3GPP TSG RAN WG1 #120 **R1-2500967**

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Source: **Transsion Holdings**

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

Agenda item: **9.5.1**

Document for: **Discussion & Decision**

1. Introduction

In RAN1#119 meeting, the following agreements[1] on on-demand SSB SCell operation were achieved：

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. RAN1 is discussing whether to introduce other periodicity value(s) for on-demand SSB.
- 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

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

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

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.

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 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

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*)

In this contribution, some considerations for on-demand SSB SCell operation will be discussed.

2. On-demand SSB SCell operation

2.1. Scenarios for on-demand SSB

In the RAN1#116bis meeting, the scenarios for on-demand SSB were discussed and the following consensus was reached:

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.

First, we explain the definitions of the scenarios and cases mentioned in the above agreements as follows::

- Scenario #2: SCell is configured to a UE but before the UE receives SCell activation command (e.g., as defined in TS 38.321)
- Scenario #2A: When UE receives SCell activation command (e.g., as defined in TS 38.321)
- Scenario #3A: After UE receives SCell activation command (e.g., as defined in TS 38.321) until SCell activation is completed
- Scenario #3B: When SCell activation is completed and SCell is activated or After SCell activation is completed and SCell is activated
- Case #1: No always-on SSB on the cell
- Case #2: Always-on SSB is periodically transmitted on the cell

Second, according to the RAN1#118bis meeting agreement on the deactivation of on-demand SSB transmission, on-demand SSB supports multiple transmissions (e.g., N transmissions), rather than just a single instantaneous transmission.

In addition, in the RAN1#116bis meeting, it was agreed that on-demand SSB transmission applies to Scenario #2A.

Based on the above analysis, it can be inferred that Scenario #2A actually covers Scenario #3A. Therefore, if the majority of companies prefer not to consider scenario #3A, we can also accept this.

Proposal 1 Scenario 3A could be considered for exclusion.

For Scenario #3B, SSB is mainly used to maintain downlink synchronization, perform L1/L3 measurements and beam management. Supporting on-demand SSB transmission enables the gNB to perform SSB transmission only when synchronization or measurement is really needed. This method not only effectively reduces the network energy consumption, but also helps the UEs to quickly obtain on-demand SSB when downlink or uplink traffic bursts occur, and quickly complete SCell synchronization and AGC compensation, thereby significantly reducing the transmission delay of the UE. In other words, scenario #3B can support on-demand SSB transmission.

In addition, after the SCell activation is completed, there may be a period of time when no traffic is transmitted, at which time you can choose to stop SSB transmission or use a longer period of always-on SSB transmission to save network energy.

In summary, at least Scenarios#3B and case#1 and Scenario#3B and case#2 can be considered under the condition of ensuring that it does not lead to a significant increase in network energy consumption.

Proposal 2 Scenarios 3B and Case #1 and Scenario #3B and Case #2 should be supported.

After discussing the scenarios for on-demand SSB, let's discuss the types of on-demand SSB. For the types of on-demand SSB, the following consensus was reached in the RAN1#118 meeting:

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

First, considering that a cell may be used simultaneously as a Scell by one UE and as a Pcell by another UE, if the on-demand SSB of the cell is CD-SSB, it may affect the camping and system information acquisition of some UEs in the cell.

In addition, if the on-demand SSB is CD-SSB, in order to avoid its impact, we must restrict the cell supporting on-demand SSB from being used as a Pcell by any UE. However, this restriction reduces the flexibility of cell configuration. Therefore, On-demand SSB for CD-SSB located on synchronization raster cannot be supported.

Proposal 3 On-demand SSB for CD-SSB located on synchronization raster cannot be supported.

2.2. Frequency location of on-demand SSB

In the RAN1#119 meeting, the following agreement was reached.

Agreement（ RAN1#119 meeting）

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.

First, as analyzed in section 2.1, on-demand SSB should not be located on synchronization raster, or should be a non-cell-defining SSB. Second, if the CD-SSB of the Scell supporting the on-demand SSB is restricted to not being located on the synchronization raster, then the Scells supporting the on-demand SSB operation will be very limited. Therefore,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.

Proposal 4 It is recommended to support 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.

Given that CD-SSB is mainly used for cell identification and camping by UEs, it must be located on the synchronization raster. Therefore, it is not allowed to support the case where always-on SSB is CD-SSB and not on a synchronization raster.

Proposal 5 It is recommended to support Alt C: Do not support the case where always-on SSB is CD-SSB and not on a synchronization raster.

2.3. Signaling of on-demand SSB operation

For signaling of on-demand SSB operation, the previous meeting reached the following agreement:

Agreement(RAN1#117 meeting)

For a cell supporting on-demand SSB SCell operation,

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

Agreement(RAN1#118 meeting)

For a cell supporting on-demand SSB SCell operation,

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

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

First, when RRC signaling or MAC CE signaling is used to indicate both Scell activation and on-demand SSB transmission, the application time of RRC signaling or MAC CE signaling will be relatively long which will inevitably increase the SSB transmission delay.

Secondly, when RRC signaling or MAC CE signaling is used to indicate both Scell activation and on-demand SSB transmission, if activation/deactivation of on-demand SSB transmission is required, the Scell needs to be activated/deactivated frequently, which will undoubtedly increase the energy consumption of the UE.

In addition, even if RRC signaling or MAC CE signaling separately indicates Scell activation and on-demand SSB transmission, since RRC signaling and MAC CE signaling generally require HARQ-ACK feedback, whereas DCI signaling does not require HARQ-ACK feedback, the delay of SSB transmission can be effectively reduced by indicating on-demand SSB transmission via DCI signaling.

In summary, DCI based signaling can be used to indicate on-demand SSB transmission.

Proposal 6 DCI based signaling to indicate on-demand SSB transmission can be supported.

Finally, since the scenarios supported by on-demand SSB transmission are based on the Scell activation status, i.e., the scenarios of on-demand SSB transmission are defined from the UE's perspective. Therefore, if DCI-based signaling is supported to indicate on-demand SSB transmission, we prefer to design DCI as UE-specific signaling.

Proposal 7 If DCI based signaling support on-demand SSB transmission, DCI is UE-specific.

2.4. Deactivation of on-demand SSB transmission

In previous meeting, the following agreement was reached.

Agreement(RAN1#118bis meeting)

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（ RAN1#119 meeting）

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

Since on-demand SSB transmission is mainly applied to Scells, when a Scell is deactivated, its corresponding on-demand SSB transmission should also be deactivated. In other words, any operation of deactivating a Scell should also be applicable to deactivating the on-demand SSB transmission of the Scell by default. Therefore, Option 4, 4a can be used to deactivate on-demand SSB transmission.

Proposal 8 Option 4, 4a can be used to deactivate on-demand SSB transmission.

2.5. Time domain location of on-demand SSB

In RAN1#119 meeting, the following agreement was reached.:

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*)

For case#2, due to the existence of always-on SSB, on-demand SSB can rely on the system frame number (SFN) and half-frame position of the always-on SSB to determine its candidate SFN and half-frame position. Specifically, the SFN

and half-frame position of the on-demand SSB can be determined based on the time domain position of the always-on SSB in SFN 0 and the predefined or configured time offset between the always-on SSB and the on-demand SSB.

Proposal 9 For case #2, it is recommended to support 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).

2.6. TX behavior of on-demand SSB burst

For the TX behavior of on-demand SSB burst, the main discussion is about time instance A , which is related to on-demand SSB transmission. Currently, when MAC CE is used to indicate on-demand SSB transmission, the relevant agreement of time instance A are as follows:

Agreement (RAN1#118bis)

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 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 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 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.

In addition, according to the discussion in RAN1#118 meeting, RRC can also be used to indicate on-demand SSB transmission. Therefore, similar to MAC CE, the definition of time instance A also needs to be discussed for RRC.

Agreement(RAN1#118 meeting)

For a cell supporting on-demand SSB SCell operation,

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

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

Specifically, similar to the MAC CE, an application time T_RRC can be defined for the RRC. In addition, the value of T_RRC can be related to the RRC process delay $T_{RRC\_Process}$. For example, when adding a Scell via RRC, the RRC

process delay required from the time an RRC reconfiguration message is sent to the completion of the RRC reconfiguration message is 16ms. Finally, similar to MAC CE, the time instance A in RRC is defined as follows:

- For SSB burst(s) indicated by on-demand SSB SCell operation via RRC, UE expects that on-demand SSB burst(s) is transmitted from time instance A which is determined as follows.
    - 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_RRC 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
    - RAN2/RAN4 to confirm the minimum value for T_RRC
- Above applies at least for the case where SCell with on demand SSB transmission and cell with signalling transmission have the same numerology.

Proposal 10 For RRC, we also need to discuss the definition of time instance A.

2.7. On-demand SSB and cell DTX

According to TR 38.864, one company's simulation results show that on-demand SSB achieves 22.0% or 43.4% base station energy savings at low loads compared to a baseline of 20ms SSB/SIB1 periodicity, for the case of with cell DTX configuration or without cell DTX configuration, respectively. In other words, on-demand SSB in conjunction with cell DTX can bring some network energy saving gain. Therefore, the feasibility of the joint use of on-demand SSB transmission and cell DTX can be studied.

Proposal 11 It is recommended that the feasibility of joint use of on-demand SSB transmission and cell DTX can be studied.

3. Conclusions

In this contribution,some views about on-demand SSB SCell operation are discussed, and the following proposals are made.

Proposal 1 Scenario 3A could be considered for exclusion.

Proposal 2 Scenarios 3B and Case #1 and Scenario #3B and Case #2 should be supported.

Proposal 3 On-demand SSB for CD-SSB located on synchronization raster cannot be supported.

Proposal 4 It is recommended to support 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.

Proposal 5 It is recommended to support Alt C: Do not support the case where always-on SSB is CD-SSB and not on a synchronization raster.

Proposal 6 DCI based signaling to indicate on-demand SSB transmission can be supported.

Proposal 7 If DCI based signaling support on-demand SSB transmission, DCI is UE-specific.

Proposal 8 Option 4, 4a can be used to deactivate on-demand SSB transmission.

Proposal 9 For case #2, it is recommended to support 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).

Proposal 10 For RRC, we also need to discuss the definition of time instance A.

Proposal 11 It is recommended that the feasibility of joint use of on-demand SSB transmission and cell DTX can be studied.

4. References

[1] "Draft Report of 3GPP TSG RAN WG1 #119 v0.3.0", RAN1#119