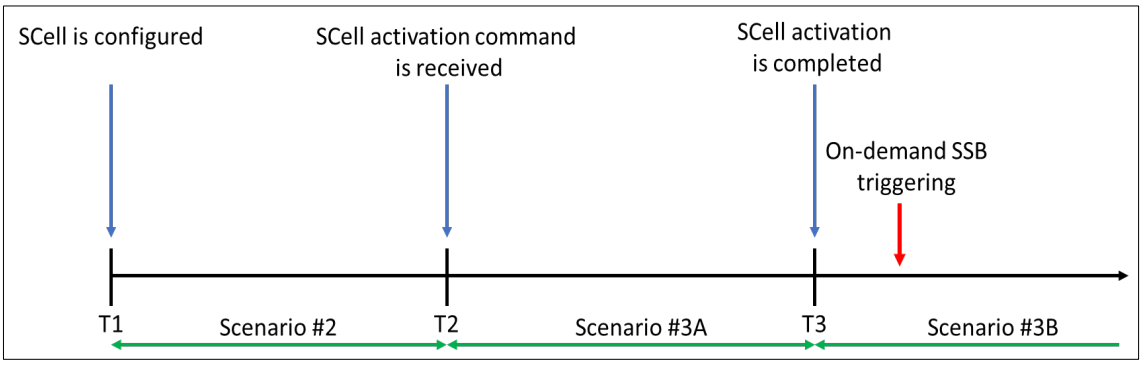
(a) Scenario #3A and Case #1

- Scenario #3A and Case #2:



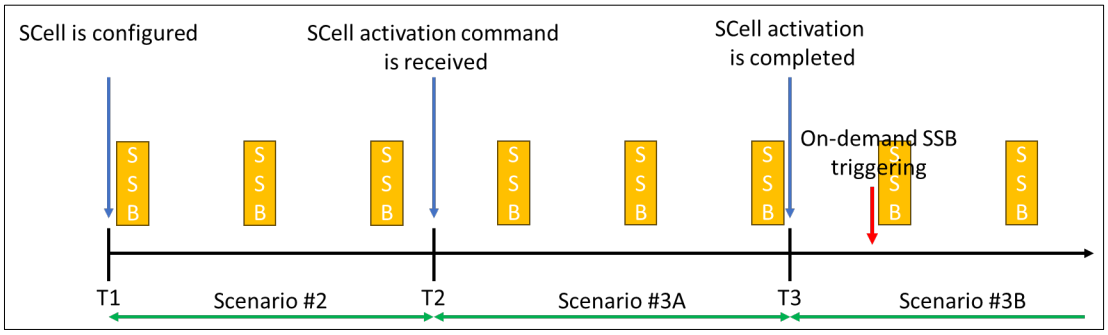
(b) Scenario #3A and Case #2

- Scenario #3B and Case #1:



(c) Scenario #3B and Case #1

- Scenario #3B and Case #2:



(d) Scenario #3B and Case #2

Figure 2: Combinations of scenario #3A/3B and case #1/2

For case#1, as mentioned above, on-demand SSB is naturally required after SCell activation command for AGC, synchronization and L1 measurement. Further, when SCell activation is completed, on-demand SSB is still needed to execute beam recovery in case of beam failure and maintain synchronization for data transmission unless the SCell is deactivated. Hence, the combinations of Scenario #3A/3B and Case #1 should be supported, which are shown in Figure 2 (a) and (c).

For case#2, UE is feasible to report L3-RSRP based on the always-on SSB before SCell activation command. If so, the SCell is a known SCell. But the always-on SSB may be too sparse to perform SCell activation and corresponding procedures. For less activation delay, on-demand SSB is needed after SCell activation command for quick fine time tracking. When SCell activation is completed, if always-on SSB configured is sparse, it may be not sufficient to maintain synchronization for data transmission. Hence, the combination of Scenario #3A/3B and Case #2 should be supported, which is shown in Figure 2 (b) and (d).

Proposal 1: For the identified scenarios and cases (as per RAN1#116 and RAN1#116-bis agreements), on-demand SSB can be triggered by gNB for the following scenarios/cases:

- **Scenario #3A and Case #1**
- **Scenario #3A and Case #2**
- **Scenario #3B and Case #1**

- **Scenario #3B and Case #2**

In RAN2#127 meeting, the following agreements on RRC and MAC-CE indication were agreed [8]:

Agreements on OD-SSB

OD-SSB transmission indication:

1. RRC based OD-SSB transmission indication is used to indicate at least the initial activation/deactivation state of OD-SSB configuration. FFS on reconfiguration.

2. New MAC-CE for OD-SSB transmission indication is introduced. We will not change legacy SCell activation/deactivation MAC CE. FFS if we need further optimization for scenario 2A.

In RAN2#127-bis meeting, the following agreements on RRC and MAC-CE indication were agreed [9]:

Agreements on OD-SSB SCell

1. No need to restrict the OD-SSB activation/deactivation state indication in RRC to initial configuration. No special specification effort is required.

2. Don't introduce further new MAC CE that combines SCell activation/deactivation and OD-SSB indication for scenario 2A.

3. NW should be able to send OD-SSB indication for multiple SCells simultaneously by a MAC CE.

According to the above RAN2 agreements, a new MAC CE for OD-SSB transmission indication is introduced and there is no change on legacy SCell activation/deactivation MAC CE. Since the new MAC CE for OD-SSB transmission indication and the legacy MAC CE for SCell activation/deactivation are two independent MAC CEs, the gNB can trigger OD-SSB when needed via the new MAC CE, irrespective of the timing relationship with SCell activation/deactivation. Therefore, all scenarios and cases, including scenario #3A/3B and Case #1/2, can be supported, there is no need to limit the triggering timing of OD-SSB. It is up to gNB implementation when OD-SSB is triggered, irrespective of the timing relationship with SCell activation/deactivation.

Observation 2: Since the new MAC CE for OD-SSB transmission indication and the legacy MAC CE for SCell activation/deactivation are two independent MAC CEs, the gNB can trigger OD-SSB when needed via the new MAC CE, irrespective of the timing relationship with SCell activation/deactivation.

Proposal 2: It is up to gNB implementation when OD-SSB is triggered, irrespective of the timing relationship with SCell activation/deactivation.

In addition, RAN2 don't introduce further new MAC CE that combines SCell activation/deactivation and OD-SSB indication for scenario #2A. Scenario #2A refers to "When UE receives SCell activation command (e.g., as defined in TS 38.321)", i.e., when UE receives SCell activation command, on-demand SSB is triggered by gNB. Therefore, In order to support scenario #2A, the new MAC CE for OD-SSB transmission indication and legacy MAC CE for SCell activation/deactivation can be sent together in one PDSCH.

Observation 3: In order to support scenario 2A, the new MAC CE for OD-SSB transmission indication and the legacy MAC CE for SCell activation/deactivation can be sent together in one PDSCH.

2.2 Whether on-demand SSB is CD-SSB or not

Whether support OD-SSB for CD-SSB located on sync-raster

In RAN1#118 meeting, one agreement was achieved related to whether on-demand SSB is CD-SSB or not [3].

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

According to the above agreement, for a cell supporting OD-SSB SCell operation, OD-SSB on the cell is not located on synchronization raster, or OD-SSB on the cell is non-cell-defining SSB. Regarding the issue of whether OD-SSB can be CD-SSB located on sync-raster, since OD-SSB cannot be used by both legacy UE and Rel-19 UE for initial access, it is not clear why gNB configures OD-SSB as CD-SSB located on sync-raster. As the motivation of supporting of OD-SSB for CD-SSB located on sync-raster is not clear, it is preferred to deprioritize the discussion of additional support of OD-SSB for CD-SSB located on sync-raster in Rel-19.

Observation 4: The motivation of supporting OD-SSB for CD-SSB located on sync-raster is not clear.

Proposal 3: Deprioritize the discussion of additional support of OD-SSB for CD-SSB located on sync-raster in Rel-19.

Frequency location of OD-SSB for the case where always-on SSB is CD-SSB

In RAN1#119 meeting, the following agreements were achieved related to frequency location of OD-SSB [1].

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
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.

In RAN1#119, it had been agreed that 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.

For the case where AO-SSB (i.e., always-on SSB) is CD-SSB, firstly, if AO-SSB is CD-SSB, it can be configured on a synchronization raster, or can be configured not on a synchronization raster. If the AO-SSB is CD-SSB on a synchronization raster, it can be used by an idle UE for initial access, so that the UE will treat the SCell as its PCell. If the AO-SSB is a CD-SSB and not a on a synchronization raster, and if the frequency location of OD-SSB is the same as the frequency location of AO-SSB, then the OD-SSB is also not on a synchronization raster. Thus, legacy UE will not use the OD-SSB which is not on a synchronization raster for initial access.

Secondly, If AO-SSB is CD-SSB on a synchronization raster, the frequency location of OD-SSB should be different from the frequency location of AO-SSB, so that legacy UE will not use the OD-SSB for initial access, thus the impact of OD-SSB on legacy UE can be avoided.

Thirdly, If AO-SSB is CD-SSB and not on a synchronization raster, the frequency location of OD-SSB should be the same or different from the frequency location of AO-SSB, subject to its configuration. If AO-SSB is CD-SSB and not on a synchronization raster, the frequency location of OD-SSB can be the same as the frequency location of AO-SSB, as it is beneficial for the UE to use both AO-SSB and OD-SSB on the same frequency location for L1/L3 measurement. On the other hand, the frequency location of OD-SSB may be configured to be different from the frequency location of AO-SSB, so that the UE can acquire the measurement results on different frequency locations or obtain diversity gain of measurements from the SSBs on different frequency locations.

Proposal 4: The following Alt 1 and Alt A in the agreement in RAN1#119 should be supported.

- **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 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.**

3 Signalling methods for on-demand SSB TX indication

In Rel-19 NES, RRC and MAC-CE have both been supported for on-demand SSB TX indication. If on-demand SSB is activated for a SCell, it should be informed as soon as possible to all the UEs sharing this SCell. UEs may use this SSB for RRM measurement, SCell activation and so on. Compared with the UE-specific RRC or MAC-CE based signaling, group-common DCI based signalling seems more suitable and more efficient to indicate on-demand SSB transmission. Moreover, as discussed in AI 9.5.3, to support SSB adaptation for SCells, a relative dynamic signaling is also preferred to adjust the periodicity of the always-on SSB. Consequently, a unified group-common DCI could be designed to indicate either on-demand SSB transmission or SSB adaptation.

Proposal 5: A unified group-common DCI could be designed to indicate on-demand SSB transmission.

The termination of on-demand SSB should be known by the UE to avoid blind SSB detection. In the last meeting, both explicit indication (Option 1) and pre-configuration (Option 2) deactivation schemes have been agreed. In our opinion, explicit indication of deactivation for on-demand SSB via MAC-CE is flexible and could be used whenever needed. Since the transmission of on-demand SSB may be continuous during Scenario 2/2A/3A/3B, deactivation MAC-CE should be applied to all these scenarios. In addition, in the case of pre-configuration, i.e. configuration/indication of the number N of on-demand SSB bursts to be transmitted after on-demand SSB is indicated, such deactivation MAC-CE could also terminate the N times on-demand SSB bursts transmission.

Proposal 6: Deactivation for on-demand SSB via MAC-CE can be applied to Scenario 2/2A/3A/3B.

Proposal 7: Deactivation for on-demand SSB via MAC-CE could also be applied to Option 2 (Configuration/indication of the number N of on-demand SSB bursts to be transmitted after on-demand SSB is indicated).

Pre-configuration scheme is beneficial to save signaling overhead, which would be applied to the scenarios where the duration of SSB transmission requirement could be predicted, e.g. semi-persistent report and aperiodic report based on on-demand SSB for either Case#1 (SCell without always-on SSB) or Case#2 (SCell with always-on SSB). As a RRC parameter, the value of N is preferred to be configured explicitly. However, SCell deactivation is not feasible to be predicted. From the energy saving perspective, when SCell is deactivated, it is intuitive to deactivate on-demand SSB simultaneously. Therefore, as a supplementary scheme, implicit indication (Option 4/4A), i.e. terminate on-demand SSB transmission when SCell deactivation happens, should also be supported.

Proposal 8: For Option 2, the value of N is preferred to be configured explicitly.

Proposal 9: In addition to Option 2, support the following options:

- **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.**

4 Contents of on-demand SSB configuration/indication

Considering the requirements of different deployment scenarios (e.g. L1/L3 measurements, SCell activation), multiple sets of on-demand SSB configurations are preferred to be available for a cell. In the RAN1#118 meeting, multiple candidate values for periodicity were agreed to be configured via RRC. In addition, the TX behavior of on-demand SSB may differ between L1/L3 measurements and SCell activation. For example, during L1/L3 measurements, a relatively long duration of on-demand SSB transmission is required to obtain stable channel quality. And SSB would be transmitted in beam sweeping mode to determine all possible UE positions. However, for SCell activation, a relatively short during of on-demand SSB transmission would be preferred to

reduce latency, and SSB may be transmitted in specific directions based on the knowledge of UE positions. Therefore, besides periodicity, multiple candidate values can also be configured by RRC for the following parameters:

- The number N of SSB bursts that will be transmitted.
- SSB positions within an on-demand SSB burst.

Proposal 10: More than one on-demand SSB configurations can be configured for the cell to UE.

Proposal 11: Besides periodicity, for the following parameters, multiple candidate values can also be configured by RRC and the applicable value is indicated by MAC-CE:

- **The number N of SSB bursts that will be transmitted.**
- **SSB positions within an on-demand SSB burst.**

For Case#2, some parameters should share the same value as that of always-on SSB, e.g. SCS, physical Cell ID and transmit power. These parameters could be omitted in on-demand SSB configuration. The other parameters should be configured as those of Case#1 for flexibility.

Proposal 12: For a cell supporting on-demand SSB SCell operation and for Case #2, UE assumes the followings for on-demand SSB are the same as for always-on SSB, unless explicitly configured.

- **Sub-carrier spacing**
- **Physical Cell ID**
- **Downlink transmit power**

In the last meeting, the time domain information of on-demand SSB has been agreed to be configured by RRC explicitly. For Case#1, two parameters, which include SFN offset and half frame index, would be used. In our opinion, it is not necessary to introduce another configuration scheme for Case#2, which would increase the spec complexity.

Proposal 13: The time domain location configuration of on-demand SSB for Case #1 is also applied for Case #2.

5 TX behavior of on-demand SSB burst

In RAN1#118bis meeting, the following agreement related to time instance A for MAC-CE was achieved [2]:

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.

As a working assumption, T is no less than T_min=$m + 3N_{slot}^{subframe,\mu}$+1, which includes HARQ-ACK timing. Since time instance A is located after T, it already provides flexibility for gNB to indicate on-demand SSB

transmission for each UE. Therefore, it is not necessary to employ multiple candidate T values. No matter the value of T_min specified, T=T_min is adequate for MAC-CE indication.

Proposal 14: Considering time instance A for MAC-CE, confirm the working assumption T=T_min.

Similar to the determination of time instance A for MAC-CE based signaling, time instance A_RRC for RRC based signaling could be determined with time offset T_RRC, where T_RRC should be dependent on the RRC procedure delay. Considering the possibility of RRC retransmission, the reference point of T_RRC should be the last slot where UE successfully receives PDSCH containing the RRC message from gNB to indicate on-demand SSB transmission.

Proposal 15: For SSB burst(s) indicated by on-demand SSB SCell operation via a RRC, UE expects that on-demand SSB is transmitted from time instance A_RRC which is determined as follows.

- **Time instance A_RRC is the beginning of the first slot containing the first actually transmitted SSB index within the first "possible" on-demand SSB burst which is at least T_RRC slots after the last slot where UE receives PDSCH containing the RRC message from gNB to indicate on-demand SSB transmission.**
- **T_RRC should be dependent on the RRC procedure delay.**

6 L1 measurement based on on-demand SSB

In RAN1#118 meeting, one agreement was achieved related to L1 measurement based on on-demand SSB [3].

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

SS-RSRP, SS-RSRQ and SS-SINR measurement have been defined for SSB based measurement. SS-RSRP, SS-RSRQ measurements are used for cell selection, cell reselection, power control calculations, mobility procedures and beam management. SS-SINR measurements are be used for connected mode mobility procedures and beam management. These measurements can be generated and reported at both Layer 1 and Layer 3. For example, a UE can provide SS-RSRP measurements at Layer I when sending Channel State Information (CSI) to the gNB. Alternatively, the UE can provide SS-RSRP measurements at Layer 3 when sending an RRC. A UE is configured to report Layer l SS-RSRP if *reportQuantity* within *CSI-ReportConfig* is set to *ssb-Index-RSRP*. For SS-RSRQ, SS-SINR and layer 3 SS-RSRP measurements, SS/PBCH Block Measurement Timing Configuration (SMTC) configuration is used. Measurement and report based on on-demand SSB can reuse these legacy procedures.

For L1 measurement, according to the above agreement, the existing legacy CSI framework can be used to configure additional measurements. According to current CSI framework, each Reporting Setting (i.e., *CSI-ReportConfig*) is associated with a CSI Resource Setting (i.e., *CSI-ResourceConfig*) for channel measurement. If the CSI-RS Resources within the CSI Resource Setting are semi-persistent, the time domain behavior of the Reporting Setting can be aperiodic (using PUSCH) or semi-persistent (using PUCCH, and DCI activated PUSCH).

In legacy system, semi-persistent CSI-RS is activated by SP CSI-RS activation MAC-CE. When semi-persistent CSI on PUCCH is required, SP CSI reporting on PUCCH activation MAC-CE is used to activate the CSI report. When semi-persistent CSI on PUSCH is required, DCI scrambled by SP-CSI-RNTI would be used to trigger the CSI report. In addition, if aperiodic CSI is expected, the report is triggered by DCI with CSI request field. Such mechanism could be applied to L1 measurement based on on-demand SSB. As shown in Figure 3, on-demand SSB transmission on SCell is activated by on-demand SSB triggering signaling mentioned in section 3, and its associated L1 reporting setting configured in PCell is triggered by another L1 report triggering signalling. The

L1 report triggering signaling could be MAC-CE or DCI depending on whether the reported is carried by PUCCH or PUSCH.

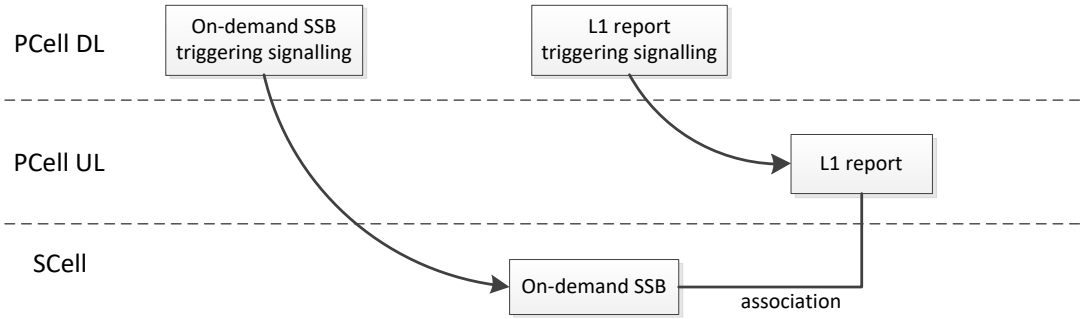


Figure 3: L1 measurement/report based on on-demand SSB

According to the above agreements, the support of LTM is a separate discussion point. However, a lot of details of on-demand SSB, including signalling methods for on-demand SSB TX indication, contents of on-demand SSB configuration/indication, TX behaviour of on-demand SSB burst and L1/L3 measurement based on on-demand SSB, are currently under discussion in RAN1 or other groups. Hence, it is not the right time to discuss LTM based on on-demand SSB right now. In addition, it seems that LTM based on on-demand SSB is out of scope of Rel-19 NES WID. Therefore, we propose to deprioritize the discussion of LTM based on on-demand SSB in Rel-19.

Proposal 16: Deprioritize the discussion of LTM based on on-demand SSB in Rel-19.

6.1 Enhancements on resource setting configuration

In this section, the enhancements on CSI resource configuration for on-demand SSB measurement are discussed. The issue on reusing the existing CSI framework to resource setting configuration based on on-demand SSB and related solution are provided.

Issue-1: How to add on-demand SSB resource configuration to existing CSI resource configuration?

Based on the existing CSI framework, the IE *CSI-ResourceConfig* in TS 38.331 gives the CSI resource configuration for CSI-RS resources and SSB resources [6]. The IE *CSI-ResourceConfig* defines a group of one or more *NZP-CSI-RS-ResourceSet*, *CSI-IM-ResourceSet* and/or *CSI-SSB-ResourceSet*. The *csi-SSB-ResourceSetList* is the list of references to SSB resources used for CSI measurement and reporting in a CSI-RS resource set.

However, the SSB resource in *CSI-SSB-ResourceSet* is legacy periodic SSB and the IE *CSI-ResourceConfig* does not support resource configuration of on-demand SSB. The issue of how to add on-demand SSB resource configuration to existing CSI resource configuration should be resolved.

***CSI-ResourceConfig* information element**

```
-- ASN1START
-- TAG-CSI-RESOURCECONFIG-START


CSI-ResourceConfig ::=      SEQUENCE {
    csi-ResourceConfigId        CSI-ResourceConfigId,
    csi-RS-ResourceSetList      CHOICE {
        nzp-CSI-RS-SSB              SEQUENCE {
            nzp-CSI-RS-ResourceSetList  SEQUENCE (SIZE (1..maxNrofNZP-CSI-RS-
ResourceSetsPerConfig)) OF NZP-CSI-RS-ResourceSetId

OPTIONAL, -- Need R
```

```
            csi-SSB-ResourceSetList     SEQUENCE (SIZE (1..maxNrofCSI-SSB-
ResourceSetsPerConfig)) OF CSI-SSB-ResourceSetId  OPTIONAL  -- Need R


      },
        csi-IM-ResourceSetList      SEQUENCE (SIZE (1..maxNrofCSI-IM-ResourceSetsPerConfig))
OF CSI-IM-ResourceSetId
    },

    bwp-Id                      BWP-Id,
    resourceType                ENUMERATED { aperiodic, semiPersistent, periodic },
    ...,
    [[
    csi-SSB-ResourceSetListExt-r17      CSI-SSB-ResourceSetId
OPTIONAL  -- Need R
    ]]
}


-- TAG-CSI-RESOURCECONFIG-STOP
-- ASN1STOP
```

Solutions to issue-1

In order to solve the issue-1 above, the existing CSI resource configuration should be enhanced. There are two solutions to add on-demand SSB resource configuration to existing CSI resource configuration.

The Alt-1 solution is that the existing IE *CSI-ResourceConfig* should include the on-demand SSB resource configuration information. The Alt-1 solution has less specification impact but it will change the contents of the existing IE *CSI-ResourceConfig.*

The Alt-2 solution is that a new dedicated resource configuration IE for on-demand SSB resource configuration should be introduced, e.g. *CSI-ResourceConfig-NES.* The Alt-2 solution will not change the contents of the existing IE *CSI-ResourceConfig* but it has more specification impact since a new IE will be introduced.

Proposal 17: Consider two candidate solutions to add on-demand SSB resource configuration to existing CSI resource configuration.

- **Alt-1: The existing IE *CSI-ResourceConfig* should include the on-demand SSB resource configuration information.**
- **Alt-2: A new dedicated resource configuration IE for on-demand SSB resource configuration should be introduced, e.g. *CSI-ResourceConfig-NES*.**

6.2 Enhancements on CSI reporting configuration

In this section, the enhancements on CSI reporting configuration for on-demand SSB measurement are discussed. The issue on reusing the existing CSI framework to CSI reporting configuration based on on-demand SSB and related solution are provided.

Issue-2: How to add on-demand SSB reporting configuration to existing CSI reporting configuration?

Based on the existing CSI framework, the IE *CSI-ReportConfig* in TS 38.331 gives the CSI reporting configuration for the periodic, semi-persistent and aperiodic L1 measurement reports [6]. The IE *CSI-ReportConfig* is used to configure a periodic or semi-persistent report sent on PUCCH on the cell in which the *CSI-ReportConfig* is included, or to configure a semi-persistent or aperiodic report sent on PUSCH triggered by DCI received on the cell in which the *CSI-ReportConfig* is included.

However, the reporting configuration in *CSI-ReportConfig* is designed for legacy periodic SSB and the IE *CSI-ReportConfig* does not support reporting configuration of on-demand SSB. The issue of how to add on-demand SSB reporting configuration to existing CSI reporting configuration should be resolved.

CSI-ReportConfig information element

```
-- ASN1START
-- TAG-CSI-REPORTCONFIG-START


CSI-ReportConfig ::=                SEQUENCE {
    reportConfigId                          CSI-ReportConfigId,
    carrier                                 ServCellIndex                   OPTIONAL,   --
Need S
    resourcesForChannelMeasurement          CSI-ResourceConfigId,
    csi-IM-ResourcesForInterference         CSI-ResourceConfigId            OPTIONAL,   --
Need R
    nzp-CSI-RS-ResourcesForInterference     CSI-ResourceConfigId            OPTIONAL,   --
Need R
    reportConfigType                        CHOICE {
        periodic                                SEQUENCE {
            reportSlotConfig                        CSI-ReportPeriodicityAndOffset,
            pucch-CSI-ResourceList                  SEQUENCE (SIZE (1..maxNrofBWPs)) OF PUCCH-
CSI-Resource
        },
        semiPersistentOnPUCCH                   SEQUENCE {
            reportSlotConfig                        CSI-ReportPeriodicityAndOffset,
            pucch-CSI-ResourceList                  SEQUENCE (SIZE (1..maxNrofBWPs)) OF PUCCH-
CSI-Resource
        },
        semiPersistentOnPUSCH                   SEQUENCE {
            reportSlotConfig                        ENUMERATED {sl5, sl10, sl20, sl40, sl80,
sl160, sl320},
            reportSlotOffsetList                SEQUENCE (SIZE (1.. maxNrofUL-Allocations)) OF
INTEGER(0..32),
            p0alpha                                 P0-PUSCH-AlphaSetId
        },
        aperiodic                               SEQUENCE {
            reportSlotOffsetList                SEQUENCE (SIZE (1..maxNrofUL-Allocations)) OF
INTEGER(0..32)
        }
    },
    reportQuantity                          CHOICE {
        none                                    NULL,
        cri-RI-PMI-CQI                          NULL,
        cri-RI-i1                               NULL,
        cri-RI-i1-CQI                           SEQUENCE {
            pdsch-BundleSizeForCSI                  ENUMERATED {n2, n4}
OPTIONAL    -- Need S
        },
        cri-RI-CQI                              NULL,
        cri-RSRP                                NULL,
        ssb-Index-RSRP                          NULL,
        cri-RI-LI-PMI-CQI                       NULL
    },
```

Solutions to issue-2

In order to solve the issue-2 above, the existing CSI reporting configuration should be enhanced. There are two solutions to add on-demand SSB reporting configuration to existing CSI reporting configuration.

The Alt-1 solution is that the existing IE *CSI-ReportConfig* should include the on-demand SSB reporting configuration information. The Alt-1 solution has less specification impact but it will change the contents of the existing IE *CSI-ReportConfig.*

The Alt-2 solution is that a new dedicated reporting configuration IE for on-demand SSB reporting configuration should be introduced, e.g. *CSI-ReportConfig-NES.* The Alt-2 solution will not change the contents of the existing IE *CSI-ReportConfig* but it has more specification impact since a new IE will be introduced.

Proposal 18: Consider two candidate solutions to add on-demand SSB reporting configuration to existing CSI reporting configuration.

- **Alt-1: The existing IE *CSI-ReportConfig* should include the on-demand SSB reporting configuration information.**
- **Alt-2: A new dedicated reporting configuration IE for on-demand SSB reporting configuration should be introduced, e.g. *CSI-ReportConfig-NES*.**

In RAN1#118-bis meeting, one agreement was achieved related to enhancements on CSI reporting configuration for on-demand SSB [2].

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

For a cell supporting OD-SSB SCell operation and for Case #2 (i.e., always-on SSB is periodically transmitted on the cell), if OD-SSB transmission is indicated, a UE can perform L1 measurement based on both of always-on SSB and OD-SSB. Otherwise, the UE performs L1 measurement based on always-on SSB. In order to reduce the reporting overhead, a CSI report configuration can be associated with both of OD-SSB and always-on SSB when the UE performs L1 measurement based on both of always-on SSB and OD-SSB, so the UE can report L1 measurement of both OD-SSB and always-on SSB in one CSI report. In addition, the UE may report L1 measurement based on one of always-on SSB and OD-SSB for Case #2, for example, the UE is configured to select the strongest beam from both always-on SSB and OD-SSB for reporting. In this case, the CSI report configuration is associated with one of always-on SSB and OD-SSB, and the UE will only report one of them. Based on the above discussion, for a cell supporting OD-SSB SCell operation and for Case #2, both the Option 1 and Option 2 should be supported for UE to perform L1 measurement based on OD-SSB.

Proposal 19: For a cell supporting OD-SSB SCell operation and for Case #2, both the following options should be supported for UE to perform L1 measurement based on OD-SSB:

- **Option 1: A CSI report configuration is associated with both of OD-SSB and always-on SSB.**
- **Option 2: A CSI report configuration is associated with one of always-on SSB and OD-SSB.**

In addition, for Case #1 (i.e., there is no always-on SSB on the cell), if OD-SSB transmission is indicated, UE can perform L1 measurement based on OD-SSB. In this case, the CSI report configuration associating with one of OD-SSB and always-on SSB can be reused to report L1 measurement of only OD-SSB for Case #1.

To reduce reporting overhead and standardization effort, one or both of always-on SSB and OD-SSB should be reported via a single *CSI-ReportConfig* IE instead of multiple *CSI-ReportConfig* IEs. In order to support both the two options in the agreement in RAN1#118-bis using a single *CSI-ReportConfig* IE, the reporting configuration for AO-SSB and OD-SSB in the *CSI-ReportConfig* IE should be optional.

Proposal 20: In order to support both the two options in the agreement in RAN1#118-bis using a single *CSI-ReportConfig* IE, the reporting configuration for AO-SSB and OD-SSB in the *CSI-ReportConfig* IE should be optional.

For Case #2, always-on SSB is like a background SSB and it can be used by all UEs in this SCell. So beam sweeping may be used when transmitting always-on SSB. However, OD-SSB may be used by particular UEs

and special beam(s) may be used. The gNB can determine the beam(s) of OD-SSB according to UE measurement reporting based on always-on SSB. Hence, OD-SSB and always-on SSB may have the same beam or different beams. It is up to gNB implementation whether OD-SSB and always-on SSB have same beam or not.

Proposal 21: It is up to gNB implementation whether OD-SSB and always-on SSB have same beam or not.

6.3 Enhancements on MAC CE activation for PUCCH-based semi-persistent reporting

In this section, the enhancements on MAC CE activation for PUCCH-based semi-persistent reporting for on-demand SSB measurement are discussed. The issue on reusing the existing CSI framework to PUCCH-based semi-persistent reporting based on on-demand SSB and related solution are provided.

Issue-3: How to support the activation and deactivation of semi-persistent L1 measurement reporting on PUCCH for on-demand SSB?

Based on the existing CSI framework as shown in the following Figure 4, the MAC CE *SP CSI reporting on PUCCH Activation/Deactivation* in TS 38.321 is used to activate and deactivate the semi-persistent L1 measurement reporting on PUCCH [7]. This field *L* indciates whether the MAC CE applies to SP CSI reporting on PUCCH Activation/Deactivation for LTM or not. The field S_i indicates the activation/deactivation status of the Semi-Persistent CSI report configuration within *ltm-CSI-ReportConfigToAddModList* if L field is set to 1, or *csi-ReportConfigToAddModList* if L field is set to 0, S_0 refers to the report configuration which includes PUCCH resources for SP CSI reporting in the indicated BWP and has the lowest *CSI-ReportConfigId* or *LTM-CSI-ReportConfigId* within the list with type set to *semiPersistentOnPUCCH*, S_1 to the report configuration which includes PUCCH resources for SP CSI reporting in the indicated BWP and has the second lowest *CSI-ReportConfigId* or *LTM-CSI-ReportConfigId* and so on.

However, the existing *SP CSI reporting on PUCCH Activation/Deactivation* MAC CE is only used to activate and deactivate CSI reporting for MIMO or CSI reporting for LTM. This MAC CE does not support activation and deactivation of CSI reporting for on-demand SSB. The issue of how to support the activation and deactivation of semi-persistent L1 measurement reporting on PUCCH for on-demand SSB should be resolved.

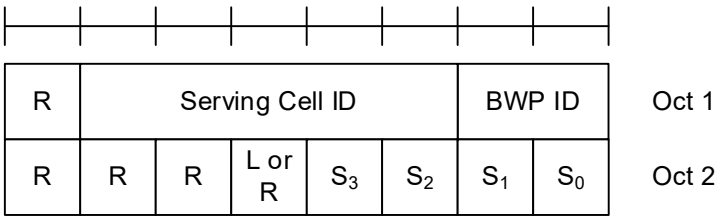


Figure 4: Existing SP CSI reporting on PUCCH Activation/Deactivation MAC CE

Solutions to issue-3

In order to solve the issue-3 above, the existing *SP CSI reporting on PUCCH Activation/Deactivation* MAC CE should be enhanced. There are two solutions to support the activation and deactivation of semi-persistent L1 measurement reporting on PUCCH for on-demand SSB.

The Alt-1 solution is that the existing *SP CSI reporting on PUCCH Activation/Deactivation* MAC CE should include the activation and deactivation of SP CSI reporting on PUCCH for on-demand SSB, e.g., one of the reserved bits can be used to indciate whether the MAC CE applies to SP CSI reporting on PUCCH Activation/Deactivation for on-demand SSB or not. If on-demand SSB is not configured, R field is present instead (i.e. set to 0). The Alt-1 solution has less specification impact but it will change the contents of the existing *SP CSI reporting on PUCCH Activation/Deactivation* MAC CE.

The Alt-2 solution is that a new dedicated MAC CE should be introduced for activation and deactivation of semi-persistent L1 measurement reporting on PUCCH for on-demand SSB. The Alt-2 solution will not change the contents of the existing *SP CSI reporting on PUCCH Activation/Deactivation* MAC CE but it has more specification impact since a new MAC CE will be introduced.

If the report configuration refered by S_i is related to on-demand SSB measurement reporting, the enhanced MAC CE or the new introduced MAC CE can also be used to activate and deactivate semi-persistent L1 measurement reporting on PUCCH for on-demand SSB.

Proposal 22: Consider two candidate solutions to activate and deactivate semi-persistent L1 measurement reporting on PUCCH for on-demand SSB.

- **Alt-1: The existing *SP CSI reporting on PUCCH Activation/Deactivation* MAC CE should include the activation and deactivation of SP CSI reporting on PUCCH for on-demand SSB, e.g., one of the reserved bits can be used to indicate whether the MAC CE applies to SP CSI reporting on PUCCH Activation/Deactivation for on-demand SSB or not.**
- **Alt-2: A new dedicated MAC CE should be introduced for activation and deactivation of semi-persistent L1 measurement reporting on PUCCH for on-demand SSB.**

6.4 Enhancements on DCI triggering for PUSCH-based semi-persistent reporting

In this section, the enhancements on DCI triggering for PUSCH-based semi-persistent reporting for on-demand SSB measurement are discussed. The issues on reusing the existing CSI framework to PUSCH-based semi-persistent reporting based on on-demand SSB and related solutions are provided.

Issue-4: How to support the triggering of semi-persistent L1 measurement reporting on PUSCH for on-demand SSB?

Based on the existing CSI framework, the DCI format 0_1 and 0_2 with CRC scrambled by SP-CSI-RNTI are used to trigger the semi-persistent L1 measurement reporting on PUSCH. Each codepoint of the DCI field *CSI request* is associated with one trigger state, and one trigger state is associated with one CSI report configuration, so the field *CSI request* is used to indciates the CSI Report Configuration for the semi-persistent L1 measurement reporting on PUSCH.

However, when the CRC of DCI format 0_1 and 0_2 is scrambled by SP-CSI-RNTI, the existing DCI field *CSI request* is used only to trigger semi-persistent CSI reporting for MIMO or CSI reporting for LTM. This DCI does not support the triggering of semi-persistent L1 measurement reporting on PUSCH for on-demand SSB. The issue of how to support the triggering of semi-persistent L1 measurement reporting on PUSCH for on-demand SSB should be resolved.

Solutions to issue-4

In order to solve the issue-4 above, the existing DCI format 0_1 and 0_2 should be enhanced. There are two solutions to support the triggering of semi-persistent L1 measurement reporting on PUSCH for on-demand SSB.

The Alt-1 solution is that the existing DCI field *CSI request* is reused to trigger semi-persistent L1 measurement reporting on PUSCH for on-demand SSB, and the existing DCI field *Transform precoding indicator* is used to indicate the DCI is used to trigger semi-persistent L1 measurement reporting on PUSCH for on-demand SSB, or for legacy MIMO/LTM. For a DCI format 0_1 or 0_2 with CRC scrambled by SP-CSI-RNTI, the bit *Transform precoder indicator* in DCI format 0_1 or 0_2 is reserved, so this reserved bit can be used to indicate whether the DCI triggers semi-persistent L1 measurement reporting on PUSCH for on-demand SSB or not. If the bit *Transform precoder indicator* in DCI format 0_1 or 0_2 with CRC scrambled by SP-CSI-RNTI is set to 1, the DCI field *CSI request* is used to trigger semi-persistent L1 measurement reporting on PUSCH for on-demand SSB. If the bit *Transform precoder indicator* is set to 0, the DCI field *CSI request* is used to trigger semi-persistent L1 measurement reporting on PUSCH for legacy MIMO/LTM. The Alt-1 solution has less specification impact but it will use the field *Transform precoding indicator.*

The Alt-2 solution is that a new dedicated RNTI (e.g., OD-SSB-SP-Reporting-RNTI) for DCI format 0_1 and 0_2 should be introduced for triggering of semi-persistent L1 measurement reporting on PUSCH for on-demand SSB. If the CRC is scrambled by OD-SSB-SP-Reporting-RNTI, the DCI field *CSI request* is used to trigger semi-persistent L1 measurement reporting on PUSCH for on-demand SSB. If the CRC is scrambled by SP-CSI-RNTI, the DCI field *CSI request* is used to trigger semi-persistent L1 measurement reporting on PUSCH for legacy MIMO/LTM. The Alt-2 solution will not use the field *Transform precoding indicator* but it has more specification impact since a new dedicated RNTI will be introduced.

Proposal 23: Consider two candidate solutions to trigger semi-persistent L1 measurement reporting on PUSCH for on-demand SSB.

- **Alt-1: The existing DCI field CSI request is reused to trigger semi-persistent L1 measurement**

reporting on PUSCH for on-demand SSB, and the existing DCI field Transform precoding indicator is used to indicate the DCI is used to trigger semi-persistent L1 measurement reporting on PUSCH for on-demand SSB, or for legacy MIMO/LTM.

- **Alt-2: A new dedicated RNTI (e.g., OD-SSB-SP-Reporting-RNTI) for DCI format 0_1 and 0_2 should be introduced for triggering of semi-persistent L1 measurement reporting on PUSCH for on-demand SSB.**

Issue-5: How to support the semi-persistent L1 measurement reporting on PUSCH for multiple on-demand SSBs from multiple SCells?

Based on the existing CSI framework, the DCI format 0_1 and 0_2 are used to trigger the semi-persistent L1 measurement reporting on PUSCH. Each codepoint of the DCI field *CSI request* is associated with one trigger state, and one trigger state is associated with one CSI report configuration, so this field *CSI request* is used to indciates the CSI Report Configuration for the semi-persistent L1 measurement reporting on PUSCH.

However, the existing each trigger state is associated with only one CSI report configuration, which means each DCI can trigger the semi-persistent L1 measurement reporting on PUSCH for on-demand SSB from only one SCell. Hence the UE has to report the on-demand SSB measurement results of multiple SCells to gNB by multiple PUSCH transmission. When there are a large number of SCells that need to be reported (the maximumn number is 32 SCells), it will result in significant reporting latency and signalling overhead. Therefore, the issue of how to support the semi-persistent L1 measurement reporting on PUSCH for multiple on-demand SSBs from multiple SCells should be resolved.

***CSI-SemiPersistentOnPUSCH-TriggerStateList* information element**

```
-- ASN1START
-- TAG-CSI-SEMIPERSISTENTONPUSCHTRIGGERSTATELIST-START


CSI-SemiPersistentOnPUSCH-TriggerStateList ::= SEQUENCE(SIZE (1..maxNrOfSemiPersistentPUSCH-
Triggers)) OF CSI-SemiPersistentOnPUSCH-TriggerState


CSI-SemiPersistentOnPUSCH-TriggerState ::=     SEQUENCE {
    associatedReportConfigInfo                      CSI-ReportConfigId,
    ...,
    [[
    sp-CSI-MultiplexingMode-r17                     ENUMERATED {enabled}
OPTIONAL   -- Need R
    ]],
    [[
    csi-ReportSubConfigTriggerList-r18              CSI-ReportSubConfigTriggerList-r18
OPTIONAL,  -- Need R
    ltm-AssociatedReportConfigInfo-r18              LTM-CSI-ReportConfigId-r18
OPTIONAL   -- Need R


    ]]
}


-- TAG-CSI-SEMIPERSISTENTONPUSCHTRIGGERSTATELIST-STOP
-- ASN1STOP
```

Solutions to issue-5

In order to solve the issue-5 above, the existing triggering state should be enhanced. There are two solutions to support the semi-persistent L1 measurement reporting on PUSCH for multiple on-demand SSBs from multiple SCells.

The Alt-1 solution is that the existing IE *CSI-SemiPersistentOnPUSCH-TriggerState* should include multiple *CSI-ReportConfigId*s. Each *CSI-ReportConfigId* is associated with one on-demand SSB resource configuration information. Hence, the enhanced *CSI-SemiPersistentOnPUSCH-TriggerState* will be associated with multiple on-demand SSBs from multiple SCells. The Alt-1 solution has less specification impact but it will change the contents of the existing IE *CSI-SemiPersistentOnPUSCH-TriggerState.*

The Alt-2 solution is that a new dedicated trigger state IE for on-demand SSB should be introduced, e.g. *CSI-SemiPersistentOnPUSCH-TriggerState-NES.* The Alt-2 solution will not change the contents of the existing IE *CSI-SemiPersistentOnPUSCH-TriggerState* but it has more specification impact since a new IE will be introduced.

Proposal 24: Consider two candidate solutions to support the semi-persistent L1 measurement reporting on PUSCH for multiple on-demand SSBs from multiple SCells.

- **Alt-1: The existing IE *CSI-SemiPersistentOnPUSCH-TriggerState* should include multiple *CSI-ReportConfigIds*. Each *CSI-ReportConfigId* is associated with one on-demand SSB resource configuration information.**
- **Alt-2: A new dedicated trigger state IE for on-demand SSB should be introduced, e.g. *CSI-SemiPersistentOnPUSCH-TriggerState-NES*.**

6.5 Enhancements on DCI triggering for aperiodic reporting

In this section, the enhancements on DCI triggering for aperiodic reporting for on-demand SSB measurement are discussed. The issue on reusing the existing CSI framework to aperiodic reporting based on on-demand SSB and related solution are provided.

Issue-6: How to support the triggering of aperiodic L1 measurement reporting on PUSCH for on-demand SSB?

Based on the existing CSI framework, the DCI format 0_1 and 0_2 with CRC scrambled by C-RNTI are used to trigger the aperiodic L1 measurement reporting on PUSCH. Each codepoint of the DCI field *CSI request* is associated with one trigger state defined in *Aperiodic CSI Trigger State Subselection MAC CE*, which indicates the selection status of the aperiodic trigger states configured within *aperiodicTriggerStateList* and one trigger state is associated with one CSI report configuration, so the field *CSI request* is used to indciates the CSI Report Configuration for the aperiodic measurement reporting on PUSCH.

However, when the CRC of DCI format 0_1 and 0_2 is scrambled by C-RNTI, the existing DCI field *CSI request* is used only to trigger aperiodic CSI reporting for MIMO or CSI reporting for LTM. This DCI does not support the triggering of aperiodic L1 measurement reporting on PUSCH for on-demand SSB. The issue of how to support the triggering of aperiodic L1 measurement reporting on PUSCH for on-demand SSB should be resolved.

Solutions to issue-6

In order to solve the issue-6 above, the existing DCI format 0_1 and 0_2 should be enhanced. The solution for supporting the triggering of aperiodic L1 measurement reporting on PUSCH for on-demand SSB is shown as following.

The solution is that a new dedicated RNTI (e.g., OD-SSB-Aperiodic-Reporting-RNTI) for DCI format 0_1 and 0_2 should be introduced for triggering of aperiodic L1 measurement reporting on PUSCH for on-demand SSB. If the CRC is scrambled by OD-SSB-Aperiodic-Reporting-RNTI, the DCI field *CSI request* is used to trigger aperiodic L1 measurement reporting on PUSCH for on-demand SSB. If the CRC is scrambled by SP-CSI-RNTI, the DCI field *CSI request* is used to trigger semi-persistent L1 measurement reporting on PUSCH for legacy MIMO/LTM.

Proposal 25: Consider the following solution to trigger aperiodic L1 measurement reporting on PUSCH for on-demand SSB.

- **A new dedicated RNTI (e.g., OD-SSB-Aperiodic-Reporting-RNTI) for DCI format 0_1 and 0_2 should be introduced for triggering of aperiodic L1 measurement reporting on PUSCH for on-demand SSB.**

7 SSB multiplexing

7.1 Relation between always-on SSB and on-demand SSB

The relation in terms of periodicity between always-on SSB and OD-SSB

In RAN1#119 meeting, the following agreements were achieved [1]:

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.

For Case #2, AO-SSB is configured to be periodically transmitted on the cell. If the configured AO-SSB cannot meet the L1/L3 measurement requirements, OD-SSB is triggered for additional quicker L1/L3 measurement. Regarding the periodicity of OD-SSB, it is unclear why the periodicity of OD-SSB is greater than that of AO-SSB. If the periodicity of OD-SSB is greater than that of AO-SSB, the purposes of triggering OD-SSB, i.e., quicker L1/L3 measurement, may be not achieved. Therefore, the periodicity of OD-SSB should be equal to or smaller than that of AO-SSB.

Proposal 26: Regarding the relation in terms of periodicity between always-on SSB and OD-SSB, the periodicity of on-demand SSB should be equal to or smaller than that of always-on SSB.

The relation in terms of time location between always-on SSB and OD-SSB

In RAN1#119 meeting, the following agreements were achieved [1]:

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

As agreed in RAN1#119, RAN1 assumes the time location of OD-SSB in Q2 refers to the time location of possible OD-SSB burst. The time domain location of OD-SSB can be configured independently. And the time domain location of OD-SSB can be same or different from the time domain location of AO-SSB, subject to its configuration.

Proposal 27: Regarding the relation in terms of time location between always-on SSB and OD-SSB, the time location of OD-SSB can be the same as or different from the time location of always-on SSB.

The relation in terms of frequency location between always-on SSB and OD-SSB

In RAN1#119 meeting, the following agreements were achieved [1]:

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.

In RAN1#119, it had been agreed that the frequency location of OD-SSB is the same as the frequency location of AO-SSB at least for the case where AO-SSB is not CD-SSB. For the case where AO-SSB is CD-SSB, it is related to whether the AO-SSB is on the synchronization raster. As discussed in section 2.2, if AO-SSB is CD-SSB on a synchronization raster, the frequency location of OD-SSB is different from the frequency location of AO-SSB. 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.

Proposal 28: Regarding the frequency location of OD-SSB for the case where always-on SSB is CD-SSB,

- **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.**
- **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.**

The spatial relation between the always-on SSB and OD-SSB

In RAN1#119 meeting, the following agreements were achieved [1]:

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.

In RAN1#119, it has been agreed that at least the case where SSB indices within OD-SSB burst are identical to SSB indices within AO-SSB burst is supported. In fact, there is no closed spatial relationship between the AO-SSB and OD-SSB. The inclusion or exclusion relationship between the SSB indices within OD-SSB burst and the SSB indices within AO-SSB should not be restricted. It is up to gNB implementation whether SSB indices within OD-SSB burst are or are not the subset of SSB indices within AO-SSB burst. For example, as shown in Figure 5, the AO-SSB and OD-SSB on a SCell are configured on the same frequency location but in different time locations. The periodicity of OD-SSB is 40ms and the periodicity of AO-SSB is 80ms. As shown in Figure 6, three beam-cases of spatial relation between the AO-SSB and OD-SSB can be configured by gNB as follows:

- Beam-case 1: SSB indices within OD-SSB burst are the subset of SSB indices within AO-SSB burst, as shown in Figure 6 (a).
- Beam-case 2: SSB indices within OD-SSB burst are not the subset of SSB indices within AO-SSB burst, as shown in Figure 6 (b).
- Beam-case 3: SSB indices within AO-SSB burst are the subset of SSB indices within OD-SSB burst, as shown in Figure 6 (c).

Proposal 29: Regarding the spatial relation between the always-on SSB and OD-SSB, it is up to gNB implementation whether SSB indices within on-demand SSB burst are or are not the subset of SSB indices within always-on SSB burst.

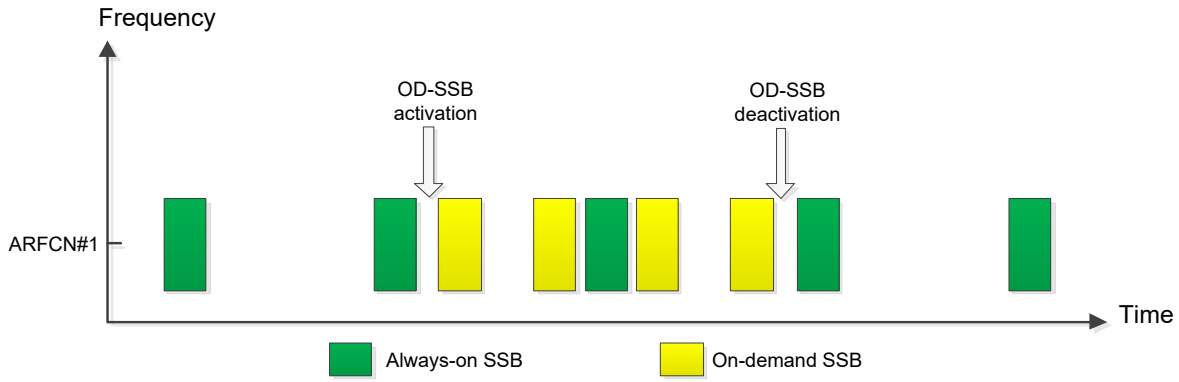
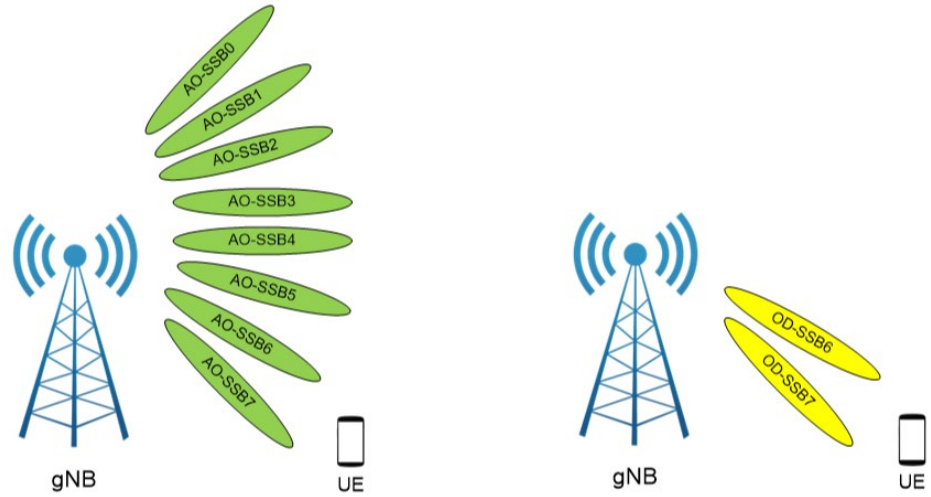
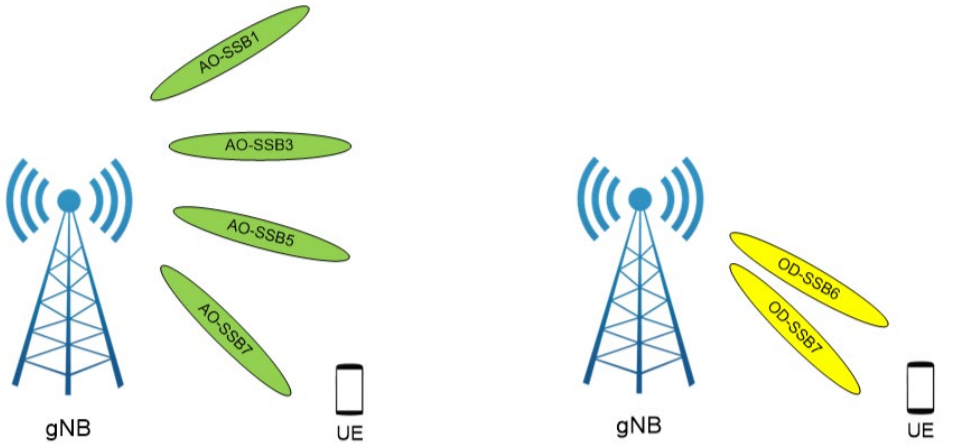


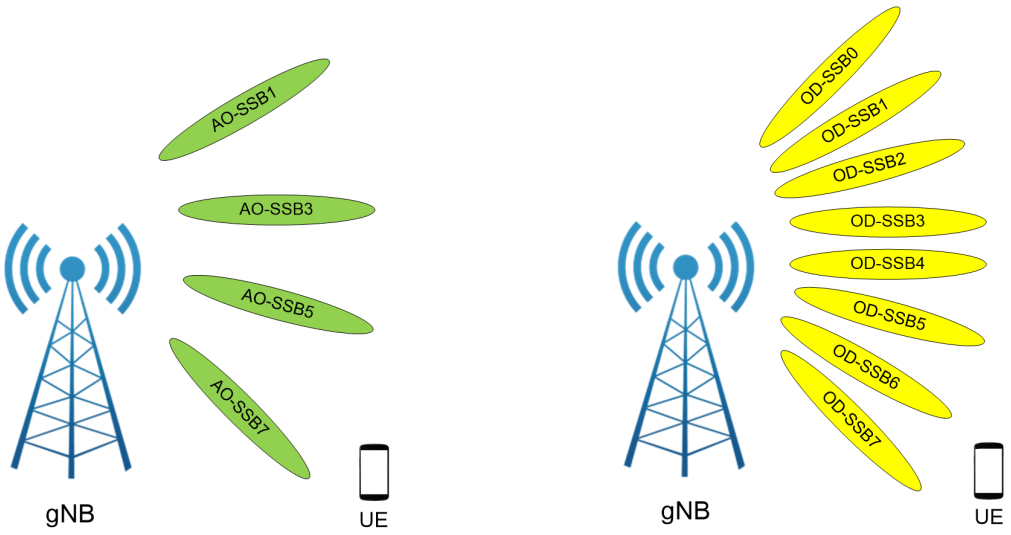
Figure 5: AO-SSB and OD-SSB in time and frequency domain



(a) Case 1: SSB indices within OD-SSB burst are the subset of SSB indices within AO-SSB burst



(b) Case 2: SSB indices within OD-SSB burst are not the subset of SSB indices within AO-SSB burst



(c) Case 3: SSB indices within AO-SSB burst are the subset of SSB indices within OD-SSB burst

Figure 6: AO-SSB and OD-SSB in spatial domain

7.2 Overlapping between always-on SSB and on-demand SSB

In RAN1#118-bis meeting, one agreement was achieved related to overlapping between always-on SSB and on-demand SSB [2].

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 RAN4#112-bis meeting, one agreement was achieved related to always-on SSB and OD-SSB time/frequency domain relation [10].

Agreement:

- In OD-SSB Case 2, RAN4 to first discuss the deactivated SCell requirement for Scenario 1. RAN4 to further discuss whether to define the requirement for the scenario 2 and 3 if scenario 2 and 3 are supported in RAN1 based on RAN1's agreement.
  - Scenario 1: OD-SSB and always-on SSB are with same SSB carrier frequency, same offset but different periodicities.
  - Scenario 2: OD-SSB and always-on SSB are with same SSB carrier frequency, different offsets and periodicities.
  - Scenario 3: OD-SSB and always-on SSB are within different SSB carrier frequencies.
- Send the above information to RAN1, further discuss the text including the questions to RAN1 in the LS.
- RAN4 will inform RAN1 if any further agreement.

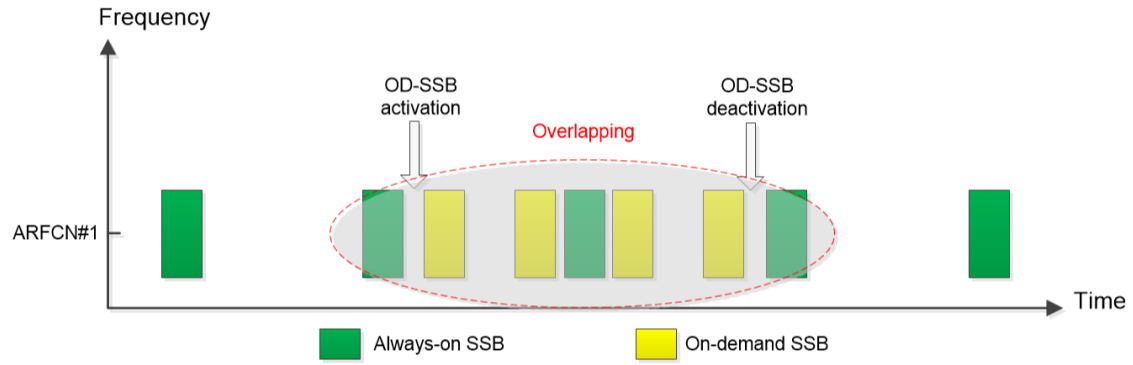
For a cell supporting on-demand SSB SCell operation and for Case #2, always-on SSB is periodically transmitted on the cell, since always-on SSB and OD-SSB may be configured with different signallings, always-on SSB and OD-SSB may overlap in time domain, frequency domain or both of them. For example, as discussed in section 2.2, if always-on SSB is CD-SSB on a synchronization raster, the frequency location of on-demand SSB should be different from the frequency location of always-on SSB. Hence, both the Mux-Case #1 (i.e., no time-domain overlap between always-on SSB and on-demand SSB) and the Mux-Case #2 (i.e., always-on SSB and on-demand SSB overlap at least in time or frequency domain) are reasonable cases.

Three Overlapping-Cases between always-on SSB and OD-SSB in time and/or frequency domain as follows:

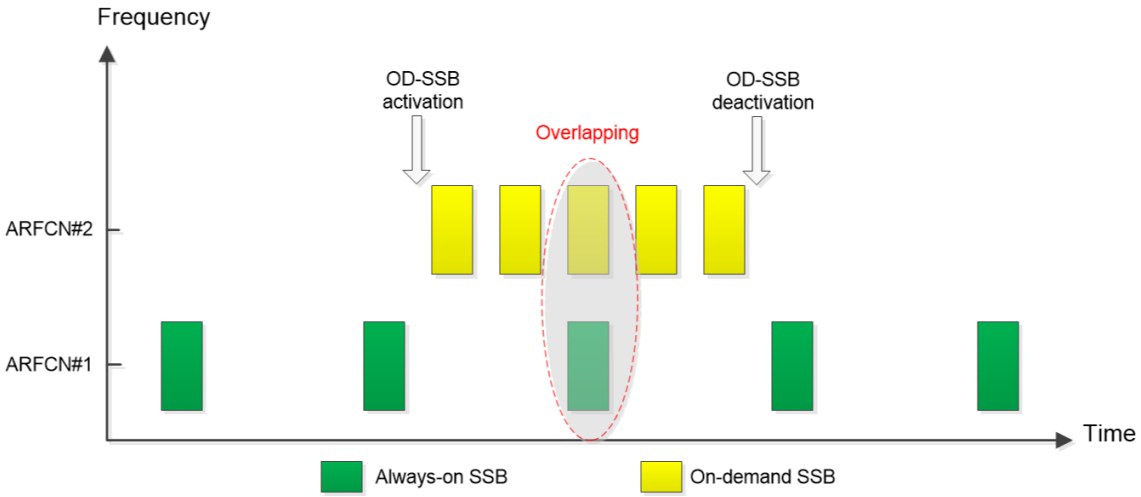
- Overlapping-Case #1: Always-on SSB and on-demand SSB overlap in frequency domain, and they

don’t overlap in time domain (Figure 7 (a)).

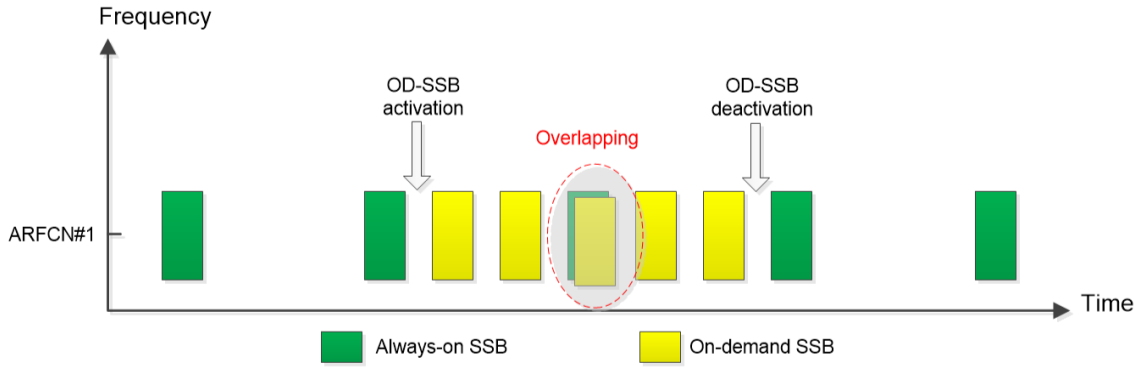
- Overlapping-Case #2: Always-on SSB and on-demand SSB overlap in time domain, and they don’t overlap in frequency domain (Figure 7 (b)).
- Overlapping-Case #3: Always-on SSB and on-demand SSB overlap in both time domain and frequency domain (Figure 7 (c)).



(a) Overlapping-Case #1



(b) Overlapping-Case #2



(c) Overlapping-Case #3

Figure 7: Three Overlapping-Cases between always-on SSB and OD-SSB in time and/or frequency domain

For Overlapping-Case #1, always-on SSB and on-demand SSB overlap in frequency domain, and they don’t overlap in time domain. In this case, always-on SSB and on-demand SSB are configured with the same *absoluteFrequencySSB*, the UE can measure both always-on SSB and on-demand SSB for L1 measurement reporting.

For Overlapping-Case #2, always-on SSB and on-demand SSB overlap in time domain, and they don't overlap in frequency domain. For example, as discussed in section 2.2, if always-on SSB is CD-SSB on a synchronization raster, the frequency location of on-demand SSB should be different from the frequency location of always-on SSB. In this case, always-on SSB and on-demand SSB are configured with different *absoluteFrequencySSB*, the UE can measure always-on SSB and on-demand SSB for L1 measurement reporting on ARFCN #1 and ARFCN #2, respectively.

For Overlapping-Case #3, always-on SSB and on-demand SSB overlap in both time domain and frequency domain. In this case, since always-on SSB is used by all UEs in this SCell and on-demand SSB may be used by particular UEs, always-on SSB should be prioritized over on-demand SSB to avoid the collision between always-on SSB and on-demand SSB. In fact, if the SSB configuration of always-on SSB is the same as that of on-demand SSB, the always-on SSB and on-demand SSB can reuse the overlapped time-frequency SSB position.

Therefore, there is no need to limit the overlapping between always-on SSB and on-demand SSB in time or frequency domain. It is up to gNB implementation on how to configure time/frequency domain relation between always-on SSB and on-demand SSB. If always-on SSB and on-demand SSB overlap in both time domain and frequency domain, always-on SSB should be prioritized over on-demand SSB to avoid the collision between always-on SSB and on-demand SSB.

Proposal 30: There is no need to limit the overlapping between always-on SSB and on-demand SSB in time or frequency domain.

- **It is up to gNB implementation on how to configure time/frequency domain relation between always-on SSB and on-demand SSB.**
- **If always-on SSB and on-demand SSB overlap in both time domain and frequency domain, always-on SSB should be prioritized over on-demand SSB to avoid the collision between always-on SSB and on-demand SSB.**

8 Further details on on-demand SSB operation

8.1 Rate-matching handling

On-demand SSB transmission of the serving cell is not known by legacy UEs. Since UE-dedicated activation/deactivation signaling is used, PDSCH of one Rel-19 UE may also be impacted by the on-demand SSB transmission of the other Rel-19 UEs. In addition, activation/deactivation of on-demand SSB of the neighboring cells would change the interference to cell edge UEs. Therefore, rate-matching issue needs to consider on-demand SSB transmission of both serving cell and neighboring cell. In our opinion, UE-dedicated PDSCH should be rate matched around the actual transmission of on-demand SSB of the serving cell. On the other hand, UE-dedicated PDSCH should be always rate matched around on-demand SSB of the neighboring cell irrespective its transmission. Correspondingly, semi-static rate matching pattern could be used. The detailed rate matching pattern and its configuration feasible for on-demand SSB could be further studied.

Proposal 31: Rate-matching issue needs to consider on-demand SSB transmission of both serving cell and neighboring cell.

9 Conclusion

In this contribution, we discuss on-demand SSB SCell operation, and give the following observations and proposals:

Observation 5: In the current system, after UE receives SCell activation command, for a known SCell, UE acquires SSB for fine time tracking. For an unknown SCell, UE acquires SSB to perform AGC, synchronization and L1 measurement report.

Observation 6: Since the new MAC CE for OD-SSB transmission indication and the legacy MAC CE for SCell activation/deactivation are two independent MAC CEs, the gNB can trigger OD-SSB when needed via the new MAC CE, irrespective of the timing relationship with SCell activation/deactivation.

Observation 7: In order to support scenario 2A, the new MAC CE for OD-SSB transmission indication and the legacy MAC CE for SCell activation/deactivation can be sent together in one PDSCH.

Observation 8: The motivation of supporting OD-SSB for CD-SSB located on sync-raster is not clear.

Proposal 32: For the identified scenarios and cases (as per RAN1#116 and RAN1#116-bis agreements), on-demand SSB can be triggered by gNB for the following scenarios/cases:

- **Scenario #3A and Case #1**
- **Scenario #3A and Case #2**
- **Scenario #3B and Case #1**
- **Scenario #3B and Case #2**

Proposal 33: It is up to gNB implementation when OD-SSB is triggered, irrespective of the timing relationship with SCell activation/deactivation.

Proposal 34: Deprioritize the discussion of additional support of OD-SSB for CD-SSB located on sync-raster in Rel-19.

Proposal 35: The following Alt 1 and Alt A in the agreement in RAN1#119 should be supported.

- **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 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.**

Proposal 36: A unified group-common DCI could be designed to indicate on-demand SSB transmission.

Proposal 37: Deactivation for on-demand SSB via MAC-CE should be applied to Scenario 2/2A/3A/3B.

Proposal 38: Deactivation for on-demand SSB via MAC-CE could also be applied to Option 2 (Configuration/indication of the number N of on-demand SSB bursts to be transmitted after on-demand SSB is indicated).

Proposal 39: For Option 2, the value of N is preferred to be configured explicitly.

Proposal 40: In addition to Option 2, support the following options:

- **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.**

Proposal 41: More than one on-demand SSB configurations can be configured for the cell to UE.

Proposal 42: Besides periodicity, for the following parameters, multiple candidate values can also be configured by RRC and the applicable value is indicated by MAC-CE:

- **The number N of SSB bursts that will be transmitted.**
- **SSB positions within an on-demand SSB burst.**

Proposal 43: For a cell supporting on-demand SSB SCell operation and for Case #2, UE assumes the followings for on-demand SSB are the same as for always-on SSB, unless explicitly configured.

- **Sub-carrier spacing**
- **Physical Cell ID**
- **Downlink transmit power**

Proposal 44: The time domain location configuration of on-demand SSB for Case #1 is also applied for Case #2.

Proposal 45: Considering time instance A for MAC-CE, confirm the working assumption T=T_min.

Proposal 46: For SSB burst(s) indicated by on-demand SSB SCell operation via a RRC, UE expects that on-demand SSB is transmitted from time instance A_RRC which is determined as follows.

- **Time instance A_RRC is the beginning of the first slot containing the first actually transmitted SSB index within the first "possible" on-demand SSB burst which is at least T_RRC slots after the last slot where UE receives PDSCH containing the RRC message from gNB to indicate on-demand SSB transmission.**
- **T_RRC should be dependent on the RRC procedure delay.**

Proposal 47: Deprioritize the discussion of LTM based on on-demand SSB in Rel-19.

Proposal 48: Consider two candidate solutions to add on-demand SSB resource configuration to existing CSI resource configuration.

- **Alt-1: The existing IE *CSI-ResourceConfig* should include the on-demand SSB resource configuration information.**

- **Alt-2: A new dedicated resource configuration IE for on-demand SSB resource configuration should be introduced, e.g. *CSI-ResourceConfig-NES*.**

Proposal 49: Consider two candidate solutions to add on-demand SSB reporting configuration to existing CSI reporting configuration.

- **Alt-1: The existing IE *CSI-ReportConfig* should include the on-demand SSB reporting configuration information.**
- **Alt-2: A new dedicated reporting configuration IE for on-demand SSB reporting configuration should be introduced, e.g. *CSI-ReportConfig-NES*.**

Proposal 50: For a cell supporting OD-SSB SCell operation and for Case #2, both the following options should be supported for UE to perform L1 measurement based on OD-SSB:

- **Option 1: A CSI report configuration is associated with both of OD-SSB and always-on SSB.**
- **Option 2: A CSI report configuration is associated with one of always-on SSB and OD-SSB.**

Proposal 51: In order to support both the two options in the agreement in RAN1#118-bis using a single *CSI-ReportConfig* IE, the reporting configuration for AO-SSB and OD-SSB in the *CSI-ReportConfig* IE should be optional.

Proposal 52: It is up to gNB implementation whether OD-SSB and always-on SSB have same beam or not.

Proposal 53: Consider two candidate solutions to activate and deactivate semi-persistent L1 measurement reporting on PUCCH for on-demand SSB.

- **Alt-1: The existing *SP CSI reporting on PUCCH Activation/Deactivation* MAC CE should include the activation and deactivation of SP CSI reporting on PUCCH for on-demand SSB, e.g., one of the reserved bits can be used to indicate whether the MAC CE applies to SP CSI reporting on PUCCH Activation/Deactivation for on-demand SSB or not.**
- **Alt-2: A new dedicated MAC CE should be introduced for activation and deactivation of semi-persistent L1 measurement reporting on PUCCH for on-demand SSB.**

Proposal 54: Consider two candidate solutions to trigger semi-persistent L1 measurement reporting on PUSCH for on-demand SSB.

- **Alt-1: The existing DCI field CSI request is reused to trigger semi-persistent L1 measurement reporting on PUSCH for on-demand SSB, and the existing DCI field Transform precoding indicator is used to indicate the DCI is used to trigger semi-persistent L1 measurement reporting on PUSCH for on-demand SSB, or for legacy MIMO/LTM.**
- **Alt-2: A new dedicated RNTI (e.g., OD-SSB-SP-Reporting-RNTI) for DCI format 0_1 and 0_2 should be introduced for triggering of semi-persistent L1 measurement reporting on PUSCH for on-demand SSB.**

Proposal 55: Consider two candidate solutions to support the semi-persistent L1 measurement reporting on PUSCH for multiple on-demand SSBs from multiple SCells.

- **Alt-1: The existing IE *CSI-SemiPersistentOnPUSCH-TriggerState* should include multiple *CSI-ReportConfigIds*. Each *CSI-ReportConfigId* is associated with one on-demand SSB resource configuration information.**
- **Alt-2: A new dedicated trigger state IE for on-demand SSB should be introduced, e.g. *CSI-SemiPersistentOnPUSCH-TriggerState-NES*.**

Proposal 56: Consider the following solution to trigger aperiodic L1 measurement reporting on PUSCH for on-demand SSB.

- **A new dedicated RNTI (e.g., OD-SSB-Aperiodic-Reporting-RNTI) for DCI format 0_1 and 0_2 should be introduced for triggering of aperiodic L1 measurement reporting on PUSCH for on-demand SSB.**

Proposal 57: Regarding the relation in terms of periodicity between always-on SSB and OD-SSB, the periodicity of on-demand SSB should be equal to or smaller than that of always-on SSB.

Proposal 58: Regarding the relation in terms of time location between always-on SSB and OD-SSB, the time location of OD-SSB can be the same as or different from the time location of always-on SSB.

Proposal 59: Regarding the frequency location of OD-SSB for the case where always-on SSB is CD-SSB,

- **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.**
- **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.

Proposal 60: Regarding the spatial relation between the always-on SSB and OD-SSB, it is up to gNB implementation whether SSB indices within on-demand SSB burst are or are not the subset of SSB indices within always-on SSB burst.

Proposal 61: There is no need to limit the overlapping between always-on SSB and on-demand SSB in time or frequency domain.

- **It is up to gNB implementation on how to configure time/frequency domain relation between always-on SSB and on-demand SSB.**
- **If always-on SSB and on-demand SSB overlap in both time domain and frequency domain, always-on SSB should be prioritized over on-demand SSB to avoid the collision between always-on SSB and on-demand SSB.**

Proposal 62: Rate-matching issue needs to consider on-demand SSB transmission of both serving cell and neighboring cell.

10 References

[1] Chair notes RAN1#119, 3GPP TSG RAN WG1 Meeting #119, November 18th – 22nd, 2024.

[2] Chair notes RAN1#118-bis, 3GPP TSG RAN WG1 Meeting #118-bis, October 14th – 18th, 2024.

[3] Chair notes RAN1#118, 3GPP TSG RAN WG1 Meeting #118, August 19th – 23rd, 2024.

[4] Chair notes RAN1#116-bis, 3GPP TSG RAN WG1 Meeting #116-bis, April 15th –19th, 2024.

[5] 3GPP TS 38.133, Requirements for support of radio resource management (Release 18), V18.4.0 (2023-12).

[6] 3GPP TS 38.331, Radio Resource Control (RRC) protocol specification (Release 18), V18.2.0 (2024-06).

[7] 3GPP TS 38.321, Medium Access Control (MAC) protocol specification (Release 18), V18.2.0 (2024-06).

[8] Report of 3GPP TSG RAN WG2 meeting #127, 3GPP TSG RAN WG4 Meeting #127, August 19th – 23rd, 2024.

[9] Draft Report of 3GPP TSG RAN WG2 meeting #127bis, 3GPP TSG RAN WG4 Meeting #127bis, October 14th – 18th, 2024.

[10] RAN4 #112bis RRM session meeting report, 3GPP TSG RAN WG4 Meeting #112-bis, October 14th – 18th, 2024.