3GPP TSG RAN WG1 #120 **R1-2500353**
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Title: **Discussions on on-demand SSB SCell operation**
Agenda Item: **9.5.1**
Document for: **Discussion and Decision**

1. Introduction

In RAN#102, it has been approved in the Rel-19 Network Energy Saving WID [1] to specify the procedures and signaling method(s) to support on-demand SSB SCell operation for UEs.

1. Specify procedures and signalling 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 signalling)
    - 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.

In this contribution, we provide our views on the on-demand SSB SCell operation, including the scenarios and potential issues, as well as some possible solutions.

2. Scenarios of On-demand SSB operation in SCell

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
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 the RAN1#116bis meeting, it was agreed that on-demand SSB can be indicated by gNB for Scenario #2 and Scenario #2A. Meanwhile, Scenario #3A and Scenario #3B will be further studied. The intentions to support on-demand SSB operation in Scenario #2A and Scenario #3A are the same, i.e., shorten the delay of SCell activation procedure. As shown in Figure 1, the difference between Scenario #2A and Scenario #3A lies in that the on-demand SSB indication should be transmitted along with the SCell activation command in the same slot on Scenario #2A, while in Scenario #3A, the on-demand SSB indication could be transmitted after the SCell activation command. From the perspective of delay, Scenario #2A could minimize the delay of the SCell activation procedure by the earlier on-demand SSB indication compared to Scenario #3A. However, in our opinion, whether to send on-demand SSB indication in Scenario #2A or Scenario #3A can depend on network implementation, hence Scenario #3A can also be supported.

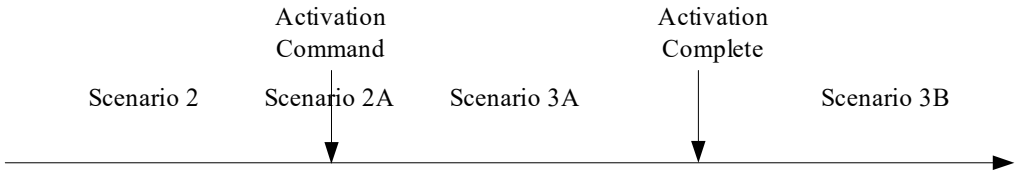

Figure 1: The Scenario of on-demand SSB operation on SCell

Proposal 1：For on-demand SSB SCell operation, support Scenario #3A and it is up to gNB implementation to indicate on-demand SSB in Scenario #2A or Scenario #3A.

While in Scenario #3B, when an SCell is activated, UE would perform synchronization and AGC periodically on this SCell for data transmission and reception. Hence, periodical SSB transmission needs to be always available and cannot be fully shut down (i.e. case 1) when SCell is active. Hence, it should be guaranteed that there are always-on periodic SSB transmissions in Scenario #3B to satisfy such requirement. Given periodic SSB transmissions are already available in Scenario #3B, there is no clear motivation to support additional on-demand SSB when SCell is activated. Therefore, there is no need to support on-demand SSB Scell operation in scenario #3B.

Proposal 2: For on-demand SSB SCell operation, do not support Scenario #3B, i.e., on-demand SSB should not be indicated by gNB after SCell activation is complete.

In the previous meeting, it was proposed by some companies to consider whether the on-demand SSB could be supported by SSB-less SCell where the reference cell is specified. If following the current spec, UE obtains timing reference from the configured or default reference cell for the SSB-less Scell. Besides, gNB needs to guarantee the condition of SSB-less Scell as specified by RAN4 is satisfied. For proponent that supports on-demand SSB operation for SSB-less Scell, it is argued that gNB is hard to guarantee the condition especially the RTD condition for a UE that may be moving anywhere in the cell. Thus on-demand SSB is needed to perform measurement of RTD between SSB-less Scell and reference cell. However, whether the argued problem for SSB-less Scell is existing needs RAN4 input and verification, which is out of RAN1 capability. Besides, the definition of RTD measurement based on on-demand SSB seems out of current WID scope.

Observation 1: RAN4 input on the problem of SSB-less Scell is needed to verify the motivation to support on-demand SSB in SSB-less Scell.

Proposal 3: Do not discuss support of on-demand SSB in SSB-less SCell where reference cell is configured until more RAN4 input is available.

3. Limitation of on-demand 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

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

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.

Based on the first agreement in the above, one FFS point is whether to support that OD-SSB is CD-SSB located on sync-raster. In our opinion, the on-demand SSB should not be CD-SSB located on sync raster. If on-demand SSB is associated with SIB#1, SSB period needs to be indicated in the SIB1, then UE may misunderstand that the detected SSB is periodically transmitted. However, the on-demand SSB is actually a 'short term' signal for measurement. This misalignment will impact the legacy UEs. For example, when a legacy UE detects an on-demand CD-SSB associated with SIB#1, it will regard this as an accessible serving cell where the SSB is periodically transmitted as configured by SIB1. However, when on-demand SSB terminates its transmission, legacy UE will see a connection failure, which will degrade the legacy UE's UE experience. Therefore, OD-SSB for CD-SSB located on sync raster shouldn't be supported to avoid such impact to legacy UEs.

Proposal 4: For a cell supporting on-demand SSB SCell operation, do not support that on-demand SSB on the cell is CD-SSB located on synchronization raster.

Furthermore, whether OD-SSB is allowed to be located in different frequency with always-on SSB for case 2 should be determined. In our understanding, if always-on SSB and on-demand SSB locate in different frequencies, UE needs to retune RF chain to search on-demand SSB after on-demand SSB is activated. Then there would be an interruption time similar with BWP switching where UE can't transmit or receive on all the serving cells. Thus, restricting always-on SSB and on-demand SSB locate in a same frequency is needed to avoid interruption and performance impact to UE due to RF retuning. Besides, OD-SSB should be NCD-SSB since OD-SSB is limited to SSB not on sync raster or NCD-SSB.

Observation 2: There will be interruption to UE when OD-SSB is triggered in different frequency location with always-on SSB.

Proposal 5: For on-demand SSB on the cell, support 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 where on-demand SSB is NCD-SSB.

Proposal 6: For on-demand SSB on the cell, support 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 where on-demand SSB is NCD.

Regarding the relation between on-demand SSB and always-on SSB in time-domain, there is no special reason to limit that always-on SSB and on-demand overlap in time-domain. Especially when the transmission parameters of on-demand SSB and always-on SSB are nearly identical. Notably, if the periodicity of on-demand SSB is set to 5ms, an overlap would always occur because the on-demand SSB is transmitted in every half frame. Therefore, there is no need to restrict that whether there is time-domain overlap between always-on SSB and on-demand SSB or not.

Proposal 7: Whether always-on SSB and on-demand SSB overlapping in time-domain is not restricted.

4. Timing of On-demand SSB operation

4.1. Start timing after on demand SSB indication (Time instance A)

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.

Since the RRC signalling has been agreed to indicate the transmission of on-demand SSB and the processing time of RRC signalling is different from that of MAC CE, it is important to determine the time instance A for SSB burst(s) indicated by on-demand SSB SCell operation via a RRC message. Otherwise, UE would not know when to start to receive the on-demand SSB, potentially resulting in misalign with the network regarding the ending time of the 'short-term' on-demand SSB transmission if it is indicated to transmit N times.

Similarly, the time instance A could also be 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' slots after the slot where UE receives a signalling from gNB to indicate on-demand SSB transmission. The difference lies in the value of T', since the processing time of RRC signalling is different from that of MAC CE. Similar to the timeline of MAC CE indicating on-demand SSB transmission, after the network activate the on-demand SSB through RRC reconfiguration message, UE would response an *RRCReconfigurationcomplete* message. Then network starts to transmit on-demand SSB. Therefore, the value of T' should at least contains the time gap between the slot where UE receives a signalling from gNB to indicate on-demand SSB transmission to the time instance where the network successfully complete the process of *RRCReconfigurationcomplete* message. Hence, T' is not less than T_min' = $T_{RRC\_process}$ + T1 + T2 , where $T_{RRC\_process}$ is the requirement time from the end of the reception of RRCReconfiguration message to the time when the UE shall be ready for the reception of uplink grant for UE, i.e. RRC procedure delay defined in TS38.331, as shown in Figure 2. T1 is the delay from slot $n' + \frac{T_{RRC\_Process}}{NR\ slot\ length}$ until the transmission of *RRCReconfigurationcomplete* message and slot n' is the last slot overlapping with the PDSCH containing the RRC reconfiguration message. In addition, T2 is the *Reconfigurationcomplete* message processing delay in network and could be 3ms [3].

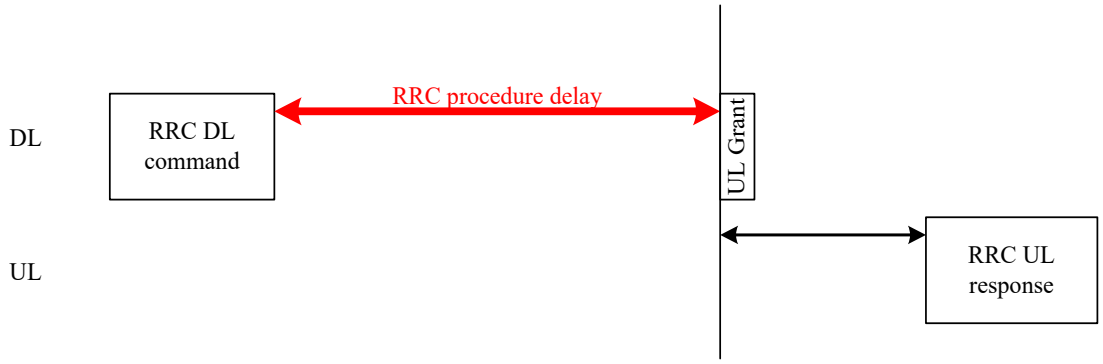

Figure 2: Illustration of RRC procedure delay

Proposal 8: Time instance A 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' slots after the slot where UE receives a RRCReconfiguration message from gNB to indicate on-demand SSB transmission.

Proposal 9: T' is not less than T_min' = $T_{RRC\_process} + T1 + T2$***, where*** $T_{RRC\_process}$ ***is the RRC procedure delay. T1 is the delay from slot*** $n' + \frac{T_{RRC\_Process}}{NR\ slot\ length}$ ***until the transmission of RRCReconfigurationcomplete message and slot n' is the last slot overlapping with the PDSCH containing the RRC reconfiguration message. In addition, T2 is the RRCReconfigurationcomplete message processing delay in network.***

When SCell with on-demand SSB transmission and the cell with signalling transmission have different numerologies, the value of T is different in different cells, and it's not clear in which cell the slot n is determined. One alternative is to determine time instance A with the numerology of the cell with signalling transmission. And slot n is the slot where UE receives signalling from gNB in the cell with signalling transmission. Another alternative is to determine time instance A with the numerology of SCell with on-demand SSB transmission since the on-demand SSB transmission is performed on this cell. Correspondingly, slot n should be the slot in the SCell with on-demand SSB transmission overlapped with the slot where UE receives signalling from gNB in the cell with signalling transmission.

By contrast, it's more preferred to determine time instance A with the numerology of the cell with signalling transmission, to keep the same with the numerology of the signalling transmission, since the processing time is related to the numerology of the signalling.

Proposal 10: When SCell with on demand SSB transmission and cell with signalling transmission have different numerologies, the value of T is determined with the numerology of the cell with signalling transmission.

4.2. End timing for on demand SSB transmission

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 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

In the last meeting, Option 1 (i.e. explicit indication of deactivation for on-demand SSB via MAC CE) and Option 2 (i.e. configuration/indication of the number N of on-demand SSB bursts to be transmitted) have been supported to deactivate on-demand SSB transmission with several FFS points.

Regarding "FFS: Which scenario Option 1 is used", it is preferred NOT to apply option 1 for case 1. In Case #1, where there is no always-on SSB on the SCell, UE would perform synchronization and AGC periodically on this cell for data transmission and reception after the completion of SCell activation. Thus, on-demand SSB should not terminate before the SCell deactivation, ensuring continuous periodic SSB transmission for synchronization and AGC procedure once activated alongside the SCell activation command. For OD-SSB activation in Scenario #2, Option 2 is enough since the intention is to perform L3 measurement which needs only a number of SSB occasions. If Option 1 is enabled especially for scenario #2A, OD-SSB can be deactivated any time so that it means there may be no SSBs after the completion of SCell activation, which is not acceptable from UE side. Thus Option 1 is not applicable for Case #1 and other option is needed to ensure that there is continuous SSB after the completion of SCell activation and before Scell deactivation.

Proposal 11: Option 1 is not applied to Case #1.

As analyzed above for case 1, other option is needed to ensure that there is continuous SSB after the completion of SCell activation and before Scell deactivation when there is no always-on SSB. Naturally, Option 4 and 4a can achieve this purpose.

Proposal 12: Support Option 4 and 4a for Case #1 in addition to Option 2.

To maintain a unified design, a specific value of N could indicate the number N of on-demand SSB bursts to be transmitted after on-demand SSB is indicated, i.e. Option 2. And a nonnumerical indication of N could indicate that on-demand SSB transmission is deactivated along with the deactivation of SCell.

Proposal 13: A nonnumerical indication of N indicates that on-demand SSB transmission is deactivated along with the deactivation of SCell.

A remaining FFS states that whether the value of N can be implicitly determined using a timer. In our opinion, the time of on-demand SSB transmission depends on different Scenario and different period. Thus, it is difficult to configure only several values of transmission timer. In addition, how to determine the start of this timer also needs to be decided. Given Option 2 has been agreed, there is no need to introduce another similar method requiring more efforts.

Proposal 14: Do not support that the value of N can be implicitly determined using a timer.

5. Configuration of On-demand SSB operation

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

- 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

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, 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, 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*)

When there is no always-on SSB on the cell, i.e. Case #1, the on-demand SSB configuration should be provided to UE to determine how to receive on-demand SSB and the parameters shown below have been agreed in the previous meetings.

- ***Frequency of the on-demand SSB***
- ***Periodicity of the on-demand SSB***
- ***SSB positions within an on-demand SSB burst***
- ***Sub-carrier spacing of the on-demand SSB***
- ***Physical Cell ID of the on-demand SSB***

- ***Downlink transmit power of on-demand SSB***
- ***SFN offset***
- ***half frame index***
- ***The number N of on-demand SSB bursts to be transmitted***

In the last meeting, it has been agreed that configuring the time domain location of on-demand SSB per on-demand SSB periodicity by RRC for Case #1 based on SFN offset and half frame index. However, the configuration approach for on-demand SSB in the presence of periodically transmitted always-on SSB has not been finalized. One alternative is to adopt a unified configuration method as in Case #1, while another alternative is to introduce a time offset between always-on SSB and on-demand SSB. In our opinion, there is no need to introduce additional parameter, as the time domain location parameter is already defined. It would be simpler to adopt the same configuration method as in Case #1.

Proposal 15: For Case #2 (i.e., Always-on SSB is periodically transmitted on the cell), support Alt A that the configuration method of time domain location of on-demand SSB is same as for Case #1.

Similarly, to support on-demand SSB SCell operation, the other parameters provided by RRC for Case #1 should also be extended for Case #2. However, when always-on SSB is periodically transmitted on the cell, there would already be overall configurations about always-on SSB in the serving cell configuration. Thus if a parameter of on-demand SSB matches that of always-on SSB, it need not be reconfigured by the RRC. Then, it is essential to first determine which parameters for on-demand SSB are identical to those of always-on SSB.

As analyzed in Chapter 3, it is crucial to ensure that always-on SSB and on-demand SSB operate on the same frequency to prevent interruptions caused by RF retuning between them. Furthermore, there is no motivation to support a different SCS or downlink transmit power for on-demand SSB, and the Physical Cell ID should be consistent across both types of SSB. Consequently, the parameters, e.g. Physical Cell ID, sub-carrier spacing, frequency, and downlink transmit power can be referred to the configuration of always-on SSB.

Proposal 16: For a cell supporting on-demand SSB SCell operation, at least the following parameters for on-demand SSB configuration can be referred to the configuration of always-on SSB for Case #2:

- ***Frequency of the on-demand SSB***
- ***Sub-carrier spacing of the on-demand SSB***
- ***Physical Cell ID of the on-demand SSB***
- ***Downlink transmit power of on-demand SSB***

As on-demand SSB is mainly designed to accelerate the procedure of SCell measurement and SCell activation, the periodicity would be probably shorter than that of always-on SSB. Moreover, to further achieve the power saving of the network, the transmitted on-demand SSB positions in burst could only be part of the always-on SSB positions in burst, as some beams of SSB are useless for UE.

Proposal 17: For a cell supporting on-demand SSB SCell operation, support to independently provide at least the following parameters for on-demand SSB configuration by RRC for Case #2:

- ***Periodicity of the on-demand SSB***
- ***SFN offset***
- ***half frame index***
- ***SSB positions within an on-demand SSB burst***
- ***The number N of on-demand SSB bursts to be transmitted***

The discussion revolved around whether the RRC parameters for on-demand SSB should reuse existing legacy RRC parameters or employ new ones. If legacy RRC parameters are reused, there must be a mechanism to indicate whether the SSB-related parameters pertain to on-demand SSB or always-on SSB. This ensures that even if the parameter names remain unchanged, the UEs can identify which type of SSB the parameters apply to. However, as highlighted earlier, certain parameters, such as periodicity, differ between on-demand and always-on SSB and the transmission number of SSB has not been defined in legacy. This necessitates the introduction of new RRC parameters. Therefore, to maintain simplicity and a unified design, it is advisable to configure some new parameters for on-demand SSB

Proposal 18: The parameters for on-demand SSB configuration are configured by new parameters for both Case #1 and Case #2.

A remaining issue is to identify whether there is other relevant parameter than periodicity could be configured with multiple values by RRC and the applicable value is indicated by MAC CE. First, there should be multiple candidate values for parameter N to support different on-demand SSB transmission durations across various scenarios. Similarly, the transmitted on-demand SSB positions in burst could also be configured with multiple

candidate types, and the final transmitted pattern is indicated by MAC CE for different scenarios, as the suitable beam may be changed with the mobility of UE.

Proposal 19: For a cell supporting on-demand SSB SCell operation, the on-demand SSB transmission number N and SSB positions in burst can be configured with multiple candidate values by RRC and the applicable value can be indicated by MAC CE.

6. L1 measurement and report

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 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

6.1. On-demand SSB for CSI report

When always-on SSB is periodically transmitted on the cell, there would be two kinds of SSB on the cell. Then when UE performs L1 measurement report, it should be determined whether the CSI report configuration is associated with both on-demand SSB and always-on SSB (i.e. Option 1), or only one of always-on SSB and on-demand SSB (i.e. Option 2).

When CSI report configuration is associated with both on-demand SSB and always-on SSB, the associated SSB resources would be uneven given the on-demand SSB is tiggered by network dynamically. This is a new behavior compared to legacy and will increase the complexity of UE. Moreover, as the periodicity of on-demand SSB and always-on SSB is different, if the periodicity of CSI report is the same as the periodicity of on-demand SSB, there might be no measurement resource between the two report resources after on-demand SSB is deactivated as shown in Figure 3, given the periodicity of always-on SSB is much longer than on-demand SSB. In this case, the report resource would be wasted if UE report the measurement result obtained in last CSI report period again or does not report in this report resource.

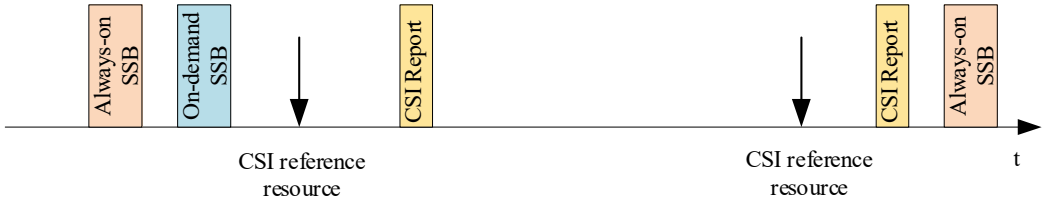

Figure 3: No SSB before CSI reference resource in some CSI report period

When CSI report configuration is associated with one of on-demand SSB and always-on SSB, the existing CSI report configuration and mechanism can be mostly reused. The only question that needs to be solved is how to distinguish the CSI resource associated with a CSI report configuration is always-on SSB or on-demand SSB. One possible method is to introduce a dedicated CSI report configuration for on-demand SSB, e.g. *ODSSB-CSI-reportconfig*, then UE could know the associated SSB type directly. Another possible method is to indicate the SSB type in the resource config associated with the CSI report configuration. UE could also determine which SSB is associated with the report configuration.

By contrast, Option 2, i.e. a CSI report configuration is associated with one of always-on SSB and on-demand SSB, is more simple and has less spec impact when always-on SSB is periodically transmitted on the cell.

Proposal 20: For UE to perform L1 measurement based on on-demand SSB when always-on SSB is periodically transmitted on the cell, Option 2, i.e. a CSI report configuration is associated with one of always-on SSB and on-demand SSB, is supported.

In legacy, semi-persistent CSI report could be triggered by MAC CE or DCI, and aperiodic CSI report is triggered by DCI. A associated *CSI-reportconfig* is indicated in trigger signalling, then UE could determine the resource location and the resource type to perform measurement. Similarly, for a cell configured with on-demand SSB, UE could distinguish whether to measure on-demand SSB or always-on SSB through the associated report configuration. Thus, reusing the triggering/activation mechanisms for semi-persistent and aperiodic CSI report based on on-demand SSB is enough.

Proposal 21: Semi-persistent and aperiodic CSI report configuration can be associated with any kind of on-demand SSB.

However, how to support triggering periodic CSI report based on on-demand SSB should be further studied. In legacy, periodic CSI report should be associated with a periodic measurement resource. But on-demand SSB would be deactivated after a short duration in most scenarios, thus it is more like a semi-persistent resource. Hence, to support periodic CSI report, one possible method is to allow triggering periodic CSI report based on on-demand SSB only when on-demand SSB is activated at the time SCell is configured to UE through RRC signalling and is deactivated along with the deactivation of SCell. In this case, on-demand SSB could be considered a periodic resource.

Proposal 22: Periodic CSI report configuration can only be associated with on-demand SSB that is activated through RRC signalling and will be deactivated along with the deactivation of SCell.

6.2. On-demand SSB for LTM

LTM is a procedure in which a gNB receives L1 measurement report(s) from a UE, and on their basis the gNB may change UE serving cell by using a cell switch command signalled via a MAC CE. The cell switch command indicates an LTM candidate configuration that the gNB previously prepared and provided to the UE through RRC signalling. Then the UE switches to the target configuration according to the cell switch command. The LTM procedure can be used to reduce the mobility latency.

To be specific, a UE can be indicated SSB per candidate cell for the UE to obtain synchronization and measure corresponding L1-RSRPs. In addition, a Candidate Cell TCI States Activation/Deactivation MAC CE can activate TCI states associated with SSB of corresponding candidate cells. This allows the UE to be DL synchronized with those cells, thereby facilitating a faster cell switch to one of those cells. And the UE can be triggered a PRACH transmission on a candidate cell by a PDCCH order that the UE receives on a serving cell and includes an SSB indication of the candidate cell for the PRACH transmission. Then UE could perform RACH-less LTM cell switch procedure.

It can be seen that a periodical SSB transmission is necessary for UE to perform the LTM procedure in legacy. If there is only on-demand SSB transmission in a cell, this cell should transfer the SSB transmission pattern after configured as a LTM candidate cell. Then the cell cannot further obtain the network power saving gain. Thus, if on-demand SSB is supported for LTM, the network could still maintain the power saving state even if being configured as a LTM candidate cell. In addition, the on-demand SSB transmission could shorten the delay of the synchronization and measurement procedure to further reduce the mobility latency as the on-demand SSB could adopt a shorter periodicity.

However, the on-demand SSB triggered in Scenario #2 and Scenario #2A would likely be deactivated after a short-term transmission. Then if the SSB resource configured in the LTM candidate cell is the on-demand SSB indicated in Scenario #2 and Scenario #2A, there may be no transmitted SSB for UE to measure during the LTM procedure after the on-demand SSB deactivates. To solve this problem, it is better to allow that on-demand SSB could be triggered by the related LTM signaling, e.g. LTM configuration message, or triggered during the LTM procedure. But obviously, this is an absolutely separate issue from the on-demand SSB SCell operation we discussed in the last few meetings. Hence, we prefer to prioritize the discussion about on-demand SSB SCell operation in this stage and deprioritize the discussion about the support of LTM.

Proposal 23: Deprioritize the discussion on support of LTM based on OD-SSB before OD-SSB for Scell measurement and activation is finalized.

7. Collision between on-demand SSB transmission and other transmissions

In legacy, there might be collision between SSB reception and other UL transmissions, e.g. PUSCH, PUCCH or PRACH. UE would not transmit the UL transmission in the slot overlap with SSB reception as shown in below:

TS 38.213 Clause 11.1

If a UE

- is configured with multiple serving cells and is provided with *directionalCollisionHandling-r16* = 'enabled' for a set of serving cell(s) among the multiple serving cells, and
- indicates support of *half-DuplexTDD-CA-SameSCS-r16* capability, and
- is not configured to monitor PDCCH for detection of DCI format 2_0 on any of the multiple serving cells,

for a set of symbols of a slot that are indicated to the UE for reception of SS/PBCH blocks in a first cell of the multiple serving cells by *ssb-PositionsInBurst* in *SystemInformationBlockType1* or by *ssb-PositionsInBurst* in *ServingCellConfigCommon* or, if the UE is not provided *dl-OrJointTCI-StateList*, by *ssb-PositionsInBurst* in *SSB-MTCAdditionalPCI* associated to physical cell ID with active TCI states for PDCCH or PDSCH, or for a set of symbols of a slot corresponding to SS/PBCH blocks configured for L1 beam measurement/reporting, the UE does not transmit PUSCH, PUCCH, or PRACH in the slot if a transmission would overlap with any symbol from the set of symbols, and the UE does not transmit SRS in the set of symbols of the slot in

- any of the multiple serving cells if the UE is not capable of simultaneous transmission and reception as indicated by *simultaneousRxTxInterBandCA* among the multiple serving cells, and
- any one of the cells corresponding to the same band as the first cell, irrespective of any capability indicated by *simultaneousRxTxInterBandCA*.

Similarly, the collision between on-demand SSB and other transmission would also exists. Then how to solve the collision in on-demand SSB operation should be studied. One possible method is to perform a prioritization procedure between on-demand SSB transmission and other transmissions. In legacy, SSB transmission would prioritize other transmission. Similarly, when on-demand SSB collides with other transmissions, on-demand SSB could prioritize over those transmissions.

Proposal 24: To support on-demand SSB operation, prioritize the on-demand SSB transmission if there is collision between on-demand SSB and other transmission.

8. On-demand SSB for BFD

In the previous meetings, it was proposed by some companies to consider supporting on-demand SSB for BFD. However, in legacy, the RS resource configuration in the *failureDetectionResourcesToAddModList* set on SCell could only be periodic CSI-RS as shown below, which means SSB could not be used for BFD on SCell.

TS 38.133 Clause 8.5.1

The UE shall assess the downlink radio link quality of a serving cell based on the reference signal in the set $\overline{q}_0$ as specified in TS 38.213 [3] in order to detect beam failure on:

- PCell in SA, NR-DC, or NE-DC operation mode,
- PSCell in NR-DC and EN-DC operation mode,
- SCell in SA, NR-DC, NE-DC or EN-DC operation mode,
- Deactivated PSCell in NR-DC and EN-DC operation mode

The RS resource configurations in the set $\overline{q}_0$ on PCell, PSCell or deactivated PSCell (if configured with *bfd-and-RLM* with value *true*) can be periodic CSI-RS resources and/or SSBs. RS resource configuration in the set $\overline{q}_0$ on SCell shall be periodic CSI-RS. UE is not required to perform beam failure detection outside the active DL BWP unless the UE supports *bwpOperationMeasWithoutInterrupt-r18*, provided that the SSB is within the configured UE-specific CBW.

It is because that the QCL source in the TCI state of PDCCH could only be CSI-RS, not an SSB, this limitation arises because the bandwidth of the SSB is likely different from that of the PDCCH, and the beam configuration of the SSB may differ from that of the PDCCH. Given the basic design of on-demand SSB wouldn't be different from the existing SSB, the same drawbacks persist when using on-demand SSBs as a reference resource for BFD. Hence, on-demand SSB should not be used for BFD on SCell either.

Observation 3: SSB is not used for BFD on Scell in legacy.

Proposal 25: Do not support on-demand SSB for BFD on Scell.

9. RRC Parameters

According to the existing agreements, some parameters of on-demand SSB have been agreed to be configured by RRC signalling. Hence, the following RRC parameter is given:

Sub-feature group	RAN2 Parent IE	Parameter name in the spec	New or existing?	Description	Value range	Default value aspect	Per (UE, cell, TRP, …)	Required for initial access or IDLE/INACTIVE
OD-SSB	ServingCellConfigCommon	On-demandSSBConfig	New	Configure parameters of on-demand SSB. The parameters include: 0) Frequency 1) Periodicity 2) SSB positions within an on-demand SSB burst 4) Sub-carrier spacing 5) Physical Cell ID 6) Downlink transmit power 7) SFN offset 8) half frame index 9) The number N of on-demand SSB bursts to be transmitted			Per cell	No
OD-SSB	On-demandSSBConfig	odssbFrequency	New	Indicates the frequency of the On-demand SSB.	ARFCN-ValueNR		Per cell	No

OD-SSB	On-demandSSBConfig	odssb-periodicity	New	Indicates the periodicity of the On-demand SSB	ENUMERATED {ms5, ms10, ms20, ms40, ms80, ms160}		Per cell	No
OD-SSB	On-demandSSBConfig	odssb-PositionsInBurst	New	Indicates the time domain positions of the transmitted On-demand SS-blocks in a half frame with On-demand SS/PBCH block as defined in TS 38.213 [13], clause 4.1. The first/leftmost bit corresponds to On-demand SS/PBCH block index 0, the second bit corresponds to On-demand SS/PBCH block index 1, and so on. Value 0 in the bitmap indicates that the corresponding On-demand SS/PBCH block is not transmitted while value 1 indicates that the corresponding On-demand SS/PBCH block is transmitted.	CHOICE { BIT STRING (SIZE (4)), BIT STRING (SIZE (8)), BIT STRING (SIZE (64)))}		Per cell	No
OD-SSB	On-demandSSBConfig	odssbSubcarrierSpacing	New	Subcarrier spacing of On-demand SSB	SubcarrierSpacing		Per cell	No
OD-SSB	On-demandSSBConfig	physCellId	New	Indicates the cell related to On-demand SSB	PhysCellId		Per cell	No
OD-SSB	On-demandSSBConfig	odssbPower	New	Average EPRE of the resources elements that carry secondary synchronization signals in dBm that the NW used for On-demand SSB transmission, see TS 38.213 [13], clause 7	INTEGER (-60..50)		Per cell	No
OD-SSB	On-demandSSBConfig	Sfn-odssb-offset	New	Indicates the SFN offset of the transmitted On-demand SSB relative to the start of the On-demand SSB period. Value 0 indicates that the On-demand SSB is transmitted in the first system frame, value 1 indicates that On-demand SSB is transmitted in the second system frame and so on.	INTEGER (0..15)	0	Per cell	No

OD-SSB	On-demandSSBConfig	HalfFrameIndex-odssb	New	Indicates whether On-demand SSB is in the first half or the second half of the frame. Value zero indicates the first half and value 1 indicates the second half.	ENUMERATED {zero, one}	0	Per cell	No
OD-SSB	On-demandSSBConfig	Odssb-transmissionNumber	New	Indicates the number N of on-demand SSB bursts to be transmitted			Per cell	No

10. Conclusion

This contribution focuses on the discussion of on-demand SSB for SCell with the following observations and proposals:

Observation 1: RAN4 input on the problem of SSB-less Scell is needed to verify the motivation to support on-demand SSB in SSB-less Scell.

Observation 2: There will be interruption to UE when OD-SSB is triggered in different frequency location with always-on SSB.

Observation 3: SSB is not used for BFD on Scell in legacy.

Proposal 1：For on-demand SSB SCell operation, support Scenario #3A and it is up to gNB implementation to indicate on-demand SSB in Scenario #2A or Scenario #3A.

Proposal 2: For on-demand SSB SCell operation, do not support Scenario #3B, i.e., on-demand SSB should not be indicated by gNB after SCell activation is complete.

Proposal 3: Do not discuss support of on-demand SSB in SSB-less SCell where reference cell is configured until more RAN4 input is available.

Proposal 4: For a cell supporting on-demand SSB SCell operation, do not support that on-demand SSB on the cell is CD-SSB located on synchronization raster.

Proposal 5: For on-demand SSB on the cell, support 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 where on-demand SSB is NCD-SSB.

Proposal 6: For on-demand SSB on the cell, support 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 where on-demand SSB is NCD.

Proposal 7: Whether always-on SSB and on-demand SSB overlapping in time-domain is not restricted.

Proposal 8: Time instance A 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' slots after the slot where UE receives a RRCReconfiguration message from gNB to indicate on-demand SSB transmission.

Proposal 9: T' is not less than T_min' $= \mathrm{T}_{\mathrm{RRC\_process}} + \mathrm{T1} + \mathrm{T2}$***, where*** $\mathrm{T}_{\mathrm{RRC\_process}}$ ***is the RRC procedure delay. T1 is the delay from slot*** $\mathrm{n}' + \frac{\mathrm{T}_{\mathrm{RRC\_Process}}}{\text{NR slot length}}$ ***until the transmission of RRCReconfigurationcomplete message and slot n' is the last slot overlapping with the PDSCH containing the RRC reconfiguration message. In addition, T2 is the RRCReconfigurationcomplete message processing delay in network.***

Proposal 10: When SCell with on demand SSB transmission and cell with signalling transmission have different numerologies, the value of T is determined with the numerology of the cell with signalling transmission.

Proposal 11: Option 1 is not applied to Case #1.

Proposal 12: Support Option 4 and 4a for Case #1 in addition to Option 2.

Proposal 13: A nonnumerical indication of N indicates that on-demand SSB transmission is deactivated along with the deactivation of SCell.

Proposal 14: Do not support that the value of N can be implicitly determined using a timer.

Proposal 15: For Case #2 (i.e., Always-on SSB is periodically transmitted on the cell), support Alt A that the configuration method of time domain location of on-demand SSB is same as for Case #1.

Proposal 16: For a cell supporting on-demand SSB SCell operation, at least the following parameters for on-demand SSB configuration can be referred to the configuration of always-on SSB for Case #2:

- ***Frequency of the on-demand SSB***
- ***Sub-carrier spacing of the on-demand SSB***
- ***Physical Cell ID of the on-demand SSB***
- ***Downlink transmit power of on-demand SSB***

Proposal 17: For a cell supporting on-demand SSB SCell operation, support to independently provide at least the following parameters for on-demand SSB configuration by RRC for Case #2:

- ***Periodicity of the on-demand SSB***
- ***SFN offset***
- ***half frame index***
- ***SSB positions within an on-demand SSB burst***
- ***The number N of on-demand SSB bursts to be transmitted***

Proposal 18: The parameters for on-demand SSB configuration are configured by new parameters for both Case #1 and Case #2.

Proposal 19: For a cell supporting on-demand SSB SCell operation, the on-demand SSB transmission number N and SSB positions in burst can be configured with multiple candidate values by RRC and the applicable value can be indicated by MAC CE.

Proposal 20: For UE to perform L1 measurement based on on-demand SSB when always-on SSB is periodically transmitted on the cell, Option 2, i.e. a CSI report configuration is associated with one of always-on SSB and on-demand SSB, is supported.

Proposal 21: Semi-persistent and aperiodic CSI report configuration can be associated with any kind of on-demand SSB.

Proposal 22: Periodic CSI report configuration can only be associated with on-demand SSB that is activated through RRC signalling and will be deactivated along with the deactivation of SCell.

Proposal 23: Deprioritize the discussion on support of LTM based on OD-SSB before OD-SSB for Scell measurement and activation is finalized.

Proposal 24: To support on-demand SSB operation, prioritize the on-demand SSB transmission if there is collision between on-demand SSB and other transmission.

Proposal 25: Do not support on-demand SSB for BFD on Scell.

Reference

[1] 3GPP TSG RAN Meeting #102, Edinburgh, Scotland, December 11th-15th, 2023, New WID: Enhancements of network energy savings for NR, RP-234065

[2] 3GPP TS 38.331, Radio Resource Control (RRC) protocol specification.

[3] 3GPP TR 37.910, Study on self evaluation towards IMT-2020 submission Chapter 5.7.2.1.