**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.
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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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### Second round

To be updated

## 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?

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### Second round

To be updated

# 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?

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### Second round

To be updated

## 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?

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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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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?

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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?

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### Second round

To be updated

# 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?

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## 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?

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## 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?

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## 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?

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## 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 4.4**

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

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# Summary

To be updated

Any other issues or comments?

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# 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.

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| TDoc | Proposals |
| R1-2100080ZTE | ***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.*** |
| R1-2100317CATT | **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.** |
| R1-2100501Nokia | **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. |
| R1-2100627Intel | **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”* |
| R1-2100910LGE | ***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.*** |
| R1-2101159vivo | **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.** |
| R1-2101165Samsung | ***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.*** |
| R1-2101267Huawei | ***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.*
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| R1-2101338Apple | **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).**  |
| R1-2101405InterDigital | ***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.*** |
| R1-2101430Qualcomm | 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. |
| R1-2101518Ericsson | **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.
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