**3GPP TSG-RAN WG1 Meeting #104-e R1-210xxxx**

**e-Meeting, Jan 25th – Feb 5th, 2021**

**Agenda Item: 5**

**Source: Moderator (ZTE)**

**Title: Summary on the physical layer aspects of small data transmission**

**Document for: Discussion**

# Introduction

This document contains the summary of issues related to the Rel-17 physical layer aspects of small data transmission for the following email discussion.

* [104-e-AI5-LS-03] Email discussion regarding LS in R1-2100025 including a potential reply LS till 2/3

The issues were triggered by the following LS from RAN2 [1]

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| **Actions:**  **To RAN1 group.**  **ACTION:** RAN2 respectfully requests RAN1 to take the above into account and provide input for:   * Configuration of the coreset and search space for monitoring the PDCCH addressed to the C-RNTI after successful completion of the RACH procedure during RA-SDT. * Configuration of association between the type 1 CG resource(s) for CG-SDT and SSB(s)   For CG resource(s), the following agreement have been achieved in RAN2:   * The configuration of configured grant resource for UE uplink small data transfer is contained in the RRCRelease message. Configuration is only type 1 CG with no contention resolution procedure for CG. * The configuration of configured grant resource can include one type 1 CG configuration. * The configuration of configured grant resource for UE small data transmission is valid only in the same serving cell. * The UE can use configured grant based small data transfer if at least the following criteria is fulfilled (1) user data is smaller than the data volume threshold; (2) configured grant resource is configured and valid; (3) UE has valid TA. FFS for the candidate beam criteria. * From RAN2 point of view: An association between CG resources and SSBs is required for CG-based SDT. FFS up to RAN1 how the association is configured or provided to the UE. Send an LS to RAN1 to start the discussion on how the association can be made. Mention that one option RAN2 considered was explicit configuration with RRC Release message * A SS-RSRP threshold is configured for SSB selection. UE selects one of the SSB with SS-RSRP above the threshold and selects the associated CG resource for UL data transmission. * When UE is in RRC\_INACTIVE, it should be possible to send multiple UL and DL packets as part of the same SDT mechanism and without transitioning to RRC\_CONNECTED on dedicated grant. |

The moderator suggests to have a three-stage discussion in this meeting:

* Phase 1 (1.25~1.27): first round discussion, collecting companies’ initial views
* Phase 2 (1.27~2.1): second round discussion, trying to reach some consensus
* Phase 3 (2.1~2.3): LS drafting based on the consensus

# Configuration of the CORESET and search space for monitoring the PDCCH addressed to the C-RNTI after successful completion of the RACH procedure during RA-SDT

Both UE-specific and common CORESET/Searchspace are mentioned in the submitted TDocs. Some companies think UE-specific configuration can provide more flexibility, while some other companies are concerned about the necessity and specification efforts. Regarding the common CORESET/Searchspace, some companies proposed to use type-1 CSS and CORESET 0 as baseline, since those configurations are available during the random access, while some other companies believe it is beneficial to configure a new common CORESET and/or CSS to avoid the potential overloading.

## SearchSpace

### First round

The following options can be found in the TDocs submitted to this meeting.

Option 1: Common SearchSpace

Option 1.1: reuse the type-1 PDCCH CSS configured by *ra-SearchSpace*

Option 1.2: reuse the type-3 PDCCH CSS

Option 1.3: a new CSS configured from system information or RRC release

Option 2: UE-specific SearchSpace

Option 2.1: configured from RRC Release message

Option 2.2: configured from Msg4/MsgB

**Discussion point 2.1**

Any preference on the listed options, and is there any other option not listed here?

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| --- | --- |
| Company | Comment |
| Samsung | Option 2 is preferred.  It’s pretty clear that the option 2 can have the full flexibility compared to option 1, and in this case, the signaling overhead is not an issue. For CG-SDT, RAN2 already considers to have SS/CORESET configuration in RRC release messages. Besides, if gNB wishes, it can configure the same SS/CORESET for different UEs, or even same for the CSS. |
| Apple | Option 2 is preferred.  Re-use common search space could increase the PDCCH blocking rate, thus the legacy UE performance would be impacted. |
| CATT | We support Option 1.3. New PDCCH CSS is used for scheduling small data transmission after successful completion of the RACH procedure during RA-SDT in order to reduce type1 PDCCH blocking rate random access of normal UE. CCE mapping position of each PDCCH candidate in the new PDCCH SS is determined according to the hash function with C-RNTI for randomization similar with CCE index determination of USS in order to reduce the PDCCH scheduling blockage rate between small data UEs  Compared with option 2, new special CSS method by broadcasting message can reduce resource and signaling overhead of the separate PDCCH SS by dedicated signaling message. |
| Intel | We support both Option 1.1 and option 2.1. It is clear that USS can be more flexible in terms of scheduling and reducing blocking among different UEs in RA-SDT procedure. Meanwhile, we also need to consider some default configuration for search space, in case when USS is not configured. In this case, our view is that Type 1 CSS should be natural way as it is already provided for RAR monitoring and can be straightforwardly extended for scheduling DL/UL data packet.  As for configuration from RRC release message or Msg4/MsgB, it can be similar to CG-SDT, where CG resource is configured via RRC release message. Note that it is more appropriate for RAN2 to make decision for this, rather than RAN1. |
| LG | We support Option 1.1, 1.2 and 2.1. gNB can determine which option is applied to SDT by configuration. |
| Huawei, HiSi | Option 1.3 is preferred. Option 2.1 is also acceptable if USS configured in RRC Release message is used only in serving cell.  For Option 1.1 and 1.2, reusing the type-1/type-3 PDCCH CSS may increase the PDCCH blocking and impact the legacy UE.  The sub-bullets of Option 2 require more RAN2 work first. For example, for Option 2.1, if UE moves to the neighbor cell, the dedicated configuration needs to be contained in the UE context and interchanged in the Xn-AP. For Option 2.2, RAN2 should first decide which RRC signaling is used in Msg4/MsgB of RA-SDT. If no proper RRC signaling can be used, the Option 2.2 is not feasible. |
| Nokia, NSB | Our proposal was Option 1.1, but if there are concerns on the loading, we can consider Option 1.2 and 1.3. Using USS has an issue when the UE is moving to a neighbor cell and is a decision that RAN1 should avoid if a CSS solution is feasible. |
| Qualcomm | Depending on the tradeoff of signaling overhead, scheduling flexibility and system loading, we think the following options can be further considered:   * Option 1.1 * Option 1.3 * Option 2.1 |
| Ericsson | In our view, Type-1 can be at least used as default search space set (option 1.1) which is already available for Msg2/Msg4/MsgB PDCCH monitoring in RACH based SDT.  Furthermore, for flexibility, and to reuse some other search space already defined in RRC connected state, an optional search space ID configuration in the RRC release message may be needed or it’s up to RAN2 to decide whether a new search space and CORESET can be defined in RRC release message. |
| InterDigital | We support Option 1.1 and 2.1. In general we agree with Intel’s views. If USS is available then the UE should prioritize it. The USS can be signaled in the RRC release message along with the CG configuration. If UE is not configured with an USS, the UE can use the default type 1 CSS. |
| vivo | We think both option 1 and option 2 can be adopted. For option 1, at least option 1.1 with Type-1 search space sets should be supported for RA-SDT, since PDCCH monitoring behavior for DCI format 0\_0/1\_0 with C-RNTI in the Type-1 CSS is already supported in Rel-15/16.  On the other hand, to provide more capacity and flexibility, and reduce latency, option 2 with UE-specific Search space sets can be supported. |
| Lenovo, Motorola Mobility | Option2 is preferred, since it is more flexible.  As a compromise, the UE specific SS could be optionally configured, and if not configured, one sub-option from option1 could be used for the scheduling. |

### Second round

Below is the status of the first round discussions. In the following I list the supporting companies for each of the options and some concerns mentioned during the first round discussions.

Option 1: Common SearchSpace

Option 1.1: reuse the type-1 PDCCH CSS configured by *ra-SearchSpace*

*Supported by: Intel, LGE, Nokia, Qualcomm, Ericsson, InterDigital, vivo*

*Pros: minimized specification effort*

*Cons: the PDCCH blocking rate and impact to the legacy UE*

Option 1.2: reuse the type-3 PDCCH CSS

*Supported by: LGE, Nokia*

*Similar pros and cons as 1.1*

Option 1.3: a new CSS configured from system information or RRC release

*Supported by: CATT, Huawei, Qualcomm, ZTE, Nokia*

*Pros: to address the overloading issue of 1.1 or 1.2*

*Cons: more spec effort that a new type of CSS needs to be defined*

Option 2: UE-specific SearchSpace

*Supported by: Samsung, Apple, Intel, Qualcomm, Huawei (only in serving cell), LGE, InterDigital, vivo, Lenovo*

*Pros: Flexibility*

*Cons: 1) when the UE is moving to a neighbour cell, the dedicated configuration needs to be contained in the UE context and interchanged in the Xn-AP; 2) resource and signalling overhead*

Option 2.1: configured from RRC Release message

Option 2.2: configured from Msg4/MsgB

*Details of option 2.1 and 2.2 can be further discussed in RAN2.*

The views are a bit diverse, while it seems companies supporting option 1.1 or 1.2 are also open for defining/configuring a different SearchSpace, either common or UE-specific, for the sake of flexibility and to avoid the overloading issue. So let us take another round of discussion and see if we can reach consensus to a single solution (seems the combination of different options is a possible solution, e.g. one for default configuration and the other for the flexibility). If this is not doable maybe another way is to identify on which options are feasible and what the pros and cons from RAN1 perspective are, and then provide those information to RAN2.

***Proposal 2.1:***

* From RAN1 perspective, at least a new SearchSpace that is different from the existing common SearchSpace should be supported for monitoring the PDCCH addressed to the C-RNTI after successful completion of the RACH procedure during RA-SDT
  + It is up to RAN2 decision if the new SearchSpace is UE-specific or common to the UEs performing RA-SDT
* If the new SearchSpace is not configured, type-1 PDCCH CSS can be reused.

Any comments or suggestions on the proposal 2.1?

|  |  |
| --- | --- |
| Company | Comment |
| Nokia, NSB | New USS doesn’t seem to add much value over existing USS. The new SS should be specifically about CSS, and that way the mobility situation can be supported with ease.  So we’d be OK with the above if we can take the decision that the new search space is a common search space. |
| CATT | We prefer CSS for the new search space with consideration of mobility and resource and signaling overhead of USS. |
| Samsung | RAN2 might need us to decide on either the Search space is UE specific or UE common information, and whether it is UE specifically or cell specifically configured. |
| Apple | We are generally ok with the proposal except the last bullet. We don’t see the necessity to define the default search space, as we already know the drawback of re-using the existing common search space. |
| Ericsson | We’re basically fine with the intention of the proposal. But maybe we do not have to make decisions for RAN2. And what RAN1 can provide to RAN2 could be   * From RAN1 point of view, there’s no issue to use existing CSS and USS, at least Type 1 CSS can be a default SS for SDT PDCCH monitoring. * RAN1 also think a new SS can be defined for SDT if needed, but it’s up to RAN2 to decide whether and how to define it. |
| Huawei, HiSi | Similar to Samsung, prefer to decide in RAN1 to use new USS or new CSS, or both. |
| Moderator (ZTE) | Some companies still have concern to use the ra-searchspace; and some companies have concern on the USS.  So can we try to agree on new CSS if there is no specific concern for this option? |
| Intel | Our view is that Type 1 CSS can be used as default SS. For the additional SS, we prefer USS over CSS as it is more flexible and can help reduce the blocking. |
| Samsung | Although ideally we (RAN1) should make a complete decision and provide it to RAN2, I start to feel it might not be the same understanding from all companies. So we can be fine with FL’s proposal. But we are certainly ok if we can narrow down some options.  To us, the overhead in RRC release message is not critical, as we explained, RAN2 will likely have it for CG-SDTanyway. So it can be UE specifically configured. Then next, whether its USS and CSS, maybe I am wrong, from configuration perspective, gNB can configure the USS resource to be exactly the same a CSS, (as well as CORESET). Thus, I don't see any problem for this direction. The “handover” is raised in the cons, but I think, how to handle SDT in handover situation is a general question for RAN2 to handle, not only the CORESET/SS configuration. |
| LG | We can live with the updated proposal. |
| Qualcomm | We prefer USS or a new CSS. If neither USS nor new CSS is configured, Type-1 CSS can be re-used. |
| vivo | We support the proposal. From our understanding, the new SearchSpace that is UE-specific or common does not make too much difference.  For monitoring on Type-1 CSS, as it is already specified in the current spec, it can be default behavior. |

## CORESET

### First round

The following options can be found in the Tdocs submitted to this meeting.

Option 1: common CORESET

Option 1.1: CORESET 0

Option 1.2: CORESET other than CORESET 0

Option 2: UE-specific CORESET configuration

Option 2.1: configured from RRC Release message

Option 2.2: configured from Msg4/MsgB

**Discussion point 2.2**

Any preference on the listed options, and is there any other option not listed here?

|  |  |
| --- | --- |
| Company | Comment |
| Samsung | Option 2 is preferred.  Same reason as in previous comment. |
| Apple | Option 1 is related to common CORESET, option 2 is CORESET configuration, both options seem not on the same level.  Option 1 is preferred.  The usage of CORESET is common for group of users, but it can be configured per UE. |
| CATT | We support Option 1.and CORESET for RA-SDT is flexibly configured by gNB. |
| Intel | We support both Option 1.1 and Option 2.1. As we mentioned above, both need to be supported: one for default configuration and another for flexibility. |
| LG | We support Option 1.1, 1.2 and 2.1. gNB can determine which option is applied to SDT by configuration. |
| Huawei, HiSi | Option 1 is preferred.  Whether to use Option 1.1 and Option 1.2 can be configured by the network in the system information. |
| Nokia, NSB | Option 1 is preferred |
| Qualcomm | Depending on the tradeoff of signaling overhead, scheduling flexibility and system loading, we think the following options can be further considered:   * Option 1.1 * Option 1.2 * Option 2.1 |
| Ericsson | Use the CORESET associated to the existing search space used for SDT.  It’s up to RAN2 to decide whether a new CORESET can be defined in RRC release message if a new search space is configured in RRC release message. |
| InterDigital | We support Option 1.1 and 2.1 for similar reasons as previous proposal. |
| Vivo | We think both option 1 and option 2 can be supported. For option 2, option 2.1 is preferred. |
| Lenovo, Motorola Mobility | Same comment as for point 2.1. |

### Second round

The situation is similar as that for SearchSpace, probably we can first decide the solution for SearchSpace, and then the CORESET associated to that SearchSpace can be used.

***Proposal 2.2:***

* FFS UE-specific CORESET or common CORESET, depending on the conclusion for SearchSpace.

Any further comments or suggestions to make more progress?

|  |  |
| --- | --- |
| Company | Comment |
| Nokia, NSB | Agree, this should settle itself when the CSS vs. USS decision is taken. |
| CATT | We prefer FL proposal 2.2. |
| Apple | We are fine with this proposal. |
| Ericsson | Agree. |
| Huawei, HiSi | OK |
| Intel | We are fine with the proposal |
| LG | We are fine with this proposal. |
| Qualcomm | agree |
| vivo | Agree |

# Configuration of association between the type 1 CG resource(s) for CG-SDT and SSB(s)

It was mentioned in the LS that “From RAN2 point of view: An association between CG resources and SSBs is required for CG-based SDT. FFS up to RAN1 how the association is configured or provided to the UE. Send an LS to RAN1 to start the discussion on how the association can be made. Mention that one option RAN2 considered was explicit configuration with RRC Release message”.

## Configuration of SSBs and CG resources

### First round

The following options can be found in the Tdocs submitted to this meeting. If we go with option 1, then the association between SSBs and CG occasions for the CG configuration is needed. For the other two options, the association can be avoided. While option 2 may not be as flexible as option 1, and option 3 needs to additionally configure SRS resources for the inactive UEs.

* Option 1: one or multiple SSBs can be configured per CG configuration
* Option 2: single SSB per CG configuration
* Option 3: SSB is associated with SRS resource by SRS-SpatialRelationInfo

**Discussion point 3.1**

Any preference on the listed options, and is there any other option not listed here?

|  |  |
| --- | --- |
| Company | Comment |
| Samsung | Option 1 is preferred.  As far as we discussed with RAN2, the intention is also allow UE to select one SSB and use the associated PUSCH resource for the SDT, thus gNB can understand the preferred DL beam by UE, which facilitate the follow up transmission. Thus option 2 will require each SSB configuring with one CG configuration, and option 3 seems only focusing on the beam management which has no connection with SDT transmission, e.g., will the UE requires further SRI indication before/during SDT?  For option 1, we can build up the SSB-PUSCH (CG-SDT) association, as we did for SSB-RO in RACH procedure. |
| Apple | Option 1 is preferred.  We are not so clear the Option 2, does it mean only one SSB is configured in the cell or SSB to CG configuration is one to one mapping? The former interpretation doesn’t need to define the association. But according RAN2 agreement, SS-RSRP threshold is used for SSB selection, which means multi-SSBs are assumed. If the second interpretation is the intention, the difference between option 1 and option 2 is just one or multiple to one mapping and one to one mapping between SSB and CG configuration. Option1 is include the option 2. |
| CATT | We support Option 1. Considering the mobility of SDT UE in the inactive mode, multiple SSBs should be configured per CG configuration and this is straightforward method on the association between SSB and CGO. |
| Intel | We support Option 2. Further, in term of configuration, we think SSB can be associated with SRS resource with SRS-SpatialRelationInfo and a reference to ssb-index. For multiple SSBs associated with CG-PUSCH resource, it is not clear to us how gNB can identify the Tx beam used for CG-PUSCH if multiple SSBs are associated. Our understanding is that one SSB is associated with one CG-PUSCH resource and multiple CG-PUSCH resources can be configured in a cell. Based on selected SSB-RSRP threshold, UE can select one corresponding CG-PUSCH for transmission. |
| LG | We support Option 3. The existing configuration can be reused for CG-SDT possibly with modification. |
| Huawei, HiSi | Prefer Option 1 but with some comments, e.g..  *One CG configuration is associated to one or multiple SSBs, and multiple CG configurations can be associated with different SSBs. The association is configured per UE, e.g. in RRC release messages.*  Option 3 seems to associate the UE’s Tx beam with SSB, which in our opinion is not the main motivation of the LS. Besides, UE power saving is one of the main motivations of SDT WI. Introducing SRS and beam management in RRC\_INACTIVE not only adds more specification impact, but also causes much power consumption. |
| Nokia, NSB | Option 1 |
| Qualcomm | Option 1 is preferred. |
| Ericsson | Before doing down-selection, we may need to understand following RAN2 agreements which seem telling that a UE will select a good enough SSB among a set of SSBs first and then select a corresponding CG PUSCH resource for CG based SDT.   1. From RAN2 point of view: An association between CG resources and SSBs is required for CG-based SDT. FFS up to RAN1 how the association is configured or provided to the UE. Send an LS to RAN1 to start the discussion on how the association can be made. Mention that one option RAN2 considered was explicit configuration with RRC Release message 2. A SS-RSRP threshold is configured for SSB selection. UE selects one of the SSB with SS-RSRP above the threshold and selects the associated CG resource for UL data transmission.   If multiple SSBs are supposed for UE to down select based on the SS-RSRP and an RSRP threshold, reusing mapping rules similar to SSB to RO mapping rules is enough in our view.  If only single SSB is assumed and both gNB and UE already knows this SSB beam assumed for SDT, there’s no need to discuss the mapping. |
| InterDigital | Option 1 |
| vivo | Option 1 is preferred.  Besides, it should be clarified that whether one or multiple CG configurations are used for SDT. |
| Lenovo, Motorola Mobility | Option 1 is preferred |

### Second round

Below is the status of the first round discussions. In the following I list the supporting companies for each of the options and some concerns mentioned during the first round discussions.

* Option 1: one or multiple SSBs can be configured per CG configuration

Supported by: Samsung, Apple, CATT, Huawei (no need of mapping), Nokia, Qualcomm, InterDigital, vivo, Lenovo

* Option 2: single SSB per CG configuration

Supported by: Intel

Concern: lack of flexibility

* Option 3: SSB is associated with SRS resource by SRS-SpatialRelationInfo

Supported by: LGE

Concern: spec efforts to introduce SRS resource and beam management in RRC\_INACTIVE state

Both option 2 and option 3 are supported by single company. Although those two options can avoid more detailed mapping design between SSB and CG resources, but both have some drawbacks and it seems this is not exactly what RAN2 asked for.

Therefore, it is proposed to go with the majority view for option 1. And the details will be discussed under section 3.2.

***Proposal 3.1:***

* One or multiple SSBs can be configured per CG configuration for CG-SDT.

Any further comment on proposal 3.1?

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| --- | --- |
| Company | Comment |
| Nokia, NSB | Support the proposal. |
| CATT | We prefer Proposal 3.1 |
| Samsung | Fine. |
| Apple | Support the proposal. |
| Huawei, HiSi | Support |
| Intel | With the understanding that one SSB is associated with one CG resource unit (CG occasion + DMRS unit) and one CG configuration can have more than one CG resources, we are fine with the proposal. |
| LG | We can live with this proposal considering the majority’s view. |
| Qualcomm | ok |
| vivo | Support the proposal. |

## Details of association between SSB and CG resources

### First round

If option 1 in section 3.1 is adopted, the following issues need to be further discussed

1) Mapping period

* + Option 1.1: reuse that of SSB-RO mapping (including mapping cycle, association period, association pattern period)
  + Option 1.2: reuse that of SSB-MsgA PO mapping
  + Option 1.3: the association period is explicit indicated in RRC configuration
  + Option 1.4: the association is explicitly provided in RRC Release message

**Discussion point 3.2.1**

Any preference on the listed options, and is there any other option not listed here?

|  |  |
| --- | --- |
| Company | Comment |
| Samsung | Similar to SSB-RO association, I think the SSB-(CG-SDT)PUSCH association period could be determined. |
| Apple | Option 1.2 is preferred.  Some parameters of the PO configuration could be used for CG configuration, such as PO periodicity, the time offset from PRACH slot, number of slot containing the PO, number of the POs in each slot, etc |
| CATT | We support option 1.1 and similar method with SSB-RO association can be used for SSB-CGO association. |
| Intel | We suggest to defer the discussion before we conclude on Discussion point 3.1 |
| LG | If Option 1 in section 3.1 is adopted, we prefer Option 1.4. But, we can also defer the discussion before we conclude on Discussion point 3.1 |
| Huawei, HiSi | None of them. We don’t see the need to specify “mapping period” in the main bullet.  Unlike RO/PO in RACH, where each SSB has corresponding CG PUSCH occasions, for SDT it is not necessary for the network to configure the same amount of CG PUSCH occasions associated to each SSB. The network knows UE specific information, therefore can configure more resource associated to certain SSB(s), not to all SSB(s), so as to decrease the PUSCH detection associated to other SSB(s).  In line with the discussion in 3.1.1 where the association can be configured per CG configuration, e.g. by explicitly provided in each *ConfiguredGrantConfig* in UE-specific signaling, the main bullet should be removed or modified as:   1. ~~Mapping period~~ Association between SSB and CG resources   And we support 1.4 with modification as   * + Option 1.4-modified: the association is explicitly provided in each *ConfiguredGrantConfig* in UE-specific signaling, e.g. RRC Release message |
| Nokia, NSB | Option 1.3 (sort of), but similar to Huawei’s comment, there is no period in the association. There should be an association from an SSB to a CG configuration, there is no need for any period in the association. Due to this, there is no need to define any timing similar to SSB-RO or SSB-MsgA, just a linkage from SSB to CG-PUSCH configuration. |
| Qualcomm | In terms of resource allocation for PUSCH/DMRS (and indexing/ordering of CGO), we prefer a solution based on Option 1.2, which can reduce the signaling overhead of CGO specification.  In terms of the signaling/indication of association period, we share a similar view as Huawei and Nokia, which provides more flexibility to accommodate different traffic patterns for UEs performing CG-SDT. |
| Ericsson | Option 1.1 and/or 1.2 assuming multiple SSBs are to be mapped to the CG PUSCH resources.  Note that we assume option 1.2 is actually option 1.1 except that multiple DMRS resources can be configured per PUSCH occasion, given that SSB to MsgA PO mapping is determined indirectly via SSB to RO mapping and RO to PO mapping. |
| InterDigital | We support Option 1.3 or Option 1.4 and, similarly to Huawei and Nokia, we think the SSB association should be defined to a CG configuration without the association period. |
| vivo | We prefer option 1.2, i.e. SSB is mapped to a CG occasion and the associated DMRS resource (port/sequence/scrambling ID) in a manner similar to 2-step RA mapping rule. |
| Lenovo, Motorola Mobility | Option 1.4 is preferred |

2) Mapping ratio

* + Option 2.1: One SSB map to one CG occasion
  + Option 2.2: N SSB map to one CG occasion with different DMRS resources
  + Option 2.3: One SSB map to M CG occasion, M>=1
  + Option 2.4: the association is explicitly provided in RRC Release message

**Discussion point 3.2.2**

Any preference on the listed options, and is there any other option not listed here?

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| --- | --- |
| Company | Comment |
| Samsung | The mapping ratio could be explicitly indicated. |
| Apple | We are fine with Option 2.2 and Option 2.4. |
| CATT | We prefer to Option 2.4 because gNB can flexibly configure the association mapping ratio by dedicated signalling based on the number of SSBs and CGO. |
| Intel | We suggest to defer the discussion before we conclude on Discussion point 3.1 |
| LG | If Option 1 in section 3.1 is adopted, we prefer Option 2.4 e.g. with mapping one SSB to one or more PUSCH occasions or mapping multiple SSB to multiple PUSCH occasions. |
| Huawei, HiSi | Proposal modifications to the main bullet as not clear we need to specify mapping ratio, and propose one more option 2.5 in line with the flexibility that UE specific RRC can provide for certain SSBs,  2) Mapping ~~ratio~~ rules:   * + Option 2.5: N (N>=1) SSB map to all CG occasions in one CG configuration. |
| Nokia, NSB | In our view the mapping is not to a CG-PUSCH occasion (please see the RAN2 LS and RAN2 meeting notes, and even the heading 3.2 of this document), but to a CG-PUSCH configuration, which contains the DMRS resource configuration and CG occasion configuration.  Option 2.3 (sort of), one SSB maps to M CG configurations, where M≥1 |
| Qualcomm | Option 2.4 is preferred. |
| Ericsson | Option 2.2 is a bit preferred if only single PO is allowed per CG period and if only single CG configuration is configured, since it can save some time frequency resources.  If multiple POs can be configured per CG period, option 2.1 may also be fine.  Note that we assume here “CG occasion” term in the options means a timing frequency resource used for one CG PUSCH transmission in one CG period. |
| InterDigital | We agree with Nokia that the SSB mapping should be to a CG configuration rather than to a CG occasion. |
| vivo | We think that an SSB should be associated with a CG occasion with a given DMRS resource. We prefer an updated option 2.2 that N SSB map to one CG occasion with different DMRS resources, where one SSB is mapped to a DMRS resource on the CG occasion. |
| Lenovo, Motorola Mobility | Option 2.4 is preferred |

3) In case of K repetition:

* + Option 3.1: K CG resources in a CG period are considered as one CG occasion for the mapping
  + Option 3.2: K CG resources in a CG period are considered as K CG occasion for the mapping
  + Option 3.3: Repetition is not supported for CG-SDT

**Discussion point 3.2.3**

Any preference on the listed options, and is there any other option not listed here?

|  |  |
| --- | --- |
| Company | Comment |
| Samsung | K repetitions can be considered as K CG PUSCH occasions. |
| Apple | Option 3.3 is preferred.  CG-based solution needs to reserve dedicated resources for each UE, the reserved resources could not be shared among UEs. if repetition is supported, the overhead is the concern. |
| CATT | We prefer Option 3.1 and CG repetition should be considered for CG-SDT in order to increase the reliability of CG transmission |
| Intel | Our view is that this is considered as single CG resource and CG occasion even when repetition is configured. |
| LG | If Option 1 in section 3.1 is adopted, we prefer to exclude Option 3.3. |
| Huawei, HiSi | If option 2.5 in 3.2.2 can be proceeded then there is no need to discuss this, i.e. the same handling w/ or w/o repetitions. |
| Nokia, NSB | k is a property of the CG-PUSCH configuration and when a CG-PUSCH configuration is selected, the k-value of that configuration is to be used. No need to discuss this point separately. |
| Qualcomm | The answer to 3.2.3 depends at least on the solution to 3.2.1.  If Option 1.2 (or 1.1) is considered for 3.2.1, Option 3.2 would be an appropriate solution to 3.2.3.  If Option 2.4 is adopted for 3.2.1, we share a similar view as Nokia regarding the configuration of K for CGO. |
| Ericsson | Option 3.1, note that we assume option 3.1 means only one SSB is mapped to K repetitions from one transmission, i.e. K repetitions are only mapped once. |
| InterDigital | Repetitions should be supported for CG-SDT. |
| vivo | We think the repetitions case should be dependent on the discussion point 3.2.2. We prefer option 3.1 for K repetitions. |

4) Validation

(Samsung) Proposal: the valid PO is the PO in UL part in a slot, or at least Ngap symbols after the end of the DL part in a slot or after the end of the SSB in a slot.

(QC) Before CG-SDT, UE needs to validate the PUSCH occasion(s) and the TA. The PUSCH validation procedures specified in Section 8.1A of TS 38.213 can be re-used for the validation of CG-SDT resources.

**Discussion point 3.2.4**

Do you agree with the above proposals?

|  |  |
| --- | --- |
| Company | Comment |
| Samsung | This is needed for gNB to flexibly configure the resources with less complexity. |
| Apple | UE needs to check whether the UL slot is valid before SDT transmission, the validation rule defined for PO can be the starting point. |
| CATT | First of all, we should focus on RAN2 requirement on configuration of association between CGO and SSB in RAN2 LS. |
| Intel | We are fine to consider the validation for CG-PUSCH similar to PO validation in 2-step RACH. |
| LG | We also think that RAN1 should focus on RAN2 requirement on configuration of association between CGO and SSB in RAN2 LS. We suggest to postpone this discussion to next meetings. |
| Huawei, HiSi | UE needs to check the validation of TA and PUSCH occasions. At least the PUSCH occasions whose part or all symbols are within DL symbols/slots should be dropped. |
| Nokia, NSB | 1. Validation rule defined for PUSCH transmission should be used as the starting point. 2. There is no TA validation procedure in section 8.1A of TS38.213, just PUSCH validation. A TA validation procedure is needed. |
| Qualcomm | We think both TA validation and PUSCH occasion (CGO) validation need to be done before CG-SDT. If TA validation fails, UE needs to skips the CG-SDT occasion, regardless the PUSCH validation is successful or not.  As a baseline, the PUSCH validation procedures for msgA of 2-step RACH can be re-used.  When PUSCH repetition is supported for CG-SDT, additional validation rules can be considered when necessary, with a goal to minimize the spec impact and reduce UE’s power consumption. |
| Ericsson | PO validation can follow the validation rules in legacy for configured grant configured PUSCH transmissions.  According to the WI, the UE is only allowed to transmit in the CG-SDT resource with a valid TA. But the details can be discussed in RAN2. |
| InterDigital | We agree with the proposals, and with Nokia’s comment that a TA validation procedure is needed. TA validation details can be left to RAN2. |
| vivo | We think the validation for CG-SDT resource is needed. The PUSCH validation procedures for msgA of 2-step RACH can be re-used.  TA validation should be discussed in RAN2. |

### Second round

It seems the previous discussion points need to be re-organized a bit according to the comments received. There was some confusion between CG occasion and CG configuration. Maybe it is beneficial to clarify first that one CG configuration includes multiple CG transmission occasions and DMRS resources, and multiple CG configurations may be configured for CG-SDT. So the issue is whether the mapping is needed between the SSB(s) configured for each CG configuration and the CG resources (including transmission occasions and DMRS) for that CG configuration. Personally I think it is needed, otherwise the gNB does not know which receiver beam should be applied for a particular transmission occasion.

Different solutions can be found based on companies’ feedback during the first round discussions.

1) the SSB to RO mapping rule can be reused. For the PRACH resources the SSBs are mapped to ROs and preambles, similarly for the CG resources we can map different SSBs to different PUSCH occasions and DMRS resources. Although the rule can be reused, some details (e.g. mapping ratio and association period) may still need to be revisited, due to the different candidate values of periodicity between CG and RO as well as different number of resources between DMRS and preambles.

2) similar to what we had in the 2-step CFRA, the association is defined explicitly in MAC spec. This solution is also mentioned in the RAN2 LS.

3) another solution is that the SSBs are associated with all the CG occasions in a CG configuration. But the question is if multiple SSBs are mapped to the same CG occasion, how does gNB identify which SSB is selected by the UE, e.g. using different DMRS?

We had quite similar issues when the 2-step CFRA was discussed in Rel-16 2-step RACH WI, and at that time the final decision was made in RAN2 based on RAN1’s inputs. Probably a similar approach can be taken here, i.e. list the feasible solutions and ask RAN2 to select one.

Regarding the other detailed issues such as repetition and validation, maybe we can further discuss it once the basic principle of association is decided.

***Proposal 3.2***:

* From RAN1 perspective, the following alternatives can be considered for the association between the configured SSBs and the CG resources (including transmission occasions and DMRS) per CG configuration for CG-SDT.
  + Alt. 1: Reuse the SSB-to-RO mapping rules
    - FFS the potential RAN1 impact, e.g. mapping ratio and association period
  + ~~Alt. 2: The association is defined explicitly in MAC spec, similar to 2-step CFRA~~
    - ~~No RAN1 impact is expected~~
  + Alt. 3: All the CG transmission occasions per CG configuration are associated with the same set of SSB(s).
    - ~~FFS how to identify the selected SSB if multiple SSBs are configured per CG configuration, e.g. using different DMRS, or restrict the set of SSBs that should be mapped to the same Rx beam?~~
  + Other solutions are not precluded
* FFS whether repetition is supported for CG-SDT or not, and if supported how to handle the mapping between the SSBs and repetitions
* FFS TA validation (preferably in RAN2) and PUSCH validation for CG-SDT.

Any comments or suggestions on proposal 3.2?

|  |  |
| --- | --- |
| Company | Comment |
| Nokia, NSB | We prefer Alt3. as the SSB to CG-PUSCH resource configuration mapping already provides SSB-to-PUSCH transmission occasion mapping, there is no need to have some PRACH-like SSB-to-RO mapping in addition. Different CG-PUSCH resource configurations have different (non-overlapping) TOs if different Rx beams are to be applied for different SSB-associated SDT-CG-PUSCH transmissions.  If more than one SSBs are mapped to the same CG-PUSCH resource, that is because Rx beamforming is not used to differentiate between these SSBs, but they map to the same Rx beam. This is no different from in Rel-15 RACH, where mapping multiple SSB beams to the same RO can be configured. |
| CATT | We prefer Alt.1 because gNB can flexibly configure the association mapping ratio by dedicated signalling based on the number of SSBs and CGO and compared with Alt.3, this can reduce overhead of gNB blind detection. |
| Samsung | Alt.1 is preferred.  Not fully understand how alt.3 works. Does it mean the using the PO(s) in one CG PUSCH period to map all the SSBs (e.g., in one SSB period, or specifically configured SSB sets which might be only part of the SSBs are there)? if this is the case, this similar thought has been discussed for SSB-RO mapping, which the issue and reason not support this is also similar. From time to time, the mapping ratio will be different, then the PO resources for each SSB are different. Thus when UE selects the SSB based on its latest measurement, it may find less PO or even no PO to use. In general, as we understand the RAN2 intention for the SSB-PO association is also intended for derive the UE preferred DL beam by the detected PO. |
| Apple | We prefer Alt1.  For Alt.3, we are not so clear how to associate the DL beam and UL beam. If no association is defined, the DL transmission for SDT will transmit in very SSB, which cause the resource waste. |
| Ericsson | Alt1 is a bit preferred given the CG PUSCH is different from MsgA PUSCH in CFRA in our view since MsgA PUSCH resource is actually associated to the preamble ID defined by the SSB resource configured for CFRA. If there’s no dedicated SSB resource in CFRA, the SSB the preamble mapping in CBRA will be used and only PUSCH resource index 0 is used. But for CG PUSCH, there’s no preamble allocation.  CFRA-SSB-Resource ::= SEQUENCE {  ssb SSB-Index,  ra-PreambleIndex INTEGER (0..63),  ...,  [[  msgA-PUSCH-Resource-Index-r16 INTEGER (0..3071) OPTIONAL -- Cond 2StepCFRA  ]]  Alt 2 may also need some discussions in RAN1 due to the difference between MsgA (preamble+PUSCH) and CG PUSCH. No matter the mapping is defined in RAN1 or RAN2 spec. the mapping order is similar to SSB to RO mapping anyway in our view.  Another thing is that we assume the SSB to CG PUSCH mapping is mainly to let gNB know which SSB beam could be good for transmitting a confirmation message from gNB to UE in response to the reception of a CG PUSCH according to discussions in RAN2.  Alt 3 seems to be a separate issue, i.e. when multiple CG configuration is supported, whether we do SSB to CG PUSCH mapping per CG configuration or for all CG configurations. So it’s would be better to put it in a separate proposal to include some options for companies to discuss in our view. Or maybe discuss it together with proposal 3.1?  At least there’s already an agreement below from RAN2 in this meeting that multiple CG configurations are supported:   1. *As a baseline assumption, it’s a network configuration issue whether to support multiple CG-SDT configurations per carrier in RRC\_INACTIVE (i.e. we will not restrict network configuration for now).* |
| Huawei, HiSi | Alt. 3.  The FFS is not needed. As Nokia commented, the configured multiple SSB can directly associated to certain CG configuration.  For Ericsson comment, it is true and a separate proposal, irrelevant to the current proposal 3 as it is talking about ‘per CG configuration’. |
| Moderator (ZTE) | To Ericsson comment, the current proposal is to clarify whether the association is done at the CG configuration level or the CG resource unit (PUSCH occasion + DMRS) level. Probably it is helpful to draw some figures to explain how those alternatives work and the difference among them.  Alt. 1: the SSBs are mapped to PUSCH occasions + DMRS for each CG configuration. UE select the SSB first and determine the corresponding CG configuration and the corresponding CG resource within that CG configuration, gNB receive the CG resource using the receiver beam corresponding to the SSB.    Alt. 3: all the SSBs configured per CG configuration can be used for that CG configuration. UE select the SSB first and choose any of the PUSCH occasions within the corresponding CG configuration. Since a CG resource would be associated with multiple SSBs, there should be some restriction to avoid gNB blind detection, e.g. all the SSBs configured per CG configuration should be mapped to the same receiver beam as clarified by Nokia.    For alt. 2, as explained by Ericsson, it is now also a bit unclear to me how alt.2 works differently from alt.1, probably the proponent can provide some more explanation. Thanks. |
| Intel | Thanks for the nice figure. If the above figure is correct understanding for Alt.3, it seems a bit restrictive on the SSB association with CG configuration.  We slightly prefer Alt. 2, but it does not follow 2-step RACH. Instead, it can follow existing CG-PUSCH resource configuration. For instance, for one CG-PUSCH resource unit, it can be configured with “antennaPort” and “srs-ResoureIndicator”, where antenna port is used to indicate which DMRS AP is used, while srs-ResoureIndicator can be used to indicate which associated SSB index is used for Tx beam. In this case, we can simply follow existing configuration for CG-PUSCH and associate one CG-PUSCH resource unit with one SSB index.  In our view, the main difference between Alt. 1 and Alt.2 is whether we would use MsgA PO or CG-PUSCH configuration as a starting point. For the former case, we need to follow similar procedure as SSB to RO association to define the link between SSB and PO. For the latter case, our understanding is that existing configuration for CG-PUSCH can be reused. |
| Samsung | First, question to FL’s explanation on Alt.3, by saying “all the SSBs configured per CG configuration can be used for that CG configuration”, it means gNB will configure the SSB(s) for the CG-PUSCH resource, which implies gNB will decide which and how many SSBs a UE can be associated with? E.g., UE1 associated with SSB1, UE2 associated with SSB2? Since this is RRC inactive state (although not totally RRC idle), we think it could be very likely the UE will reselect the preferred SSB, then how gNB can ensure the configured SSBs including the “good DL beams” for UE?  [FL] My understanding is that a UE can be configured with multiple CG configurations, assuming CG config. 1 is associated with SSB 1~3 and CG config.2 associated with 4~6, etc; The SSB is still selected by UE first, for example if UE selects SSB2, it can use any of the CG resource for CG config.1; if UE reselect SSB4, it will use the CG resource for CG config.2.  Second, confusion on Gary’s comments. I thought Alt.1 is to use the CG-PUSCH configuration, rather than msgA PO as starting point. I don’t see any connection between Alt.1 to 2step RACH msgA PUSCH, in which the PUSCH is configured related to RACH slot, and association with done per RACH slot basis. But indeed, alt.1 will directly have a SSB-PUSCH association. For alt.2, I am not sure it works well for this purpose, it will put huge burden on gNB scheduling. For example, if there is 8 SSBs, then gNB needs to configure 8 CG-PUSCH configurations, and each of them can be separated by direct signaling. This is too much for us. I think the association rules (which holds for SSB-RO already) is already a good example for alleviating the burden. Remember, 2step CFRA is used in handover, and these explicit indication is used for CSI-RS based (at least motivated for it), while UE already report some preferred DL beams to the serving cell, so the configuration may not seem too complicated. But this CG-PUSCH, to me is more like a contention based PUR. |
| Intel | To Samsung, sorry for the confusion. We may need further discussion on how the detailed signalling structure or configuration of CG-PUSCH resource for each alternative.  Regarding the difference between Alt. 1 and Alt. 2, our understanding is that it highly depends on how many SSBs that gNB would configure for UE to operate for CG-SDT. If the number of SSBs is limited, our understanding is that Alt.2 can provide more flexibility as gNB can configure separate CG-PUSCH resources for CG-SDT. Further, we do not need to design the SSB to PO association and simply reuse the existing configuration for CG-PUSCH resource, including SSB index and DMRS AP, which would reduce the spec effort.  [FL] If I understand correctly, this corresponding to the latest Alt.3 and for the FFS part using DMRS ports to differentiate different SSBs for the CG configuration.  On the other hand, if the number of SSBs is large, e.g., reusing the number of SSB beams for initial access, then Alt. 1 may be more appropriate based on the similar rule as defined for SSB to RO association. In this case, gNB may configure a limited set of parameters for SSB to PO association for CG-SDT operation. |
| LG | We do not need to go beyond Proposal 3.1 for this meeting. In our view, RAN1 could further study Alt 1 and Alt 3 based on contributions for next meetings.  In addition, we may not need to associate all SSB to one or more CG configurations/occasions from UE perspective. RAN2 previously agreed that for CG-SDT, the configuration of configured grant resource for UE small data transmission is valid only in the same serving cell. Thus, we think that this UE may be in low mobility or stationary. Or, if UE has no good SSB for CG resources, UE could fall back to RA-SDT. Thus, it seems good to add:   * FFS: whether only subset of all SSBs can be associated for the CG resources from UE perspective. |
| Qualcomm | Alt 2 is preferred if:   1. the serving cell for CG-SDT does not change after UE switches from CONNECTED to INACTIVE state;   or   1. before switching from CONNECTED state to INACTIVE state, UE measures the SSB of the serving cell for CG-SDT and reports the measurements.   Otherwise, Alt 1 is used.  [FL] If I understand correctly, the “Alt 2” mentioned here means the SSB will be explicitly configured, but the main debating point is whether or not to map the SSB to each of the PUSCH resources. I am still not quite sure how this Alt.2 behaved differently from the other alternatives. |
| Huawei, HiSi02 | Great thanks for FL explanation and the nice figures. I think FL has got our point and we agree with FL response to Samsung (and largely to Intel). What Intel wants may be a further step under Alt 3, if further finer granularity of selection/association is preferred as FL explained for the FFS, however by which, it requires sharing the CG PUSCH resources in T-F domain but differentiated users by e.g. DMRS. This is exactly one of the reason we do not prefer Alt. 1. Or Alt 2, where SSB-RO-PO mapping is specified based on the contention based PUSCH resource configuration by natural, while for SDT in INACTIVE, it is not necessary, since gNB has UE specific information already. Thus no need to associate all SSBs to different CG occasions as done in SSB-to-RO (in a cell-specific manner) - which also bring gNB blind detection burden as happens in 2-step RACH.  A bit further clarification: the number of SSBs associated to each CG configuration can be different, e.g. CG config. 1 is associated with SSB 1 while CG config.2 associated with SSB 2~4. There is no need to restrict the number in specification and can be up to network configuration. With the **UE-specific** SSB-to-CGO mapping, gNB can configure more CGO in one CG configuration that associated to the SSB(s) when UE goes to RRC\_INACTIVE, and configure less CGO in other CG configuration associated to other SSB(s).  Also since it is UE specific configuration, we think the FFS may not be needed, because it is up to gNB to configure UE-1 and UE-2 at the overlapping T-F resources but with different DMRS resources, in each respective CG configurations. |
| Nokia, NSB02 January 29th | If we configure just 1 CG-PUSCH resource for all SSBs, then it resembles the random access operation where only one RO pattern exists, and then you need to have a mechanism to select a particular RO out of the pattern to match the SSB. This approach would work, but then there is no point in SSB-to-CG-PUSCH config relation as we should just have a pool of CG-PUSCH transmission occasions that are mapped with some other mechanism (like with RACH) to the SSBs.  If we however configure a relation from SSB to CG-PUSCH configuration, then each SSB can have its own TO pattern already. If the network maps multiple SSBs to one CG-PUSCH, that is because it does not need to differentiate between these SSB beams. This is also possible with RACH multiple SSBs to one RO mapping and the property should be retained here.  It would also be possible to have both approaches merged. It would be equivalent to having one set of SSBs mapped to one RO set, and another set of SSBs mapped to another RO set, and then have the SSB-to-RO mapping operating within each distinct group. However, we don’t see a point in such a mix at this stage. If there is a need to identify the SSB the UE is on, then 1-to-1 mapping from SSB to CG-PUSCH resource can be used and different CG-PUSCH resources can have different time/frequency/DMRS configuration to identify the SSB the UE had picked.  It might be the best to take a time-out as LG suggests and work on contributions on this matter for the next meeting. |
| Moderator (ZTE) 02 | Thanks HW and Nokia for the clarifications to alt.3. I have removed the FFS for now, assuming it is up to gNB implementation.  Alt. 2 will be removed unless proponent can provide how it works differently from alt.1 or 3.  I think the discussions and clarifications are really helpful, so maybe we can try to make consensus on these workable solutions first, and add a note that other solutions are not precluded. |
| vivo | Alt. 1 is preferred. We are open to further discuss the other alternatives. It is not clear to us that how many CG transmission occasions per CG configuration can be configured, and how many CG configurations can be configured, and how the CG transmission occasion is mapped to the set of SSBs in case of multiple CG transmission occasions. We may need to clarify how these alternatives work for SDT before making the decision on which alternative is adopted. |
| Samsung | Thanks FL and proponents for the explanation, it seems understandable how alt.3 works now. I tend to agree that both alternatives can work; it is just how it could better fit in the purpose of the association.  From our understanding, the purpose of association which RAN2 asked us to design for, it’s the same purpose of that for association between SSB-RO, as gNB to configure the CG-PUSCH resources (via UE specific signalling), gNB cannot predict the selected SSB when UE actually does the CG-SDT (I see companies saying using the lasted SSB or latest reported SSB as reference, but if this is useful, I wonder RAN2 has not bother to send LS to RAN1 on this issue). Alt.1 is the way directly for this purpose.  Alt.3 indeed brings the flexibility, by different SSB(s) associated with different CG-PUSCH configuration. But we may ask whether this flexibility is what RAN2 asked RAN1 for. Without knowing which SSB or which sets of SSB UE is going to use, how gNB configures PUSCH to only a few SSB(s)? so the proper way is still at least all SSB needs to have some PUSCH resource. Then next flexibility is some SSB can associate with more PUSCH, others can associate with less. Again, how does this flexibility can help without knowing how many UEs in which SSBs to do CG-SDT? Isn’t this is the same reason that for SSB-RO association, we design the equal resources for each SSB? Thus, to us, these flexibilities so far did not show attractive benefits or necessities. The burden that for gNB to schedule has been mentioned in previous comments, thus not repeated here.  We are fine to further discuss these two alternatives even in next meeting, more discussion is needed and some background check may need from RAN2. But if we need to do some down selection now, we did not accept the direction implied by Alt.3 |
| CATT | For Alt.3, it isn’t clear to us how gNB configures a subset of SSBs to CG configuration and why different CG configuration corresponds to different subset of SSBs for the same UE.  We are fine to continue to discuss about the association between the configured SSBs and the CG resources for CG-SDT the next meeting. |

# Other physical layer issues related to small data transmission

There are some other physical layer issues of small data transmission mentioned by different companies. As these issues may not be directly related to RAN2’s LS, the moderator think they could be discussed with lower priority.

## Other issues related to PDCCH addressed by C-RNTI (Huawei)

For the DCI formats and aggregation levels (ALs) of PDCCH candidates for subsequent scheduling, only the Format 0\_0/1\_0 and the existing ALs {4, 8, 16} in CSS should be supported from the complexity and power saving point of view. The additional fields in 0\_1/1\_1, e.g. for multi-layer transmission and beam management, are not required for SDT. Format 2\_x/3\_x are also unnecessary during SDT procedure.

In R15/R16, the UE may assume that the DMRS antenna port associated with PDCCH receptions in the CORESET configured by *pdcch-ConfigSIB1* (CORESET#0) and the corresponding SSB are quasi co-located [2]. Here, for monitoring the PDCCH in subsequent RA-SDT, the UE should also assume the QCL of DMRS antenna port between the PDCCH receptions and corresponding SSB, regardless whether the common CORESET is CORESET#0 or not.

***Proposal 2****: Support only the DCI Format 0\_0/1\_0 and ALs= {4, 8, 16} of PDCCH candidates for subsequent scheduling after initial RA-SDT.*

***Proposal 3****: UE assumes that the DMRS antenna port associated with PDCCH receptions addressed to C-RNTI and the corresponding SSB are quasi co-located.*

**Discussion point 4.1**

Do you agree with the above two proposals?

|  |  |
| --- | --- |
| Company | Comment |
| Huawei, HiSi | Agree.  The SDT work item is mainly for UE power saving and network signaling reduction. The Proposal 2 aims at decreasing the UE blind detection to save the UE power. The Proposal 3 aims at increasing the DL performance of PDCCH, which improves the success rate of blind detection, also benefit to UE power saving. |
| Nokia, NSB | Proposal 2: OK to use x\_0 only, and the ALs that are associated to these formats and the chosen SS should be kept unchanged.  Proposal 3: The same QCL rule as in Rel-15 should be kept |
| Qualcomm | The proposals above look good to us in principle. |
| vivo | In principle, we agree with the proposal. In addition, this QCL assumption can be applied for the case of CORESET #0 or other CORESET for SDT as discussion point 2.2. |
| CATT | Intention of proposal 2 and proposal 3 are fine with us and detail ALs value of PDCCH candidates & QCL rule can be further studied. |
| LG | We are generally fine with Proposal 2 and 3. Proposal 2 could be changed to:  ***Proposal 2****: Support only the DCI Format 0\_0/1\_0 and ALs= {4, 8, 16} of PDCCH candidates for subsequent uplink scheduling after initial RA-SDT.* |

## BWP for SDT

(ZTE) In RAN2, whether the BWP associated with CG-SDT resources is configurable or not is being discussed. This aspect can be left to RAN2. RAN1 may further study the **BWP switching** if RAN2 agree that the multiple BWPs for CG-SDT resources is configurable.

(Apple) Proposal 1: For RA-SDT, the **initial BWP** is applied for UL and DL data transmission, USS set is configured for SDT transmission.

(QC) From RAN1 perspective, UE shall monitor PDCCH addressed to C-RNTI in **initial DL BWP or active DL BWP** after successful completion of the RACH procedure during RA-SDT.

**Discussion point 4.2**

Which BWP shall be applied for RA-SDT and CG-SDT respectively?

|  |  |
| --- | --- |
| Company | Comment |
| Apple | To avoid retuning from one BWP to another to receive the SDT related info and system information, the initial BWP is suitable for SDT transmission and reception. |
| Huawei, HiSi | For the RA-SDT, this should be discussed following section 2.2.  For the CG-SDT, both the initial UL/DL BWP and UE-specific UL/DL BWP for RRC INACTIVE can be used, up to network configuration. |
| Nokia, NSB | Agree with Qualcomm |
| vivo | Both initial BWP or non-initial BWP can be used. For SDT, initial BWP should be at least supported.  Also, whether the same or different BWPs for RACH procedure and subsequent transmission during SDT are used need to be determined. If different BWPs are used, the switching behavior during subsequent transmission should discussed, e.g. to avoid retuning. |
| CATT | At least initial BWP should be supported. |
| LG | We think that SDT specific UL BWP could be configured for RA SDT and/or CG-SDT. But, if SDT specific UL BWP is not configured, initial UL BWP is used for SDT. |

## TA validity within and across SSBs (Nokia)

The TA timer by itself is not a condition enough to validate if the UE still has a valid TA, since the configured timer duration does not reflect the UE’s mobility conditions and therefore the UE can become time misaligned before the TA timer expires. Also, the UE may be still time aligned when the TA timer expires. Therefore, in NB-IOT’s PUR, the TA validation procedure was extended to also include the observation of the variantion of the serving cell RSRP. Below we revisit this procedure as defined in TS 38.331 in clause 5.3.3.19

A UE before proceeding with its PUR transmission, has to ensure that the current measured serving cell RSRP as neither increased above the *increaseThresh* nor has decreased below the *decreaseThresh*, when compared to previous serving cell RSRP when the UE knows that the TA was valid. However, the same serving cell RSRP based TA validation procedure is not necessarilly sufficient in NR, mainly due to the characteristics associated with the NR’s beam-based operation.

**Observation: TA validation based on serving cell RSRP variation is not robust in a NR system due to the multi-beam scenarios.**

**Proposal: RAN1 to study additional TA validation mechanisms that can make TA validation robust in multi-beam scenarios.**

**Discussion point 4.3**

Should RAN1 study additional TA validation mechanism in multi-beam scenario? If so, what are the candidate solutions?

|  |  |
| --- | --- |
| Company | Comment |
| Huawei, HiSi | To be handled in RAN2. |
| Nokia, NSB | Prefer discussing this in RAN1, but if the decision is to defer this to RAN2, that should be said in the response LS |
| Qualcomm | Agree with the comments of Nokia.  Specifically, SSB-based measurement is a main reference for TA validation, which belongs to PHY procedures of UE. |
| vivo | This issue should be discussed in RAN2. |
| CATT | This issue should be firstly addressed in RAN2. |
| LG | RAN2 agreed the followings this week:  *From RAN2 point of view, assume similar to PUR, that we introduce a TA validation mechanism for SDT based on RSRP change, i.e. RSRP-based threshold(s) are configured. Ask RAN1 to confirm. FFS on how to handle CG configuration when TA expires or when is invalid due to RSRP threshold. Details of the TA validation procedure can be further discussed.*  We think that, if needed, RAN2 could ask RAN1 to work after initial RAN2 discussion on any additional TA validation mechanisms. |

## UL Tx spatial filter (Huawei)

***Proposal:*** *For promoting SDT performance, the rules of setting transmit spatial filter for CG-SDT can be also considered as in existing RACH procedure, if the UE is equipped with multiple Tx antennas.*

* *UE uses the same spatial filter as in the last PUSCH in RRC\_CONNECTED within a timer and without the changing of best SSB regarding RSRP.*
* *UE uses the same spatial filter as in the last PUSCH in the previous RA procedure within a timer and without the changing of best SSB regarding RSRP.*

**Discussion point 4.4**

Do you agree with the above proposal?

|  |  |
| --- | --- |
| Company | Comment |
| Huawei, HiSi | Agree.  The SDT work item is mainly for UE power saving and network signaling reduction. The two rules extended from existing specification can promote SDT performance, which help to reduce UE Tx power and decrease the network implementation complexity. |
| Nokia, NSB | Do not agree. The best SSB should be used |
| InterDigital | Agree with Nokia. |
| CATT | FFS after the basic decisions are taken. |
| LG | We think that the best SSB can be used. But, this issue could be postponed and discussed later after some progress on basic operation. |

## UE-specific configurations for SDT (vivo)

**Proposal:**  **For RACH-SDT, following UE-specific configurations for SDT need to be further discussed.**

* + CORESET and TCI state info
  + UE-specific search space
  + UE-specific TDRA
  + UE-specific PUCCH resource/timing
  + the num of DL/UL HARQ process
  + initial BWP and non-initial BWP
  + RLM/BFD/BFR configuration
  + Power control related parameters
  + SR resource
  + SPS/CG for subsequent data transmission for subsequent transmission

**Discussion point 4.5**

Do you think any of the above UE-specific configurations should be provided for RA-SDT?

|  |  |
| --- | --- |
| Company | Comment |
| LG | Some of them could be provided by RA-SDT based on RAN1/RAN2 discussion. |
| Nokia, NSB | FFS after the basic decisions are taken. |
| Qualcomm | Since R17 SDT WI did not allocate any RAN1 TU, it is preferred to re-use the solutions available in R16 2-step RACH as much as possible. |
| vivo | For UE-specific configuration for RA-SDT, the key questions are when and what to indicate the UE-specific configuration.  These UE-specific configurations/parameters should be further discussed if UE-specific search space or CORESET would be used for SDT. |
| Lenovo, Motorola Mobility | FFS |
| CATT | Agree with Nokia. |

# Summary

To be updated

Any other issues or comments?

|  |  |
| --- | --- |
| Company | Comment |
|  |  |
|  |  |
|  |  |

# References

1. R1-2100025 LS on physical layer aspects of small data transmission ZTE
2. R1-2100080 Discussion on the physical layer aspects of small data transmission ZTE, Sanechips
3. R1-2100317 Discussion on physical layer aspects of small data transmission CATT
4. R1-2100501 On physical layer aspects of small data transmission Nokia, Nokia Shanghai Bell
5. R1-2100627 Discussion on LS on small data transmission Intel Corporation
6. R1-2100910 Discussion on physical layer aspects of small data transmission LG Electronics
7. R1-2101159 Discussion on RAN1 impacts for small data transmisison vivo
8. R1-2101165 Discussion on physical layer aspects of small data transmission Samsung
9. R1-2101267 RA and CG based small data transmission Huawei, HiSilicon
10. R1-2101338 Discussion on physical layer aspects of small data transmission Apple
11. R1-2101405 Physical layer aspects of small data transmission InterDigital, Inc.
12. R1-2101430 Reply to RAN2 LS on SDT resource configuration Qualcomm Incorporated
13. R1-2101518 [DRAFT] LS reply on physical layer aspects of small data transmission Ericsson

# Appendix

List of proposals in the submitted contributions.

|  |  |
| --- | --- |
| TDoc | Proposals |
| R1-2100080  ZTE | ***Proposal 1:***  ***A new field specifically defined for CORESET/Seachspace configuration can be added in the PDCCH-ConfigCommon for RA-SDT C-RNTI DCI.***  ***Proposal 2:***  ***For CG-SDT, down-select from the following alternatives for the configuration of SSBs for the CG-SDT***   * ***Alt. 1: only one SSB is configured per CG configuration for the first transmission, which is explicitly indicated in RRC release message.***    + ***FFS autonomous beam switching mechanism or fall back method in case of beam failure for the subsequent data transmission.*** * ***Alt. 2: multiple SSBs are configured per CG configuration, and the mapping between SSBs and CG occasions should be defined.***   + ***FFS whether a subset of SSB indexes can be configured per CG configuration, to be indicated in RRC release message***   ***Proposal 3:***   * ***If multiple SSBs are configured per CG configuration, at least support one-to-one mapping between SSBs and CG occasions, and the configured CG repetition number (number of occasions in one CG period) is limited to 1;*** * ***FFS if the repetition is configurable, and further study the following possibilities***   + ***one SSB mapping to one CG occasion, the configured CG repetition number can be lager than one, while the actual repetition number is still limited to 1;***   + ***one SSB mapping to K CG occasions, where K is the configured repetition number as well as the actual repetition number.***   ***Proposal 4:***  ***If multiple SSBs are configured per CG configuration, it is preferable to explicitly configure the association period between SSB and CG occasions.*** |
| R1-2100317  CATT | **Proposal 1: Separate PDCCH search space from existing CSS is supported for scheduling small data transmission after successful completion of the RACH procedure during RA-SDT.**  **Proposal 2: Parameters related to separate PDCCH SS can be configured to small data UEs by the broadcast signaling. CCE mapping position of each PDCCH candidate in the separate PDCCH SS is determined according to the hash function with C-RNTI for randomization parameter.**  **Proposal 3: After successful completion of the RACH procedure during RA-SDT, UE should monitor separate PDCCH for small data transmission. UE should stop monitoring separate PDCCH search space after UE receives RRC release signaling or high layer signaling of configuration on USS (UE specific search space)/Type3-CSS(Common search space).**  **Proposal 4: Mapping ratio between SS/PBCH blocks and TOs of one Type1 CG configuration can be configured by RRC signaling within the association period.**  **Proposal 5: When PUSCH repetition is applied for Type1 CG configuration during CG-SDT, SS/PBCH blocks should be associated with one TO bundle including K TOs corresponding to the K repetitions.** |
| R1-2100501  Nokia | **Proposal 1:** The UE monitors the C-RNTI for small data transmission after the successful completion of the RA-SDT procedure in CSS type1 applying the CORESET configuration associated to that CSS.  **Observation 1:** The UE in RRC\_INACTIVE needs to support beam correspondence for the CG-PUSCH resource to SSB relation to be useful.  **Proposal 2:** From RAN1 perspective the CG-PUSCH resource to SSB relation can be provided explicitely in the RRC configuration. It should be possible to associate one CG-PUSCH configuration to several (or to all) SSBs.  **Observation 2:** TA validation based on serving cell RSRP variation is not robust in a NR system due to the multi-beam scenarios.  **Proposal 3:** RAN1 to study additional TA validation mechanisms that can make TA validation robust in multi-beam scenarios.  **Proposal 4:** Provide RAN2 with an LS response corresponding to the proposals and observations above. |
| R1-2100627  Intel | **Proposal 1**   * *If configured with dedicated configuration of CORESET and SS set for PDCCH monitoring during RA-SDT procedure and if the configuration is valid for RA-SDT, UE shall monitor the PDCCH addressed to C-RNTI according to the configured CORESET and SS set, and the CORESET and SS set used for detecting DCI format with CRC scrambled with RA-RNTI.* * *If UE is not configured with dedicated configuration for CORESET and SS set for RA-SDT, UE shall monitor PDCCH addressed to C-RNTI according to the CORESET and SS set used for detecting DCI format with CRC scrambled with RA-RNTI.*   **Proposal 2**  *CG-PUSCH resource is associated with an SRS resource with SRS-SpatialRelationInfo containing the ID of a reference “ssb-Index”* |
| R1-2100910  LGE | ***Proposal 1: Type3-PDCCH CSS set or USS set can be supported for monitoring the PDCCH addressed to the C-RNTI after successful completion of the RACH procedure during RA-SDT.***  ***Proposal 2: Dedicated configuration of CSS Type 3 PDCCH or USS should be provided before or when UE goes to RRC\_INACTIVE.***  ***Proposal 3: At least CORESET0 can be used for monitoring the PDCCH addressed to the C-RNTI after successful completion of the RACH procedure during RA-SDT.***  ***Proposal 4: If needed, other CORESET than CORESET0 can be also considered for monitoring the PDCCH addressed to the C-RNTI after successful completion of the RACH procedure during RA-SDT.***  ***Proposal 5: RAN1 needs to further discuss details about CORESET/SS for RA-SDT.***  ***Observation 1: For CG in RRC\_CONNECTED, SRS resources are mapped to spatial information e.g. SSB(s).***  ***Observation 2: Since RAN2 agreed that the configuration of configured grant resource for UE uplink small data transfer is contained in the RRCRelease message, IE SRS-SpatialRelationInfo indicated by SRS-ResourceIndicator in IE rrc-ConfiguredUplinkGrant (i.e. SRS-resourceId) can be also provided to UE for association between the type 1 CG resource(s) for CG-SDT and SSB(s).***  ***Proposal 6: Some of SRS configuration for CG-SDT (e.g. IE SRS-SpatialRelationInfo in SRS-Config) can be provided to a UE for association between the type 1 CG resource(s) for CG-SDT and SSB(s).***  ***Proposal 7: Respond to RAN2 based on the above observations and the proposals.*** |
| R1-2101159  vivo | **Observation 1: PDCCH monitoring with CRC scrambled by C-RNTI in CSS for subsequent transmission of RA-SDT can be supported in NR.**  **Proposal 1:**  **If USS is supported for PDCCH monitoring with CRC scrambled by C-RNTI for RA-SDT/CG-SDT, low power consumption for PDCCH monitoring in USS needs to be considered.**  **Proposal 2:**  **For RACH-SDT, following UE-specific configurations for SDT need to be further discussed.**   * + **CORESET** **and TCI state info**   + **UE-specific search space**   + **UE-specific TDRA**   + **UE-specific PUCCH resource/timing**   + **the num of DL/UL HARQ process**   + **initial BWP and non-initial BWP**   + **RLM/BFD/BFR configuration**   + **Power control related parameters**   + **SR resource**   + **SPS/CG for subsequent data transmission for subsequent transmission**   **Proposal 3:**  **NR-U CG (or MsgA PO) resource allocation method is reused for NR SDT.**  **Proposal 4:** **For NR SDT, the association between SSB and SDT CG resource is 1:1 mapping.**  **Proposal 5:**  **For NR SDT, SSB is mapped to a CG occasion and the associated DMRS resource (port/sequence/scrambling ID) in a manner similar to 2-step RA mapping rule.** |
| R1-2101165  Samsung | ***Proposal 1: the CORESET and search space used for RA-SDT is configured in msg4.***  ***Proposal 2: Configure the number of PUSCH transmission occasion (PO) in one SDT-PUSCH period by new parameter or re-interpret the number of repetitions configured.***  ***Proposal 3: the valid PO is the PO in UL part in a slot, or at least Ngap symbols after the end of the DL part in a slot or after the end of the SSB in a slot.***  ***Proposal 4: the mapping ratio (number of SSB per PO) is configured by gNB and no larger than 1;***  ***Proposal 5: the SSB-PO association starts from the*** *timeReferenceSFN* ***indicated by gNB.*** |
| R1-2101267  Huawei | ***Observation 1:*** *Both the subsequent UL and DL transmissions will be scheduled by PDCCH addressed to the C-RNTI. The number of subsequent transmissions for one UE can be large.*  ***Observation 2:*** *The UE-specific CORESET/SearchSpace may require more specification impacts.*  ***Proposal 1:*** *As a baseline, the UE uses common CORESET (e.g. CORESET#0) and a new common SearchSpace configured in system information for monitoring C-RNTI after contention resolution of initial RA-SDT. FFS if the bandwidth of UE-specific CORESET is not larger than initial BWP and UE is in serving cell, UE can also use the UE-specific CORESET/SearchSpace.*  ***Proposal 2****: Support only the DCI Format 0\_0/1\_0 and ALs= {4, 8, 16} of PDCCH candidates for subsequent scheduling after initial RA-SDT.*  ***Proposal 3****: UE assumes that the DMRS antenna port associated with PDCCH receptions addressed to C-RNTI and the corresponding SSB are quasi co-located.*  ***Proposal 4:*** *Support one CG configuration associated to one or multiple SSBs. Multiple CG configurations can be configured to associate with different SSBs. The configuration can be based on UE report and/or request.*  ***Proposal 5:*** *The association can be updated by DCI or high layer signaling after one CG-SDT.*  ***Proposal 6:*** *For promoting SDT performance, the rules of setting transmit spatial filter for CG-SDT can be also considered as in existing RACH procedure, if the UE is equipped with multiple Tx antennas.*   * *UE uses the same spatial filter as in the last PUSCH in RRC\_CONNECTED within a timer and without the changing of best SSB regarding RSRP.* * *UE uses the same spatial filter as in the last PUSCH in the previous RA procedure within a timer and without the changing of best SSB regarding RSRP.* |
| R1-2101338  Apple | **Proposal 1:** **For RA-SDT, the initial BWP is applied for UL and DL data transmission, USS set is configured for SDT transmission.**  **Proposal 2: The mechanism of MsgA PUSCH association with SSB is re-used for association between the type 1 CG resource(s) for CG-SDT and SSB(s).** |
| R1-2101405  InterDigital | ***Proposal 1: For PDCCH monitoring addressed to C-RNTI after successful completion of the RA, reply to RAN2 that:***  ***- UE can monitor dedicated search spaces if available; UE monitors common search space otherwise.***  ***- it is up to RAN2 how the UE keeps coreset and search space configurations upon transitioning into INACTIVE state.***  ***Proposal 2: CG-SDT can be configured with one-to-many mapping to SSBs.*** |
| R1-2101430  Qualcomm | From RAN1 perspective, UE shall monitor PDCCH addressed to C-RNTI in initial DL BWP or active DL BWP after successful completion of the RACH procedure during RA-SDT. The active DL BWP (if different from initial DL BWP), CORESET and search space configurations for the UE can be included in the *RRCResume* or *RRCReconfiguration* message.  From RAN1 perspective, gNB can explicitly indicate the SSB index(es) as well as the CG resources (i.e. PUSCH/DMRS occasions) associated with the SSB index(es) in the *RRCRelease* message. Each CG resource includes a PUSCH occasion and associated DMRS resource. Similar to higher layer parameter of *configuredGrantConfig* including *rrc-ConfiguredUplinkGrant*, the PUSCH occasion can be defined by a time and frequency resource and the DMRS can be defined by *antennaPort*, *cg-DMRS-Configuration* and *dmrs-SeqInitialization*. Before CG-SDT, UE needs to validate the PUSCH occasion(s) and the TA. The PUSCH validation procedures specified in Section 8.1A of TS 38.213 can be re-used for the validation of CG-SDT resources. |
| R1-2101518  Ericsson | **Response to topic 1:**  Type1-PDCCH CSS can be at least used as a default CSS for C-RNTI monitoring in SDT. It’s up to RAN2 to decide whether an optional search space or an optional search space ID of a search space defined for RRC connected state should be indicated in the RRC release message.  **Response to topic 2:** RAN1 would like to reuse mechanism of SSB to RO mapping to support the SSB to CG PUSCH mapping for UEs in RRC inactive state doing small data transmission if multiple SSBs are expected for CG-based SDT. In this case, RAN1 needs input from RAN2 on   * The possibility of configuring multiple PUSCH resources per PUSCH occasion in one CG period, * CG period candidate values, * The number of CG configurations. |