3GPP TSG RAN WG1 #120 **R1-2500736**
Athens, Greece, February 17th – 21st, 2025

Agenda Item: **9.5.1**
Source: **Xiaomi**
Title: **Discussion on on-demand SSB SCell operation**
Document for: **Decision**

1 Introduction

In RAN1#119 meeting, Rel-19 NES was heatedly discussed and 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.

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

In this contribution, we discuss necessary procedures and signalling to support on-demand SSB, including the possible methods to trigger SSB. Considering SSB is essential in NR system, we also provide our analyses for the impacts on UE behaviours if on-demand SSB is applied.

2 Discussion

2.1 Generic issues for on-demand SSB

There are two kinds of SSB defined in RAN1, i.e., cell-defining SSB and non-cell-defining SSB. For a CD-SSB, it has an associated RMSI, i.e., 8 bits information carried by MIB is used to indicate the corresponding CORESET#0 and search space#0. For NCD-SSB, it doesn't provide any information for RMSI with setting k_{SSB} to an invalid value. If a UE is trying to access to a cell and conducting cell search, reception of CD-SSB is the critical step to obtain follow-up system information, i.e., RMSI and OSI.

Considering a serving cell may play different roles from UE perspective, it can be a SCell for UE#1 while a PCell for UE#2. There is a concern for on-demand CD-SSB that an on-demand SSB Scell serves as PCell for another UE or there is another UE in IDLE/INACTIVE state camping on this cell. One example is shown in Figure 1. Here we have the following assumptions in order to better illustrate potential impacts on different UEs:

- UE#1 is an RRC_CONNECTED UE supporting on-demand SSB and the cell serves as SCell.
- UE#2 is an RRC_CONNECTED UE and the cell serves as PCell/PSCell.
- UE#3 is an RRC_IDLE/INACTIVE UE.

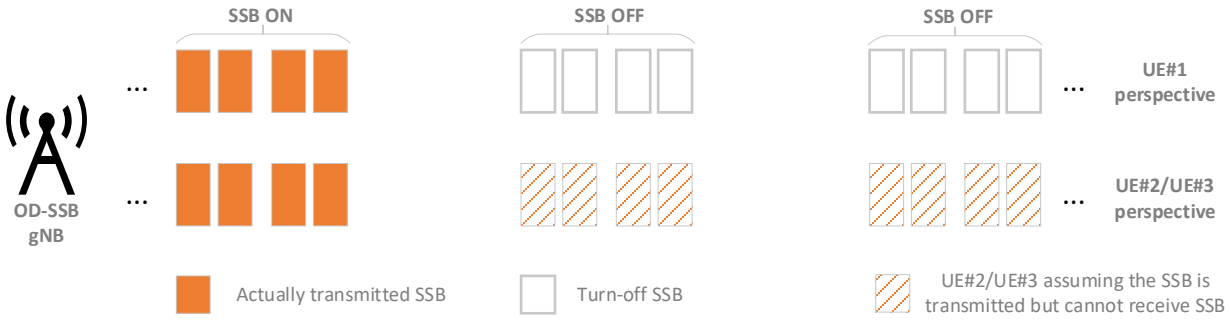

Figure 1: Example of different roles for a same serving cell

For UE#1, it doesn't make any difference whether the on-demand SSB is CD-SSB or NCD-SSB. It obtains MIB on its PCell and monitors search space#0 accordingly. In the other words, it doesn't care the MIB carried by PBCH if it is transmitted on SCell. For UE#2, if it is capable of OD-SSB, it should assume SSB is always on as gNB cannot inform UE whether SSB is on or off on PCell/PSCell. Otherwise, it is out of scope and should not be considered. If UE#2 is not capable of OD-SSB, it is the same issue as on a SCell because legacy UE cannot recognize SSB on/off anyway. For UE#3, it detects SSB assuming the SSB is transmitted with 20 ms periodicity, as specified in TS38.213. From our understanding, it is a typical case that the actual transmitting SSB pattern is different from the assumption of a UE during initial access. For example, gNB should transmit SSB aligned with *ssb-PositionsInBurst* and *ssb-PeriodicityServingCell* carried by SIB1. If UE#3 cannot receive any CD-SSB on this serving cell, it will access to the network via the same serving cell as UE#1, i.e., UE#1 and UE#3 eventually camp on the same PCell. From this point of view, we believe the current procedure and mechanism is workable.

On the other hand, gNB can freely configure SSB on any SCell for a UE. There is no restriction that only NCD-SSB can be configured on a SCell. The reason is that it can provide deployment flexibility for operator. For example, it is reasonable to keep the door open that different UE can access to the network via different PCells. Otherwise, if we nail down that the on-demand SSB has to be NCD-SSB, it means no UE can camp on an on-demand SSB serving cell.

All in all, we do agree with the analyses that CD-SSB on/off may bring some negative impacts for other UEs, e.g., RLM sych-out for RRC_CONNECTED UE or prolonged accessing procedure. On the other hand, nothing is broken if the on-demand SSB is CD-SSB and there is no restriction on SSB type for SCell in current specification. It is a kind of gNB implementation which can be up to operator's decision.

Proposal 1: On-demand SSB can be CD-SSB located on sync-raster.

SSB is transmitted in a periodic and cell-specific manner, which is the props of beam operation and RRM measurement. Basically, the power consumption caused by SSB transmission along with SSB transmission at least comes from the following two aspects:

– The SSB overhead in terms of occupied OFDM symbols within a SSB transmission periodicity is not small. On these symbols, gNB has to transmit SSB and has to meet certain requirement.

– gNB has to keep awake in order to transmit SSB on the predefined or configured SSB occasion. It makes pretty difficult that gNB transits to sleep mode even if the traffic load is quite low.

As shown in Figure 2, SSB overhead in time domain within 20 ms periodicity is 5.7%-11.42% depending on deployment. On-demand SSB technique can be used to shut down SSB when necessary, e.g., traffic load is pretty low, or the number of UE camping on SCell is quite few. Accordingly, the power consumption caused by SSB transmission can be significantly reduced. On the other hand, on-demand SSB technique is capable to resume SSB transmission once conditions changed.

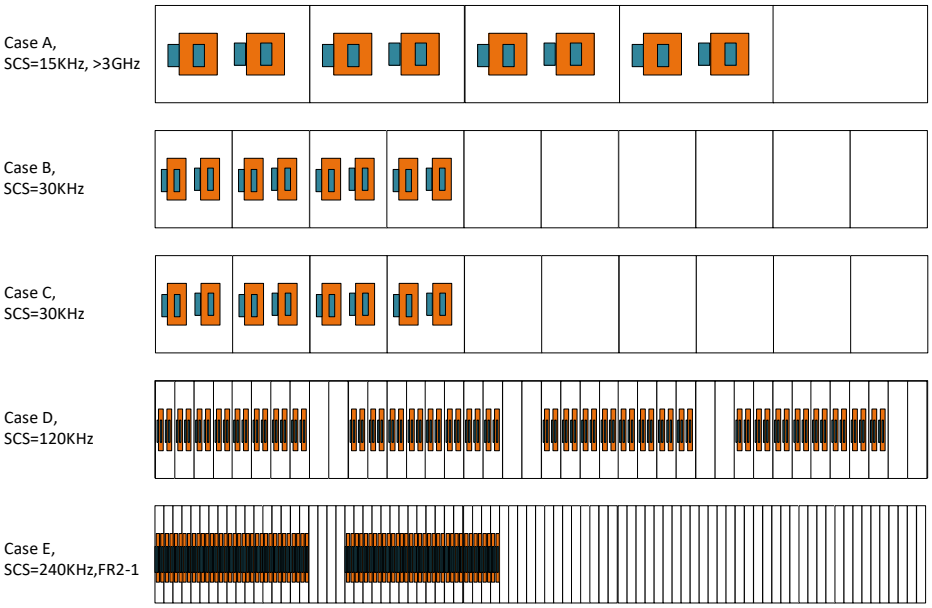

Figure 2 SSB patterns defined in current specification

Generally speaking, NES gain provided by on-demand SSB comes from the fact that gNB only transmits SSB if necessary instead of transmitting SSB periodically and mandatorily. From this point of view, any scenario wherein SSB is transmitted needs to be considered whether the always-on SSB can be replaced by on-demand SSB. Keeping this in mind, we provide our view on whether on-demand SSB can be applied to scenario #3A and scenario #3B respectively.

– Scenario #3A: Recall the discussion in RAN1#116 meeting, the group already achieved consensus that on-demand SSB should be considered during SCell activation procedure, i.e., after UE receives SCell activation command and before the SCell is activated. No matter always-on SSB is assumed or not, on-demand SSB triggered by gNB is beneficial to reduce network power consumption.

– Scenario #3B: On the other hand, it is quite controversial for the case after SCell is activated. The opponents believe that gNB has full power and full knowledge to control the transmission of SSB. For example, gNB knows fluctuation of DL traffic without any UE request and knows UL traffic via BSR. The proponents think on-demand SSB is beneficial for UE implementation. Indeed, we feel there is a gap between groups. It seems that the divergence point is whether and how to indicate SSB on/off, i.e., gNB-triggered OD-SSB or UE-triggered OD-SSB. Considering UE-triggered OD-SSB has be precluded, concern on indication mechanism should be resolved. For on-demand SSB itself, we think it is beneficial after SCell activation. Otherwise, SSB is always on and gNB has few chances to go to sleep, which makes energy saving impossible. Regarding to what kind of SSB transmission is assumed, i.e., case#1 and case#2, at least case#2 combined with scenario #3B can be supported. Besides necessity of supporting scenario #3B, another concern is on-demand SSB will significantly impact UE behaviour. Fortunately, the impacts on UE measurement behaviour can be removed by case#2. For scenario#3B and case#1, it can maximize NES gain via avoiding unnecessary SSB transmission. However, it brings negative impacts on UE implementation, e.g., UE may not be able to maintain DL synchronization and may increase UE power consumption as it has to detect SSB in vain following legacy mechanism. We agree that negative impacts on UE should be avoided. On the other hand, we think any negative impacts

can be avoided or minimized if UE clearly knows the status of SSB transmission. In short, gNB should explicitly inform UE whether the on-demand SSB is turned on or turned off.

Proposal 2: On-demand SSB can be triggered by gNB for the following scenarios/cases wherein gNB explicitly indicates UE whether SSB is on or off:
- ***Scenario #3A and Case #1***
- ***Scenario #3A and Case #2***
- ***Scenario #3B and Case #1***
- ***Scenario #3B and Case #2***

Once on-demand SSB is triggered by gNB, UE expects that on-demand SSB burst(s) is transmitted from time instance A. From our understanding, time instance A highly depends on the triggering signal design. To be specific, if the triggering message is carried by RRC, instance A could be defined as the beginning of the first slot containing the first actually transmitted SSB index within the first "possible" on-demand SSB burst after slot n. Slot n is the uplink slot wherein UE transmits ACK for the PDSCH carrying RRC signalling. T includes the RRC processing delay and time for PUCCH carrying ACK for this RRC signaling.

Proposal 3: Time instance A and value of T can be defined as below if on-demand SSB is triggered by RRC-based signalling.
- ***If triggering message is carried by RRC signalling, instance A is the first slot containing the first actually transmitted SSB index within the first "possible" on-demand SSB burst after slot n, slot n is the last downlink slot overlaps with uplink slot on which UE transmit ACK for the RRC signalling. T at least includes the RRC processing delay.***

2.2 Mechanisms of SSB triggering

As captured in the WID, there are three potential triggering methods for on-demand SSB:

- Method 1: UE uplink wake-up-signal
- Method 2: Cell on/off indication via backhaul
- Method 3: Scell activation/deactivation signalling

For method 1, the SSB will be turned on in light of UE's demand. Given that it was concluded there is no consensus on the support of on-demand SSB SCell operation triggered by UE, we focus on the other two mechanisms in this contribution. For method 2 and method 3, SSB on/off totally depends on gNB implementation, i.e., gNB can determine SSB on or SSB off alone without considering UE's requirement.

Observation 1: Different triggering method for on-demand SSB has diverse impacts on UE:
- ***Cell on/off indication based SSB triggering is transparent to UE.***
- ***SCell activation/deactivation based SSB triggering is fully gNB implementation while non-transparent to UE.***

The basic idea to realize on-demand SSB according cell on/off indication via backhaul is that PCell has full power to control SCell as they belong to same DU and share same MAC entity. If ideal backhaul is available between PCell and SCell, which is a typical case, PCell can obtain the conditions on SCell in time. From this point of view, it is possible that SCell can adjust its SSB transmission behaviour according to the cell on/off indication from PCell. To be specific, if PCell send a cell off indication to SCell via backhaul, the SCell should stop to transmit SSB. There is no signalling exchange between network and UE.

However, cell on/off indication via backhaul based SSB triggering is totally transparent to UE. If UE follows legacy behaviour without knowing that SSB is shut down, there will be negative impacts on legacy procedures. For example, UE has to sustain detection on time occasion without SSB transmission which leads to unnecessary power consumption. More importantly, UE may derive incorrect measurement results with the assumption that SSB is still transmitted. It may cause serious problems on RRM procedure and BFR procedure as the accuracy of measurement may be significantly degraded.

In addition, as shown in Figure 5, UE may always need to detect several consecutive SSB bursts before it synchronizes to the SCell resuming SSB transmission. Without any UE indication, NW has no idea on the DL synchronization status at UE side. Hence, gNB has to schedule UE with a conservative method in order to avoid degradation of data transmission due to out of synch issue. Hence large transmission delay is perceived. Therefore, we prefer to not support cell on/off indication based SSB triggering method.

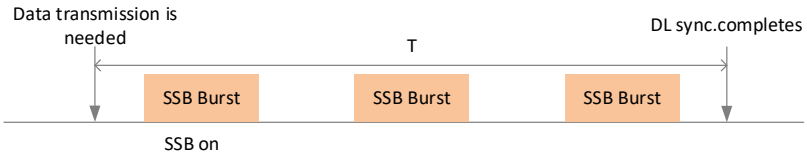

Figure 3 Delay in data transmission

Proposal 4: Cell on/off indication based SSB triggering method should be deprioritized as there are many negative impacts on legacy procedures if UE follows legacy behaviours without knowing that SSB is shut down.

In RAN1#118 meeting, the following agreement was achieved:

Agreement in RAN1#118

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.

In current specification, RRC contains SCell modification can also be used to modify the SCell configuration and activate the Scell. It is straightforward to extend RRC signaling based solution to other cases.

Proposal 5: For other cases other than the following case, support RRC based signaling to indicate on-demand SSB transmission.

– ***This RRC also configures the SCell, activates the SCell, and provides on-demand SSB configuration.***

Deactivation of on-demand SSB

In RAN1#119, the deactivation of on-demand SSB transmission was discussed and the following agreement was achieved:

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

Per the agreement on MAC CE based OD-SSB indication, there is no restriction on applicable scenarios. Same principle should be also used for OD-SSB deactivation, i.e., option 1 can be applied to any scenario supporting OD-SSB operation.

Proposal 6: For a Scell supporting on-demand SSB operation, Option 1 can be used to deactivate on-demand SSB transmission in scenario 2, 2A, 3A, and 3B.

Option 4/4A and option 5 associates with SCell deactivation, which is not a universal solution. To be specific, these options cannot be applied to scenario wherein SCell is not being deactivated. In particular, we don't see additional benefits brought by option 4/4A compared to option 2.

Proposal 7: For a Scell supporting on-demand SSB operation, Option 4, 4A are not supported.
- ***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***

Parameters for OD-SSB configuration

In RAN1#119, the parameters for OD-SSB configuration were further discussed with the following agreements:

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.

For Case#2, i.e., aways-on SSB is periodically transmitted on the cell, the following two alternatives were identified for additional SSB configuration:
- 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*)

Alt B has merit of less signaling overhead compared with Alt A. Hence, we prefer to adopt Alt B to determine time location of additional SSB.

Proposal 8: For Case#2, Alt B is used to determine the time domain location of on-demand SSB, i.e., based on a single parameter which is to indicate the time offset between always-on SSB and on-demand SSB.

Mux-Cases of always-on SSB and on-demand SSB

For the frequency relationship between always-on SSB and on-demand SSB, the following agreements were achieved in RAN1#119 meeting.

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.

For the both of above cases, i.e., always-on SSB is CD-SSB on a synchronization raster and not on a synchronization raster, we don't see motivation on having an on-demand SSB with a different frequency location from that of always-on SSB. Considering it has been agreed that the frequency location of on-demand SSB is the same as the frequency location of always-on SSB for the case where always-on SSB is not CD-SSB, the same principle can be reused for the other cases.

Proposal 9: When always-on SSB is CD-SSB, the frequency location of on-demand SSB is same as that of always-on SSB.

For the time location relationship between always-on SSB and on-demand SSB, the following agreement was achieved in RAN1#119 meeting.

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

When always-on SSB is assumed, on-demand SSB is used to expedite physical procedures so that latency can be reduced and system performance can be improved. Either always-on SSB or on-demand SSB is sufficient for UE. We don't see the necessity to have two SSB on the same OFDM symbol. Indeed, allowing time-overlapped SSBs will bring more efforts which is not preferred.

Proposal 10: The always-on SSB and on-demand SSB should not overlap in time domain.

For the spatial relationship between always-on SSB and on-demand SSB, the following agreement was achieved in RAN1#119 meeting.

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.

The basic principle for beam operation is that different SSB associated with different beam direction, which is identified with SSB index. In order to simplify specification and keep same assumption on beam operation, we prefer that always-on SSB and on-demand SSB with same SSB index are quasi co-located even if the centre frequency locations are different.

Proposal 11: When the centre frequency locations of always-on SSB and OD-SSB are different, SS/PBCH blocks with the same SSB indexes for always-on SSB and on-demand SSB are quasi co-located.

2.3 Impacts on UE behaviours

Whether UE needs to recognize SSB transmission status

It is well known that SSB is one of the most essential DL channels/signals in NR system. It is widely used for many basic UE procedures, including RRM, RLM, BFR, etc. If UE cannot recognize SSB transmission status, there are at least two issues need to be further considered:

- If UE doesn't know SSB has been turned off, it tries to receive SSB as normal. Unnecessary power consumption is inevitable. More importantly, it makes more difficult for UE to convert into sleep mode, which leads to more power wastage. This issue is more serious when SSB periodicity is small.
- If UE doesn't know SSB has been turned off, failure on reception of turn-off SSB is wrongly considered as degradation of channel condition. Although it is typically that the measurement results for each SSB sample are filtered before reporting, the accuracy of final measurement report is definitely deteriorated.

Power saving is very important for improving UE performance. The accuracy of measurement for reporting is essential for UE. Therefore, it is very important for UE to recognize the status of SSB transmission.

Take SCell management as an example. The measurement resource for RRM could be SSB transmitted by serving cell or neighbour cell. Based on the configuration, UE performs measurement and report the measurement results to NW. The measurement results can be used for SCell management.

As shown in Figure 9, the SCell can be added or released for a UE based on the RRM measurement results based on 38.331. [4] For example, if the RRM measurement result of SCell is worse than a configured threshold, PCell should release the SCell because it is no longer qualified for data transmission.

Figure 4 scell addition and release

On a SCell supporting on-demand SSB, as shown in Figure 10, if UE still performs RRM measurement without considering SSB on/off, the measurement results of the SCell is possibly worse than SCell release threshold. Consequently, PCell would release the SCell according to the report. However, the degradation of measurement result comes from SSB off rather than from channel condition deterioration. In the other words, a SCell supporting on-demand SSB is mistakenly removed from serving cell list. It will increase transmission delay and bring negative impacts on system performance.

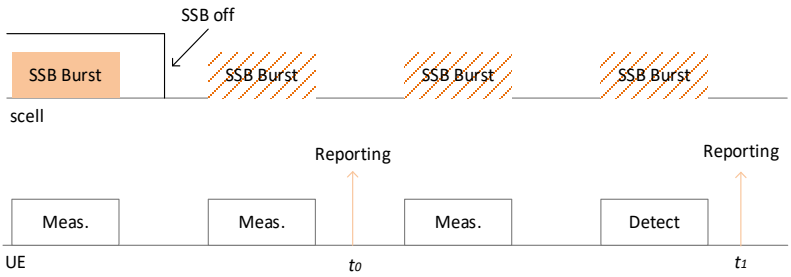

Figure 5 RRM measurement based on on-demand SSB

Proposal 12: UE should preclude measurement result associated to a SSB which is turned off by gNB.

Measurement based on on-demand SSB

In RAN1#118bis meeting, the CSI report configuration for always-on SSB and on-demand SSB were further discussed with the following agreement:

Agreement in RAN1#118bis

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

Despite of always-on SSB and on-demand SSB, neither physical structure nor functionality is changed. From this perspective, SSB type doesn't impact measurement at UE side. It has been agreed that on-demand SSB can be used for L3 measurement. Considering that L1 measurement is a key step for L3 measurement, i.e., UE measures several SSB samples which can be regarded as L1 measurement and then filtering all L1 measurement results to get L3 measurement result, there is no barrier to use on-demand SSB for L1 measurement as well. In particular, the following agreement on spatial assumption between on-demand SSB and always on SSB was made in RAN1#119 meeting, which we believe further fortify aforementioned analyses.

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.

Proposal 13: For a cell supporting on-demand SSB SCell operation and for Case #2 (i.e., Always-on SSB is periodically transmitted on the cell), both option 1 and option 2 are supported for UE to perform L1 measurement.

- ***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***

3 Conclusion

In this contribution, we discussed the procedures and signalings to support on-demand SSB and the impacts of on-demand SSB on UE behaviours were analysed. The proposes and observations are summarized as following:

Observation 1: Different triggering method for on-demand SSB has diverse impacts on UE:
- ***Cell on/off indication based SSB triggering is transparent to UE.***
- ***SCell activation/deactivation based SSB triggering is fully gNB implementation while non-transparent to UE.***

Proposal 1: On-demand SSB can be CD-SSB located on sync-raster.

Proposal 2: On-demand SSB can be triggered by gNB for the following scenarios/cases wherein gNB explicitly indicates UE whether SSB is on or off:
- ***Scenario #3A and Case #1***
- ***Scenario #3A and Case #2***
- ***Scenario #3B and Case #1***
- ***Scenario #3B and Case #2***

Proposal 3: Time instance A and value of T can be defined as below if on-demand SSB is triggered by RRC-based signalling.
- ***If triggering message is carried by RRC signalling, instance A is the first slot containing the first actually transmitted SSB index within the first "possible" on-demand SSB burst after slot n, slot n is the last downlink slot overlaps with uplink slot on which UE transmit ACK for the RRC signalling. T at least includes the RRC processing delay.***

Proposal 4: Cell on/off indication based SSB triggering method should be deprioritized as there are many negative impacts on legacy procedures if UE follows legacy behaviours without knowing that SSB is shut down.

Proposal 5: For other cases other than the following case, support RRC based signaling to indicate on-demand SSB transmission.
- ***This RRC also configures the SCell, activates the SCell, and provides on-demand SSB configuration.***

Proposal 6: For a Scell supporting on-demand SSB operation, Option 1 can be used to deactivate on-demand SSB transmission in scenario 2, 2A, 3A, and 3B.

Proposal 7: For a Scell supporting on-demand SSB operation, Option 4, 4A are not supported.
- ***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 8: For Case#2, Alt B is used to determine the time domain location of on-demand SSB, i.e., based on a single parameter which is to indicate the time offset between always-on SSB and on-demand SSB.

Proposal 9: When always-on SSB is CD-SSB, the frequency location of on-demand SSB is same as that of always-on SSB.

Proposal 10: The always-on SSB and on-demand SSB should not overlap in time domain.

Proposal 11: When the centre frequency locations of always-on SSB and OD-SSB are different, SS/PBCH blocks with the same SSB indexes for always-on SSB and on-demand SSB are quasi co-located.

Proposal 12: UE should preclude measurement result associated to a SSB which is turned off by gNB.

Proposal 13: For a cell supporting on-demand SSB SCell operation and for Case #2 (i.e., Always-on SSB is periodically transmitted on the cell), both option 1 and option 2 are supported for UE to perform L1 measurement.

- ***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***

4 References

[1] RAN1 Chair's notes, RAN1#119 meeting

[2] TS 38.213, "NR; Physical layer procedures for control", V18.1.0, January, 2024.

[3] TS 38.133, "NR; Requirements for support of radio resource management", V18.4.0, January, 2024.

[4] TS 38.331, "NR; Radio Resource Control (RRC) protocol specification", V18.0.0, January, 2024.