**3GPP TSG RAN WG1 #107-e R1-211xxxx**

**e-Meeting, November 11th – 19th, 2021**

**Source: Moderator (Intel Corporation)**

**Title: Draft summary#1 of AI: 8.1.2.4 Enhancements on HST-SFN deployment**

**Agenda item: 8.1.2.4**

**Document for: Discussion and Decision**

# Introduction

In RAN#86 meeting the work item on enhanced MIMO support was agreed for Rel-17 [1]. The objectives of WID include enhancements to multi-TRP transmission scheme in HST-SFN scenario.

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| 2. Enhancement on the support for multi-TRP deployment, targeting both FR1 and FR2:  …  d. Enhancement to support HST-SFN deployment scenario:  i. Identify and specify solution(s) on QCL assumption for DMRS, e.g. multiple QCL assumptions for the same DMRS port(s), targeting DL-only transmission  ii. Evaluate and, if the benefit over Rel.16 HST enhancement baseline is demonstrated, specify QCL/QCL-like relation (including applicable type(s) and the associated requirement) between DL and UL signal by reusing the unified TCI framework |

The document contains summary of the companies’ and moderator’s proposals.

# Possible enhancements for HST-SFN deployment

## General issues

### Issue #1-1 (Transmission schemes for PDCCH and PDSCH)

Regarding combinations of the transmission schemes for PDCCH and PDSCH that can be supported with enhanced SFN transmission schemes. Several companies have mentioned that SFN PDSCH may have worse performance comparing to Rel-16 multi-TRP repetition schemes for PDSCH. Considering this, it was proposed to also allow combination of Rel-17 SFN PDCCH and Rel-16 multi-TRP PDSCH schemes for URLLC application. Moreover, one company has mentioned that single TRP PDSCH should be also supported with TRP-based pre-compensation scheme for PDCCH.

#### Round-1

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|  |  | PDSCH | | | |
| PDCCH |  | Rel-15 | Rel-16 | Scheme 1 | Pre-compensation |
| Rel-15 | N/A | N/A | Supported | Supported |
| Rel-17 URLLC | N/A | N/A |  |  |
| Scheme 1 | Supported | Yes: LGE, DOCOMO  No: QC, | Supported | Not supported |
| Pre-compensation | Yes: CMCC | Yes: LGE  No: QC, | Not supported | Supported |

**Proposal #1-1:**

* TBD

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| **Company** | **Comment** |
| Moderator | Please provide your preference directly in the table above focusing on the cases highlighted in yellow. In this table provide justification why the proposed combination should or should not be supported. |
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### Issue #1-2 (RRC configuration of CC sets for MAC CE activation)

Regarding configuration of the CC list that can be addressed by single MAC CE entry. In RAN1#106b-e meeting, it was agreed as working assumption to reuse the existing Rel-16 RRC parameters defined for PDSCH. In this meeting several companies proposed to confirm the working assumption.

#### Round-1

**Proposal #1-2:**

* Confirm the working assumption from RAN1 #106b-e meeting to reuse legacy Rel-16 RRC parameters *simultaneousTCI-UpdateList1*, *simultaneousTCI-UpdateList2* to define set of the serving cells which can be addressed by a single MAC CE for activation of two TCI states of CORESET with the same CORESET ID for all the BWPs.

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| **Company** | **Comment** |
| Moderator | It seems most of the companies are OK to confirm the working assumption |
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### Issue #1-3 (TCI state update for CORESETs on BWPs/CC not configured with SFN)

In RAN1#106-e meeting it was agreed to study whether and how to update the CORESET with TCI state that is not configured to SFN scheme in the indicated CCs set. The following proposals were made to this issue.

**Issue#1-3:**

* For CCs not configured with SFN, 1st TCI state of the two indicated TCI states is selected.
  + **Supported by**: NTT DOCOMO, CATT, Lenovo / MotMobility
* UE doesn’t expect to receive a MAC-CE activating two TCI states of a CORESET that is not identified for SFN scheme by RRC
  + It is up to editor whether and now to capture this in the specification
  + **Supported by**: Nokia / NSB, Qualcomm

#### Round-1

**Proposal#1-3:**

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| **Company** | **Comment** |
| Moderator | More inputs are needed for this issue |
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### Issue #1-4 (Restriction of SFN scheme configuration)

In RAN1#105-e meeting, it was agreed that mixed SFN modes (scheme-1 and TPR-based pre-compensation) is not expected across CORESETs and across PDSCH. However, it is still FFS whether different SFN schemes are possible in different CCs or not according to the agreement below.

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| **Agreement**   * For TRP-based pre-compensation QCL assumptions is provided to the UE by using the existing QCL type(s) with certain QCL parameters dropped from the indicted QCL type   + FFS rule or signalling to determine which TCI state with dropped QCL parameters * UE does not expect to be configured different SFN schemes (scheme 1 or TRP pre-compensation) for both PDCCH and PDSCH.   + FFS whether this restriction is per UE or per CC * UE does not expect to be configured different SFN schemes (scheme 1 or TRP pre-compensation) for different CORESETs.   + FFS whether this restriction is per UE or per CC |

**Issue#1-4:**

The configuration restriction of different SFN schemes for PDCCH and PDSCH is defined

* **Alt 1.** Per-CC group
  + **Supported by**: Qualcomm,
* **Alt 2**: Per CC
  + **Supported by**: …

#### Round-1

**Proposal:**

* TBD

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| **Company** | **Comment** |
| Moderator | More inputs from other companies are required |
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### Issue #1-5 (RRC configuration of SFN scheme for BWPs)

One if the open issues related to support of SFN scheme for PDCCH is whether SFN scheme can be configured for BWP-DownlinkCommon according to the FFS from RAN1#106b-e meeting:

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| **Agreement**  Enhanced SFN (scheme 1 or TRP-based pre-compensation scheme) for PDCCH and PDSCH is configured by using separate per-BWP RRC parameters   * In Rel-17, all downlink BWPs (except initial BWP and FFS: BWP-DownlinkCommon) within a CC should be the same configuration of SFN scheme |

One company in [14] has made proposal to remove the FFS from the previous agreement.

#### Round-1

**Proposal #1-5**:

Update RAN1#106b-e meeting agreement by removing the “FFS:”

* Enhanced SFN (scheme 1 or TRP-based pre-compensation scheme) for PDCCH and PDSCH is configured by using separate per-BWP RRC parameters
  + In Rel-17, all downlink BWPs (except initial BWP and ~~FFS:~~ BWP-DownlinkCommon) within a CC should be the same configuration of SFN scheme

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| **Company** | **Comment** |
| Moderator | More inputs are required from other companies |
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### Issue #1-6 (Remaining details of RRC configuration and MAC CE usage)

One company in [22] has proposed to consider the case when only two TCI states are RRC-configured for SFN CORESETs. The following proposal is made to support this scenario.

#### Round-1

**Issue #1-6**:

* For a CORESET that is indicated with SFN mode by higher layer signalling and RRC-configured with only two TCI states, the UE assumes that the DM-RS antenna port associated with PDCCH receptions in the CORESET are QCL-ed with the DL RSs in the two TCI states.

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| **Company** | **Comment** |
| Moderator | The issue has been discussed in the previous meeting. Since it is related to signaling design, one option is to leave this decision up to RAN2 decision. |
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### Other issues

This section contains other issues that companies want to highlight for discussion regarding general issue.

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## UE-based solutions

### Issue #2-1 (Dynamic switching of scheme 1 and scheme-1a)

Regarding support of switching of scheme 1 and Rel-16 scheme-1a. In RAN1#104b-e meeting it was agreed to support semi-static switching and to further study possible support of dynamic switching. Views on this issue are summarized below.

**Issue#2-1:** Additional support of dynamic switching of scheme 1 and Rel-16 scheme-1a

* **Supported**: Huawei / HiSilicon, CATT, …
* **Not supported:** Qualcomm, OPPO, NEC, Nokia/NSB, Lenovo/MotMobility, Apple, Mediatek …

Based on the preference above the following proposal can be made.

#### Round-1

**Proposal #2-1 (for conclusion):**

* Dynamic switching of Rel-17 scheme 1 and Rel-16 scheme-1a is not supported

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| **Company** | **Comment** |
| Moderator | This is low priority issue, since the situation is the same as in the previous meeting. |
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### Issue #2-2 (Support of scheme 2)

Regarding support of scheme 2. A few companies expressed their preference regarding support of scheme 2 in Rel-17. Summary of the companies’ views are provided below.

**Issue#2-2:** Whether to support scheme 2 in Rel-17

* Scheme 2 is supported
  + **Supported by**: InterDigital, Intel …
* Scheme 2 is not supported / low priority
  + **Supported by**: Apple, Sony, Nokia/NSB, Qualcomm, ZTE, …

#### Round-1

**Proposal #2-2 (for conclusion):**

* Scheme 2 is not supported in Rel-17

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| **Company** | **Comment** |
| Moderator | This is low priority issue, since the situation is the same as in the previous meeting. |
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### Other issues

This section contains other issues that companies want to highlight for discussion regarding support of UE-based schemes.

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## TRP-based solutions

### Issue #3-1 (TRP-based pre-compensation in FR2)

Regarding support of TRP-based pre-compensation scheme for FR2. Several companies proposed to extend support of TRP-based pre-compensation to FR2, while one company mentioned lack of technical justification of such enhancement. Summary of the companies’ preference is provided below.

**Issue#3-1:**

* TRP-based pre-compensation scheme for PDSCH / PDCCH is only supported in FR1
  + **Supported**: Futurewei, Ericsson
* TRP-based pre-compensation scheme for PDSCH / PDCCH is supported in both FR1 and FR2
  + **Supported**: CMCC, DOCOMO, ZTE, Lenovo / MotMobility, Huawei/HiSilicon, CMCC, NTT DOCOMO, Qualcomm, Sony

Based on majority view the following proposal is made.

#### Round-1

**Proposal #3-1:**

* TRP-based pre-compensation scheme for PDSCH / PDCCH is supported in both FR1 and FR2 with UE capability per FR

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| **Company** | **Comment** |
| Moderator | In case we don’t have sufficient time to conclude on this, RAN1 can take this issue for further discussion in UE capability sessions. |
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### Issue #3-2 (Support of Variant B for TRP-based pre-compensation)

In RAN1#106e meeting working assumption on QCL assumptions to assist TRP-based pre-compensation scheme was confirmed. However, it is FFS whether Variant B should be additionally supported as QCL assumptions. Companies’ views on this issue are summarized below.

**Issue#3-2:** Whether to support Variant B for TRP-based pre-compensation as QCL types/assumption, when the same DMRS port(s) are associated with two TCI states

* Variant B is supported
  + **Supported**: Qualcomm, Intel, …
* Variant B is not supported
  + **Supported**: Mediatek, CATT, Huawei / HiSilicon, Futurewei, CATT, Mediatek, Nokia / NSB, Lenovo / MotMob, DOCOMO, Sony

Based on the companies’ preference the following proposal is made.

#### Round-1

**Proposal #3-2 (for conclusion):**

* Variant B is not supported for TRP-based pre-compensation as QCL types/assumption, when the same DMRS port(s) are associated with two TCI states

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| **Company** | **Comment** |
| Moderator | This is low priority issue, since the situation is the same as in the previous meeting. |
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### Issue #3-3 (SRS enhancements for TRP-based pre-compensation)

In RAN1#106-e meeting it was agreed to support SRS-based Doppler measurements to assist TRP-based pre-compensation scheme. It was also agreed to further study whether enhancements to SRS are required to improve accuracy of the corresponding Doppler shift measurements. Companies’ views on this issue are summarized below.

**Issue#3-3:** For TRP-based pre-compensation

* **Alt-1**: Support SRS enhancements for Doppler shift estimation
  + Support two SRS resources, where each SRS resource is configured with a different spatial relation or PL-RS
  + Introduce new SRS pattern for UL Doppler estimation purpose, comprised of at least two intra slot non-consecutive SRS symbol repetitions with a configurable time gap between the SRS symbols.
  + Introduce new usage type for SRS resource set that will be associated with Doppler tracking purpose. The new SRS pattern will be supported under the new SRS resource set usage type.
  + Implicit Doppler shift indication for HST SFN scenario will be based on SRS resource(s) defined under SRS resource set with the new usage type (Doppler tracking).
  + **Supported**: Qualcomm, Nokia / NSB, InterDigital, Sony…
* **Alt-2**: Not support of SRS enhancements in Rel-17
  + **Supported**: ZTE, Mediatek, Huawei / HiSilicon, ZTE, Mediatek, DOCOMO

#### Round-1

**Proposal #3-3 (for conclusion):**

* SRS enhancements to support TRP-based pre-compensation scheme are not supported in Rel-17

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| **Company** | **Comment** |
| Moderator | This is low priority issue, since the situation is the same as in the previous meeting. |
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### Other issues

This section contains other issues that companies want to highlight for discussion regarding support of TRP-based pre-compensation scheme.

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## Issues related to SFN transmission of PDCCH

### Issue #4-1 (CORESET overlapping with PDSCH)

One company in [16] has mentioned that the existing specification supports prioritization of PDCCH reception, in case qcl-Type set to 'typeD' of PDSCH DM-RS is different from that of the PDCCH DM-RS with which it overlaps in at least one symbol. In Rel-17 further clarification of the specification may be required in case SFN and non-SFN CORESET is overlapped with non-SFN and SFN PDSCH respectively.

**Issue #4-1:**

* Support prioritization of the reception in case CORESET activated one or two TCI states is overlapping with scheduled Rel-17 SFN PDSCH reception in same carrier or intra-band CA
  + FFS other details
* Support prioritization of the reception in case CORESET is overlapping with the scheduled single-TRP PDSCH reception in same carrier or intra-band CA
  + FFS other details
* **Supported by**: Samsung

#### Round-1

**Proposal #4-1:**

* TBD

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| **Company** | **Comment** |
| Moderator | This issue has been discussed in the previous RAN1 meeting. Suggest proponent to clarify comments received in the last RAN1 meeting, e..g, why the existing specification is not sufficient to address the considered scenario. |
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### Issue #4-2 (Default TCI for SFN PDSCH without TCI state and offset larger than threshold)

Several companies discussed the issue of PDSCH reception when TCI field is not present in DCI scheduling PDSCH with offset larger than threshold. In particular, whether to additionally support DCI formats 1\_1 and 1\_2 for PDSCH reception scheduled without TCI field. Two alternatives for default TCI state were identified as possible solutions.

**Issue #4-2:**

For PDSCH reception scheduled by DCI format 1\_0, 1\_1, and 1\_2 and if applicable the time offset between the reception of the DL DCI and the corresponding PDSCH is equal or larger than the threshold *timeDurationForQCL*

* Support configuration when there is no TCI field in the DCI scheduling PDSCH, when SFN is configured for both PDCCH and PDSCH by RRC
  + UE applies the TCI state(s) of the scheduling CORESET when receiving the PDSCH
    - if there are two active TCI states for the CORESET, UE applies the both QCL assumptions of the CORESET that schedules the PDSCH when receiving the PDSCH
    - otherwise, if there is one active TCI states for the CORESET,
      * **Alt 1**:
        + UE applies the one active TCI state of the CORESET when receiving the PDSCH
        + if the UE does not support this feature UE is expected to be configured with TCI field
      * **Alt 2**:
        + If UE supports dynamic switching between single-TRP and SFN PDSCH

UE applies the one active TCI state of the CORESET when receiving the PDSCH

* + - * + Else

UE obtains it’s QCL assumption for the scheduled PDSCH from the lowest codepoint containing two different TCI states

**Supported**: Huawei / HiSilicon (Alt 1), DOCOMO (Alt 1), Nokia / NSB (Alt 1), Ericsson (Alt 2), Samsung, Lenovo / MotMob (Alt 1?)

#### Round 1

**Proposal #4-2:**

* TBD

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| **Company** | **Comment** |
| Moderator | More inputs are required from other companies |
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### Issue #4-3 (Additional default TCI for non-SFN PDSCH and scheduling without TCI and offset larger than threshold)

One company in [5] has mentioned that when SFN PDSCH is not configured by RRC, UE is expected to operate in single TRP scheme. However, when the CORESET which schedules the PDSCH is indicated with two TCI states, if UE applies both TCI states of CORESET as the default TCI states, UE will operate using SFN scheme. It is proposed to define default TCI state assumption as the first TCI state of the CORESET for this case to keep the single TRP transmission.

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| **Case** | **SFN PDSCH configured by RRC** | **TCI state(s) of the CORESET** | **Dynamic switching** | **Default TCI state** |
| 4 | No | Two | Support | The first TCI state of the CORESET that schedules the PDSCH |
| Not support |

**Issue #4-3:**

* If the time offset between the reception of the DL DCI and the corresponding PDSCH is equal or larger than the threshold *timeDurationForQCL*, there is no TCI field in the DCI, SFN PDSCH is not configured by RRC, the CORESET which schedules the PDSCH is indicated with two TCI states, the default TCI state is defined as the first TCI state of the CORESET.

#### Round 1

**Proposal #4-3:**

* TBD

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| **Company** | **Comment** |
| Moderator | More inputs are required from other companies |
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### Issue #4-4 (Default TCI for non-SFN PDSCH and offset smaller than threshold)

In RAN1#106b-e meeting the agreement was made, where condition on “*enableTwoDefaultTCIStates*” was captured in the brackets.

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| **Agreement**  When SFN PDSCH is not configured by RRC, for PDSCH reception scheduled by DCI format 1\_0, 1\_1, 1\_2, if the time offset between the reception of the DL DCI and the corresponding PDSCH is smaller than the threshold *timeDurationForQCL,*   * For DCI format 1\_1/1\_2, support both configurations with and without TCI state field. * [If *enableTwoDefaultTCIStates* is not configured,] for both cases with and without TCI state field,   + If enhanced SFN PDCCH transmission scheme 1 is configured and the lowest CORESET ID in the latest slot is indicated with two TCI states, select the 1st TCI state of the two TCI states of the CORESET as default beam for the PDSCH reception     - FFS: Whether above applies for TRP-based pre-compensation if TRP-based pre-compensation is agreed to be support in FR2   + Otherwise, UE applies the one active TCI state of the CORESET with the lowest *controlResourceSetId* in the latest slot when receiving the PDSCH |

Several companies have mentioned that UE may be configured with Rel-16 multi-TRP based PDSCH repetition, where condition on “*enableTwoDefaultTCIStates*” may be needed.

#### Round-1

**Proposal #4-4:**

Revise RAN1#106b-e meeting agreement by removing brackets for the condition “If *enableTwoDefaultTCIStates* is not configured” and extending to TRP-based pre-compensation for PDSCH if supported in FR2:

* When SFN PDSCH is not configured by RRC, for PDSCH reception scheduled by DCI format 1\_0, 1\_1, 1\_2, if the time offset between the reception of the DL DCI and the corresponding PDSCH is smaller than the threshold *timeDurationForQCL,*
  + For DCI format 1\_1/1\_2, support both configurations with and without TCI state field.
  + ~~[~~If *enableTwoDefaultTCIStates* is not configured,~~]~~ for both cases with and without TCI state field,
    - If enhanced SFN PDCCH transmission scheme 1 or TRP based pre-compensation (if supported in FR2) is configured and the lowest CORESET ID in the latest slot is indicated with two TCI states, select the 1st TCI state of the two TCI states of the CORESET as default beam for the PDSCH reception
      * ~~FFS: Whether above applies for TRP-based pre-compensation if TRP-based pre-compensation is agreed to be support in FR2~~
    - Otherwise, UE applies the one active TCI state of the CORESET with the lowest *controlResourceSetId* in the latest slot when receiving the PDSCH

**Supported by:** ZTE, DOCOMO, Nokia / NSB, vivo (remove text in the brackets?), LGE, Xiaomi, Lenovo / MotMob, Lenovo / MotMobility, …

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| **Company** | **Comment** |
| Moderator | This issue seems dependent whether combination of SFN with Rel-16 multi-TRP PDSCH is allowed or not in Issue #1-1. |
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### Issue #4-5 (Additional default TCI for SFN PDSCH and offset smaller than threshold)

Two companies in [5], [16] have mentioned that default TCI is not defined in case of SFN PDSCH is configured, and scheduling offset is smaller than threshold according to the following cases in [5].

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| **Case** | **SFN PDSCH configured by RRC** | **enableTwoDefaultTCI-States** | **TCI codepoint indicates two TCI states** | **Dynamic switching** | **Default TCI state** |
| 2 | Yes | Configured | None | Support | If the CORESET with the lowest ID in the latest slot is indicated with two TCI states, UE applies both TCI states of the CORESET  Otherwise, UE applies the active TCI state of the CORESET with the lowest ID in the latest slot |
| 3 | Yes | Not configured | / | Support | If the CORESET with the lowest ID in the latest slot is indicated with two TCI states, select the 1st TCI state of the two TCI states of the CORESET  Otherwise, apply the active TCI state of the CORESET with the lowest ID in the latest slot |
| 4 | All | Not support | Error case (UE expects that *enableTwoDefaultTCI-States* is configured) |

It was, therefore, proposed to discuss the following proposals for default TCI state to address the remaining cases.

**Issue #4-5:**

If the time offset between the reception of the DCI and its scheduled PDSCH is less than the threshold *timeDurationForQCL*, SFN PDSCH is configured by RRC and *enableTwoDefaultTCI-States* is configured, [if UE supports the dynamic switching], but there is no TCI codepoint with two TCI states activated by MAC CE, the default TCI state for PDSCH can be determined as follow.

* If the CORESET with the lowest ID in the latest slot is indicated with two TCI states, UE applies both TCI states of the CORESET.
* Otherwise, UE applies the active TCI state of the CORESET with the lowest ID in the latest slot.

If the time offset between the reception of the DCI and its scheduled PDSCH is less than the threshold *timeDurationForQCL*, SFN PDSCH is configured by RRC and *enableTwoDefaultTCI-States* is not configured, [if UE supports dynamic switching], the default TCI state for PDSCH can be determined as follow.

* If the CORESET with the lowest ID in the latest slot is indicated with two TCI states, UE selects the first TCI state of the two TCI states of the CORESET.
* Otherwise, UE applies the active TCI state of the CORESET with the lowest ID in the latest slot.

#### Round-1

**Proposal #4-5:**

* TBD

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| **Company** | **Comment** |
| Moderator | More inputs from other companies are needed |
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### Issue #4-6 (Default spatial / PL RS for Rel-17 multi-TRP PUSCH/PUCCH)

Several companies in [4], [5], [16] have mentioned that default spatial relation and PL-RS are only defined in the case of single-TRP PUSCH/PUCCH/SRS transmission. However, for multi-TRP based PUCCH/PUSCH/SRS transmissions, default spatial relation and PL-RS are not defined. It is therefore proposed to clarify default assumptions.

**Issue #4-6:**

**Default beam and PL RS for multi-TRP PUCCH:**

**Alt 1**: When PL-RS and spatial relation information are not configured and default beam is enabled for the PUCCH transmission, if two TCI states are activated for the CORESET with the lowest ID on the active DL BWP,

* If PUCCH repetition is configured, the two TCI states activated for the CORESET with the lowest ID on the active DL BWP are used to determine the spatial relation and PL-RS of PUCCH transmission occasions, and each TCI state is associated to one PUCCH transmission occasion group.

**Alt 2**: A new RRC parameter is introduced to enable two default beams and PL-RSs for PUCCH, and if it is configured:

* when only one TCI state is applied for the CORESET with lowest ID, the TCI state is used as the only default spatial relation and PL-RS for PUCCH transmission.
* when two TCI states are applied for the CORESET with lowest ID, both TCI states are used as two default spatial relations and PL-RSs for PUCCH transmission.

**Default beam and PL RS for multi-TRP PUSCH:**

When the default spatial relation and PL-RS of PUSCH are determined by QCL assumption of CORESET with lowest ID, and two TCI states are activated for the CORESET,

* If PUSCH repetition is configured, the two TCI states activated for the CORESET with the lowest ID are used as the default spatial relation and PL-RS, and each TCI state is associated to one PUSCH transmission occasion group.
* UE does not expect that the network configures two SRS resource sets when applying default beam is enabled

**Default beam and PL RS for multi-TRP SRS:**

When the default spatial relation and PL-RS of SRS are determined by QCL RS of CORESET with lowest ID, and two TCI states are activated for the CORESET,

* If two SRS resource sets for codebook/non-codebook are configured, the two TCI states activated for the CORESET with the lowest ID are used as the default beam and PL-RS of SRS, and each TCI states is associated to one SRS resource set

**Supported by:** ZTE, vivo, Samsung, Mediatek, DOCOMO, CATT,

**Not supported:** OPPO, Xiaomi,

#### Round-1

**Proposal #4-6:**

* + TBD

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| **Company** | **Comment** |
| Moderator | In the last RAN! meeting several companies proposed to discuss this issue later. Given that this is the last RAN1 meeting for Rel-17, inputs from other companies are needed to finalize the discussion. |
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### Issue #4-7 (PDCCH monitoring prioritization with different QCL-TypeD)

Several companies proposed to discuss priority rules for PDCCH monitoring of PDCCH candidates in overlapping monitoring occasion with different QCL-TypeD when CORESET is indicated with two TCI states. Companies’ views on this issue are summarized below.

**Issue #4-7:**

* When a CORESET is activated with two TCI states which overlaps with another CORESET, support PDCCH monitoring of PDCCH candidates in overlapping monitoring occasions with QCL-TypeD properties identified according to prioritization rule
  + Down-select one alternative
    - **Alt 1**: Search Space (SS) type > serving cell index > SS set ID
      * **Supported by:** ZTE, Lenovo / MotMob,
    - **Alt 2**: SS type > serving cell index > SS set ID
      * If prioritized CORESET has one TCI state, the second QCL type D is identified by the first TCI of a CORESET with the second highest priority
      * **Supported by:** Qualcomm, Huawei / HiSilicon, Samsung
    - **Alt 3**: SS type > serving cell index > SS set ID > the number of TCI states of CORESET
      * If prioritized CORESET has one TCI state, the second QCL type D is identified according to one of the SS sets that is linked with a CORESET with the first QCL-TypeD among the multiple overlapping CORESETs); and
      * In case of multiple such CORESETs, Rel. 15 priority order is used for the second QCL-TypeD determination.
      * **Supported by:** Spreadtrum,
    - **Alt 4**: the number of TCI states for CORESET > SS type > serving cell index > SS set ID
      * **Supported by:** NTT DOCOMO (2nd preference)
    - **Alt 5:** SS type > the number of TCI states for CORESET > serving cell index > SS set ID
      * If prioritized CORESET has one TCI state, all CORESETs associated with at least the one active TCI state are also monitored.
      * **Supported by:** LGE, NTT DOCOMO (1st preference), Lenovo / MotMob, LGE, Xiaomi, Samsung,
    - **Alt 6**: SS type > serving cell index > SS set ID > the number of TCI states of CORESET
      * If the firstly prioritized CORESET is associated with one TCI state with QCL-TypeD property, the secondly prioritized CORESET with two TCI states which contains the same QCL-TypeD property with the firstly prioritized CORESET can be monitored. Other CORESETs associated with one or both of these TCI states can also be monitored.
      * If the firstly prioritized CORESET is associated with two TCI states with two QCL-TypeD properties, other CORESETs associated with one or both of these TCI states can also be monitored.
      * **Supported by:** vivo,
    - **Alt 7**: SS type > serving cell index > SS set ID
      * If the prioritized CORESET is associated with only one TCI state corresponding to one QCL-TypeD property, one SFN-ed CORESET including TCI state of this CORESET can be monitored too. Then, other CORESETs that associated with one of or same TCI states as the monitored SFN-ed CORESET can also be monitored.
        + If more than one SFN-ed CORESET include the TCI state of the prioritize CORESET, Rel-15 priority order can be used for the second QCL-TypeD determination.
        + If there is no SFN-ed CORESET includes the TCI state of the prioritize CORESET, another CORESET associated with one TCI state different from the prioritize CORESET can be prioritized secondly. Then other CORESETs that associated with same TCI states as these two prioritized CORESETs can also be monitored.
      * If the prioritized CORESET is associated with two TCI states corresponding to two QCL-TypeD properties, any other CORESETs that have been configured with same QCL-TypeD properties or a subset of these two QCL-TypeD properties as the CORESET can also be monitored.
      * **Supported by:** CATT,
    - **Alt 8**: SS type > serving cell index > SS set ID
      * Reuse legacy priority rule to identify the first QCL-TypeD property, and then, identify the second QCL-TypeD according to one of the CORESETs activated with 2 TCI states, with first QCL-typeD as one of the 2 activated TCI states.
      * In the case of multiple overlapping CORESETs activated with 2 TCI states have a TCI state with a same QCL-typeD as the first QCL-typeD, Rel-15 priority rule is followed for determining oneCORESET from the multiple CORESETs
      * If none of the CORESETs activated with 2 TCI states has a TCI state with a same QCL-typeD as the first QCL-typeD, a second QCL-typeD is not selected.
      * **Supported by:** Ericsson,
    - Note: SS type with CSS has higher priority than SS type with USS, SS set with lower index has higher priority than SS set with higher index, serving cell with lower index has higher priority than serving cell index with higher index, two TCI states for CORESET has higher priority than one TCI state

#### Round-1

**Proposal #4-7:**

* TBD

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| **Company** | **Comment** |
| Moderator | There is no alternative supported by clear majority. Suggest RAN1 to take Alt 1 as possible outcome for this issue, if there is no convergence to other alternative with enhancement. |
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### Issue #4-8 (CSS associated with SFN CORESET)

In RAN1#106bis-e meeting, the following agreement for CSS associated with SFN CORESET was made:

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| **Agreement**  For CSS associated with SFN CORESET, study the following alternatives and down-select in RAN1#107e:   * Alt 2: UE doesn’t expect PDCCH candidates in CSS to be associated with CORESET activated with two TCI states, except for CSS type 3 associated with CORESET configured with scheme 1 * Alt 3: If PDCCH candidates in CSS 0/0A/1/2/3 are associated with CORESET that activated with two TCI states, the first TCI state is applied for the CSS reception, except for CSS type 3 associated with CORESET configured with scheme 1.   + For CSS type 3 associated with CORESET configured with scheme 1,  both TCI states can be applied for the CSS reception. |

Several companies provided their preference regarding agreed alternatives as well provided some modifications with

**Issue #4-8**: For CSS associated with SFN CORESET

* **Alt 2**: UE doesn’t expect PDCCH candidates in CSS to be associated with CORESET activated with two TCI states, except for CSS type 3 associated with CORESET configured with scheme 1
  + **Supported by:** Spreadtrum, Ericsson, Samsung,
* **Alt 3**: If PDCCH candidates in CSS 0/0A/1/2/3 are associated with CORESET that activated with two TCI states, the first TCI state is applied for the CSS reception, except for CSS type 3 associated with CORESET configured with scheme 1.
  + For CSS type 3 associated with CORESET configured with scheme 1, both TCI states can be applied for the CSS reception.
  + **Supported by:** InterDigital, LGE, NTT DOCOMO, QCM (CSS type 3 is also applicable to TRP based pre-compensation), Mediatek, vivo, CATT, OPPO, Xiaomi, NEC, Lenovo / MotMob
* **New Alt 3a**: if PDCCH candidates in CSS 0/0A/1/2/3 are associated with CORESET that activated with two TCI states,
  + For CSS type 0/0A/2 configured with search space index 0, the monitoring occasions are determined by two SSB indexes associated with the two activated TCI states of the CORESET 0.
  + For CSS type 1, the first TCI state is applied
  + Otherwise, both TCI states can be applied for the CSS reception, i.e. SFN manner
  + **Supported by:** ZTE

There is clear majority that prefers Alt 3 from RAN1#106b-e meeting agreement.

#### Round-1

**Proposal #4-8**:

For CSS associated with SFN CORESET:

* **Alt 3**: If PDCCH candidates in CSS 0/0A/1/2/3 are associated with CORESET that activated with two TCI states, the first TCI state is applied for the CSS reception, except for CSS type 3 associated with CORESET configured with scheme 1.
  + For CSS type 3 associated with CORESET configured with scheme 1, both TCI states can be applied for the CSS reception.

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### Issue #4-9 (Broadcast PDSCH scheduled by a PDCCH in CSS)

One company in [8] has mentioned the issue of PDSCH transmission carrying broadcast info. In particular, if the DCI is used to scheduling broadcast information, e.g., scrambled with P-RNTI or SI-RNTI, SFN transmission cannot be applied to the scheduled PDSCH even when the associated CORESET is configured with two TCI states. In this case, one of the TCI states for the CORESETs should be applied to the PDSCH according to the following proposal.

**Issue #4-9**: For PDSCH scheduled by CSS 0/0A/1/2/3, except for CSS type 3 associated with CORESET configured with scheme 1,

* If the scheduling offset is larger than or equal to *timeDurationForQCL*, the first TCI state of the scheduling CORESET is applied for the PDSCH reception
* If the scheduling offset is smaller than *timeDurationForQCL*, the first TCI state of the CORESET with lowest ID in the same BWP is applied for the PDSCH reception
* Note: if only one TCI state is configured for the CORESET, the TCI state is applied to the PDSCH reception.
* Note: For PDSCH scheduled by CSS type 3 associated with CORESET configured with scheme 1, both TCI states can be applied for the PDSCH reception.

#### Round-1

Proposal #4-9:

* TBD

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| **Company** | **Comment** |
| Moderator | More inputs from other companies are needed |
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### Issue #4-10 (UE capability for dynamic switching between SFN and single-TRP)

One company in [22] has mentioned that the previous agreement on definition of UE not capable of dynamic switching should be amended to also include restriction for the CORESET configuration that schedules unicast PDSCH by DCI Format 1\_0 with scheduling offset larger than threshold.

**Issue #4-10:**

For UE not capable of dynamic switching between SFN scheme 1 and single-TRP

* For unicast PDSCH scheduled by DCI format 1\_0 with scheduling offset equal or larger than threshold ‘*timeDurationForQCL*, the UE does not expect the scheduling CORESET to be activated with single TCI states, if UE is configured with SFN scheme by RRC

#### Round-1

Proposal #4-10:

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| Moderator | More inputs from other companies are needed |
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## Other issues

This section contains other issues the companies want to highlight for discussion regarding support of SFN PDCCH transmission.

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## Beam Failure Detection and Recovery, Radio Link Monitoring

### Issue #5-1 (Number of BLER, number of BFD RS and prioritization of RS for implicit BFD)

Several companies discussed the issues of the BLER calculation from two TCI states, UE capability for number of implicit BFD RS and prioritization of RS for BFD monitoring, when two TCI states are activated for CORESET. Companies’ views for these issues are summarized below.

**Issue #5-1:**

* BLER for BFD RS is calculated according to the following rule. Down-select one alternative:
  + **Alt 1**: For a CORESET with two activated TCI states, two RS indexes are included in and UE calculates two hypothetical BLER for the CORESET
    - **Supported:** Convida,Intel,
  + **Alt 2**: For a CORESET with two activated TCI states, UE calculates single hypothetical BLER
    - **Supported:** ZTE, vivo, Qualcomm, Apple,
* For the implicit BFD RS, the number of monitored BFD RSs X is UE capability
  + X = 2, 3, 4
    - **Supported**: LGE, DOCOMO (X=4), Nokia/NSB, InterDigital, CATT, Lenovo / MotMob,
    - **Not supported**: vivo,
* The rules for selecting multiple BFD RSs for implicit BFD RS configuration is supported.
  + **Alt 1**: CORESET activated with two TCI states can be detected with higher priority
  + **Alt 2**: UE selects X RS provided for active TCI states for PDCCH receptions in CORESETs associated with the search space sets in an order from the shortest monitoring periodicity. If more than one CORESETs are associated with search space sets having same monitoring periodicity, the UE determines the order of the CORESET from the highest CORESET index. If the CORESET selected based on the above rule is activated with two TCI states, RS in both TCI states are selected for BFD.
  + **Alt 3**: When configured with two CORESETs with one or two active TCI States and the number of monitored BFD-RSs is 2, UE selects one RS from one CORESET and one RS from another CORESET. When supporting number of monitored BFD-RSs as 3 or 4 based on UE capability:
    - If all CORESETs are SFN-CORESETs, one BFD RS pair for SFN CORESET is counted as two BFD RSs and remaining one or two BFD-RSs are selected from first TCI state (for X = 3) or both TCI states (for X = 4) of SFN CORESET, respectively.
    - If CORESETs are a mix of SFN-CORESET(s) and non-SFN CORESET(s),
      * if X = 3, one BFD RS pair for SFN CORESET is counted as two BFD RSs and remaining one BFD-RSs are selected from TCI state of non-SFN CORESET.
      * if X = 4, one BFD RS pair for SFN CORESET is counted as two BFD RSs and remaining two BFD-RSs are selected from the TCI state of non-SFN CORESET and one TCI state from the remaining CORESET.
    - **Supported**: DOCOMO, Nokia/NSB, CATT
    - **Not supported**:

#### Round-1

Proposal #5-1:

* TBD

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| **Company** | **Comment** |
| Moderator | More inputs from other companies are needed |
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### Issue #5-2 (Explicit RS configuration for BFD)

Several companies have discussed the issue of explicit RS configuration for BFD based on the agreement from RAN1#105-e meeting.

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| **Agreement**  If enhanced SFN PDCCH transmission scheme (scheme 1 or TRP-based pre-compensation) is configured and two TCI states are activated for at least one CORESET, support the following configuration of RS for BFD   * Down-select one alternative for implicit configuration   + **Alt 1-2**: RS of CORESETs with both single and two TCI states are used   + **Alt 1-3**: RS of CORESETs with only two TCI states are used * Down-select one alternative for explicit configuration   + **Alt 2-1**: Support defining CSI-RS resource or SSB pairs as BFD RS     - FFS other details   + **Alt 2-2**: Reuse the existing Rel-15/Rel-16 approach for BFD RS configuration * Note: down-selection can be done separately for Rel-15/16 cell specific BFR and Rel-17 TRP-specific BFR, Rel-17 TRP-specific BFR to be discussed under AI 8.1.2.3 |

**Issue #5-2:**

If enhanced SFN PDCCH transmission scheme (scheme 1 or TRP-based pre-compensation) is configured and two TCI states are activated for at least one CORESET, support the following configuration of RS for BFD

* + **Alt 2-1**: Support defining CSI-RS resource or SSB pairs as BFD RS
    - FFS other details
    - **Supported by**: ZTE, CATT, Xiaomi, Lenovo / MotMob, Apple,
  + **Alt 2-2**: Reuse the existing Rel-15/Rel-16 approach for BFD RS configuration
    - **Supported by**: Convida, Qualcomm, Intel

#### Round-1

**Proposal #5-2:**

* TBD

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| **Company** | **Comment** |
| Moderator | More inputs from other companies are needed |
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### Issue #5-3 (NBI RS configuration)

Several companies have provided preference on configuration of new beam identification (NBI) reference signals based on the alternatives from RAN1#106b-e meeting.

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| **Agreement**  When two TCI states are activated for a CORESET, NBI RS can be configured as follows   * **Alt 4-1**: Using the existing Rel-15 NBI configuration based on single SSB / CSI-RS resource * **FFS addition support of** **Alt 4-2**: two new beam identification CSI-RS resource sets / new beam identification CSI-RS resource pairs or SSB pairs |

**Issue #5-3:**

When two TCI states are activated for a CORESET, NBI RS can be also configured using Alt 4-2

* Two new beam identification CSI-RS resource sets / new beam identification CSI-RS resource pairs or SSB pairs
* **Supported**: InterDigital, ZTE, Spreadtrum, Qualcomm, Nokia/NSB, CATT, LGE, Xiaomi (for SCell?), NEC, Lenovo / MotMob,
* **Not supported:** vivo, Mediatek, Convida

#### Round-1

**Proposal #5-3:**

* TBD

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| **Company** | **Comment** |
| Moderator | More inputs from other companies are needed |
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### Issue #5-4 (Applicability of the BFR enhancements)

In RAN1#106b-e meeting applicability of beam failure enhancements for different BFD procedures was discussed when two TCI states are activated for CORESET. The following proposal was made in the summary document.

**Issue #5-4:**

When two TCI states are activated for a CORESET, BFR enhancements are applicable to

* CBRA/CFRA based BFR on SpCell in Rel.15.
* BFR MAC CE based BFR on SCell in Rel.16.
* CBRA BFR on SpCell (with BFR MAC CE on Msg.3/A) in Rel.16.

The following proposal is made.

#### Round-1

**Proposal #5-4:**

When two TCI states are activated for a CORESET, BFR enhancements are applicable to

* CBRA/CFRA based BFR on SpCell in Rel.15.
* BFR MAC CE based BFR on SCell in Rel.16.
* CBRA BFR on SpCell (with BFR MAC CE on Msg.3/A) in Rel.16.

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### Issue #5-5 (Details of RLM for SFN PDCCH)

Two companies in [16], [20] raised several issues of RLM RS set configuration for enhanced SFN transmission scheme of PDCCH.

**Issue #5-5:**

* For RLM, when RLM RS set is not explicitly provided, for a CORESET indicated with two TCI states, RSs in both TCI states are used as RLM RS
  + **Supported by**: NTT DOCOMO
* For RLM, when RLM RS set is explicitly provided, for a CORESET indicated with two TCI states, study how to ensure the RLM RS includes RSs in both TCI states of a CORESET.
  + **Supported by**: NTT DOCOMO
* Study whether/how to enhance RLM RS selection rule considering CORESET activated with two TCI states
  + **Supported by**: Samsung

#### Round-1

**Proposal #5-5:**

* TBD

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| **Company** | **Comment** |
| Moderator | More inputs from other companies are needed including details for the second and third bullets. |
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## Issue #6-1 (Other non-categorized proposals)

* *TRP-specific timing offset pre-adjustment can be considered to further enhance the performance of HST-SFN transmission.*
* *Support RRC signaling to configure two PTRS ports when PDSCH/PDCCH configured with SFN scheme 1 or gNB Doppler pre-compensation, and to introduce one additional resourceElementOffset.*
* *For PDSCH transmitted with Rel-17 HST-SFN scheme 1,* 
  + - *Restricting the DMRS ports of the PDSCH within one CDM group;*
    - *New tables for antenna port indication within one CDM group are supported.*
* *To further facilitate HST-SFN operation, support to extend the QCL assumption of PDCCH/PDSCH DMRS from its serving cell(s) to non-serving cell(s).*
* *NW should explicitly configure or implicitly indicate to UE from which TRP the frequency-domain QCL assumption can be ignored.*
* *UE may assume the CSI-RS and ePDCCH DM-RS port transmitted in monitored search space set(s) associated with CORESET(s) are quasi co-located with 'QCL-TypeD', if applicable, where the 'QCL-TypeD' can be derived from indicated TCI state or default TCI state*

# Other issues

This section contains other issues the companies want to highlight.

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# References

[1] RP-193133, New WID: Further enhancements on MIMO for NR, Samsung 3GPP TSG RAN Meeting #86, Sitges, Spain, December 9-12, 2019.

[2] R1-2110765, On M-TRP Operation for HST-SFN Deployment, InterDigital, Inc.

[3] R1-2110785, Enhancements on HST multi-TRP deployment in Rel-17, Huawei, HiSilicon

[4] R1-2110952, Discussion on Multi-TRP HST enhancements, ZTE

[5] R1-2110994, Remaining issues on HST-SFN schemes, vivo

[6] R1-2111088, Discussion on enhancements on HST-SFN deployment, Spreadtrum Communications

[7] R1-2111225, Remaining issues on HST-SFN deployment, CATT

[8] R1-2111283, Enhancements on HST-SFN deployment, OPPO

[9] R1-2111383, Enhancements HST-SFN deployment, Sony

[10] R1-2111457, Enhancements on HST-SFN deployment, LG Electronics

[11] R1-2111480, Enhancements to HST-SFN deployments, Intel Corporation

[12] R1-2111544, Enhancements on HST-SFN deployment, Xiaomi

[13] R1-2111601, Enhancements on HST-SFN deployment, CMCC

[14] R1-2111668, Remaining issues on HST-SFN enhancements, Ericsson

[15] R1-2111687, Discussion on HST-SFN deployment, NEC

[16] R1-2111721, Enhancements on HST-SFN, Samsung

[17] R1-2111857, Views on Rel-17 HST enhancement, Apple

[18] R1-2111940, Enhancements for HST-SFN deployment, Lenovo, Motorola Mobility

[19] R1-2112028, On Enhancements for HST-SFN deployment, Convida Wireless

[20] R1-2112093, Discussion on HST-SFN deployment, NTT DOCOMO, INC.

[21] R1-2112180, Enhancements for HST-SFN deployment, Nokia, Nokia Shanghai Bell

[22] R1-2112200, Enhancements on HST-SFN deployment, Qualcomm Incorporated

[23] R1-2112279, Enhancements on HST-SFN deployment, MediaTek Inc.

# Appendix (Summary of the agreements)

The agreements made in RAN1#102e, RAN1#103e and RAN1#104e, RAN1#105e meetings are provided below.

**RAN1#102-e meeting agreements**

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| **Agreement**  For the discussion purpose consider the following categorization of the enhanced DL transmission schemes   * **Scheme 1**:   + TRS is transmitted in TRP-specific / non-SFN manner   + DM-RS and PDCCH/PDSCH from TRPs are transmitted in SFN manner * **Scheme 2**:   + TRS and DM-RS are transmitted in TRP-specific / non-SFN manner   + PDSCH from TRPs is transmitted in SFN manner   **Agreement**  Study the following aspects of the enhanced transmission schemes:   * **For scheme 1**:   + Target DL physical channels, i.e., PDSCH only or PDSCH + PDCCH   + Whether more than 2 QCL/TCI states are required and corresponding signaling details   + Whether and how to indicate scheme 1 for differentiation with Rel-16 non-SFNed transmission schemes with multiple QCL/TCI states   + QCL relationship between TRS and DMRS ports   + Note: Other schemes/aspects are not precluded * **For scheme 2**:   + Association of each MIMO layer of PDSCH to DM-RS antenna ports   + Whether more than 2 QCL/TCI states are required and corresponding signaling details   + Whether and how to indicate scheme 2 for differentiation with Rel-16 non-SFNed transmission schemes with multiple QCL/TCI states   Note: Other schemes/aspects are not precluded |

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| **Agreement**  Study TRP-based frequency offset pre-compensation including the following aspects:   * Aspects related to indication of the carrier frequency determined based on the received TRS resource(s) in the 1st step   + **Option 1**: Implicit indication of the Doppler shift(s) using uplink signal(s) transmitted on the carrier frequency acquired in the 1st step     - Indication for QCL-like association of the resource(s) received in the 1st step with UL signal transmitted in the 2nd step     - Type of the uplink reference signals / physical channel used in the 2nd step, necessity of new configuration and corresponding signaling details   + **Option 2**: Explicit reporting of the Doppler shift(s) acquired in the 1st step using CSI framework     - FFS: Indication for QCL-like association of the resource(s) received in the 1st step with UL signal transmitted in the 2nd step     - CSI reporting aspects, configuration, quantization, signalling details, etc. * New QCL types/assumption for TRS with other RS (e.g., SS/PBCH), when TRS resource(s) is used as target RS in TCI state * New QCL types/assumptions for TRS with other RS (e.g., DM-RS), when TRS resource(s) is used as source RS in the TCI state * Target physical channels (e.g., PDSCH only or PDSCH/PDCCH) and reference signals that should be supported for pre-compensation * Signalling/procedural details on whether/how the pre-compensation is applied to target channels * Whether multiple sets of TRS and pre-compensation on TRS is needed in 3rd step.   Note: Other aspects/schemes are not precluded |

**RAN1#103-e meeting**

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| **Agreement**  Support at least the following configuration for HST scenario in Rel-17   * The same DMRS port(s) can associate with multiple TCI states   + FFS other details   Note: DMRS and PDCCH/PDSCH from different TRPs are transmitted in SFN manner  **Agreement**  At most two TCI states are supported for HST scenario in Rel-17   * FFS: Whether to support more than two TCI states for FR2 * FFS configuration/signalling details of the TCI states   Note: DMRS and PDCCH/PDSCH from different TRPs are transmitted in SFN manner  **Agreement**  When the same DMRS port(s) are associated with two TCI states containing TRS as source reference signal, at least one variant is supported for Rel-17 HST-SFN scenario based on further evaluations   * **Variant A**: One of the TCI state can be associated with {*average delay*, *delay spread*} and another TCI states can be associated with {*average delay, delay spread, Doppler shift, Doppler spread*} (i.e., QCL-TypeA) * **Variant B**: One of the TCI state can be associated with {*average delay, delay spread*} and another TCI state with {*Doppler shift, Doppler spread*} (i.e., QCL-TypeB) * **Variant C**: One of the TCI state can be associated with {*delay spread*}  and another TCI states can be associated with {*average delay, delay spread, Doppler shift, Doppler spread*} (i.e., QCL-TypeA) * **Variant E**: Both TCI states can be associated with {*average delay, delay spread, Doppler shift, Doppler spread*} (i.e., QCL-TypeA) * FFS: Indication method to apply QCL, e.g., via new QCL-type, or reuse existing QCL-type while UE to ignore certain QCL properties * Note: Each TCI state in the above variants may be additionally associated with {Spatial Rx parameter} (i.e., QCL-TypeD) * Note: Companies are encouraged to provide evaluation results for the above variants based on agreed EVM from RAN1#102e meeting * Note: Above variants are applicable to scheme 1 and/or TRP based pre-compensation as a reference for evaluation. * This agreement is for the purpose of evaluation and does not imply the support or lack of support of scheme 1 and/or TRP based pre-compensation |

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| **Agreement**  For PDCCH reliability enhancements, support SFN scheme + Alt 1-1.   * FFS: TCI state activation for CORESET, impact on default beam, BFD resource for BFR   Where the Alt 1-1 is agreed as:  Alt 1-1: One PDCCH candidate (in a given SS set) is associated with both TCI states of the CORESET. |

**RAN1#104-e meeting**

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| **Agreement**  Scheme 1 is supported in Rel-17   * TRS is transmitted in TRP-specific / non-SFN manner * DM-RS and PDCCH/PDSCH from TRPs are transmitted in SFN manner * FFS other details     **Agreement**  For scheme 1 and SFN transmission of PDCCH support Variant E for QCL assumption in TCI state when TRS is used as source RS    **Agreement**  Two TCI states are supported for scheme 1 in FR2  **Agreement**   * Support MAC CE activation of two TCI states for PDCCH * FFS other details   **Conclusion**  The decision on support of specification based TRP pre-compensation scheme for HST-SFN scenario to be made in RAN1#104-e-bis meeting. To facilitate RAN1 decision, companies are encouraged to provide evaluation results according to the agreed evaluation assumptions. The evaluations not compliant with agreed assumptions will not be considered by RAN1 in the decision process.  **Agreement**  For HST-SFN scenario:   * Support semi-static (RRC based) switching of scheme 1 (PDSCH) with 2a, 2b, 3, 4 * FFS all other details including RRC signaling, possible RAN4 impact (if any), etc. |

**RAN1#104b-e meeting**

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| **Agreement**  Introduce enhanced MAC CE signaling for PDCCH activating two TCI states for SFN-based PDCCH transmission   * The corresponding MAC CE includes at least the following fields   + Serving cell ID   + CORESET ID   + Two TCI state IDs * FFS whether for CA scenario additionally support RRC configured set of the serving cells which can be addressed by a single MAC CE * FFS whether or not enhanced MAC CE signaling is applicable to a CORESET configured with CORESETPoolindex   Send LS to RAN2 to inform about agreement on support of enhanced MAC CE for CORESET in Rel-17. LS is endorsed in R1-2104064  **Agreement**  Specification-based TRP Doppler pre-compensation scheme is supported in Rel-17 for FR1 with one or both:   * UL RS based Doppler estimation by gNB   + FFS: Details including UL RS enhancement * DL RS based Doppler feedback by UE   + FFS: Details   + FFS: Whether UE capability needs to be introduced * Whether to support one or both will be decided later   **Agreement**   * Support dynamic (DCI-based) switching of scheme 1 (PDSCH) with single-TRP scheme by TCI state field in DCI format 1\_1/1\_2   + This feature is UE optional * FFS all other details including RRC signalling, possible RAN4 impact (if any), etc.   **Working Assumption**  All QCL source RS resource types as defined in TCI state for Rel-16 multi-TRP are supported for scheme 1  **Agreement**  Support semi-static (RRC-based) switching of scheme 1 (PDSCH) with Rel-16 scheme 1a   * FFS: Whether dynamic switching is additionally supported   **For future meeting:**  Companies to consider Proposal #3-8a in FL summary (R1-2104020) for future meetings.  Companies to consider Proposal #3-10 in FL summary (R1-2104020) for future meetings.  **Agreement**  Scheme 1 for PDSCH is identified by   * New RRC parameter and the number of TCI states indicated by DCI   + FFS RRC configuration details, e.g., per BWP or per CC   + FFS whether or not restriction to a single CDM group for DM-RS is also supported |

**RAN1#105-e meeting**

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| **Agreement**  Confirm the following working assumption from RAN1#104b-e:  All QCL source RS resource types as defined in TCI state for Rel-16 multi-TRP are supported for scheme 1.  **Agreement**  UE is not expected to be indicated by MAC CE with single TCI state per any of TCI codepoint , if UE is configured with scheme 1 PDSCH by RRC , but not capable to support dynamic switching between scheme 1 and single-TRP by TCI state field in DCI Format 1\_1/1\_2  **Agreement**  For specification based TRP-based frequency offset pre-compensation scheme   * Support dynamic (DCI -based) switching with single-TRP scheme by TCI state field in DCI format 1\_1/1\_2   + This feature is UE optional   + UE is not expected to be indicated by MAC CE with single TCI state per any of TCI codepoint , if UE is configured with TRP-based frequency PDSCH by RRC , but not capable to support dynamic switching between TRP-based frequency and single-TRP by TCI state field in DCI Format 1\_1/1\_2 * Support semi-static (RRC based) switching with Rel-16 schemes 1a, 2a, 2b, 3, 4 * Support semi-static (RRC based) switching with Rel-17 scheme 1 (PDSCH)   **Agreement**  Enhanced MAC CE signaling is not applicable to any of the configured CORESETs in a BWP if the CORESETs are configured with different *CORESETPoolindex* values in the BWP.  **Working Assumption**  For TRP-based pre-compensation, Variant A (based on RAN1#103-e meeting agreement) are supported as QCL types/assumption, when the same DMRS port(s) are associated with two TCI states.   * FFS: Additional support of Variant B   **Agreement**   * For TRP-based pre-compensation QCL assumptions is provided to the UE by using the existing QCL type(s) with certain QCL parameters dropped from the indicted QCL type   + FFS rule or signalling to determine which TCI state with dropped QCL parameters * UE does not expect to be configured different SFN schemes (scheme 1 or TRP pre-compensation) for both PDCCH and PDSCH.   + FFS whether this restriction is per UE or per CC * UE does not expect to be configured different SFN schemes (scheme 1 or TRP pre-compensation) for different CORESETs.   + FFS whether this restriction is per UE or per CC   **Agreement**  Enhanced SFN PDCCH transmission scheme (scheme 1 or TRP-based pre-compensation) is identified by the number of TCI states activated per CORESET and RRC parameter   * FFS: Configuration detail of RRC parameter   + Including whether the same RRC parameter is used for PDCCH and PDSCH   **Agreement**  If enhanced SFN PDCCH transmission scheme (scheme 1 or TRP -based pre-compensation) is configured and a CORESET is activated with two TCI states and UE is configured with enableTwoDefaultTCI-States and time offset between the reception of the DL DCI and the corresponding PDSCH is less than the threshold timeDurationForQCL, down-select rule to determine default beam(s) for Rel-17 SFN PDSCH reception in RAN1#106-e:   * **Alt 1**: Reuse rule to determine TCI states as defined for Rel-16 PDSCH scheme-1a * **Alt 2**: Introduce new rules to determine TCI states based on two TCI state(s) of the CORESET   **Agreement**  If enhanced SFN PDCCH transmission scheme (scheme 1 or TRP-based pre-compensation) is configured and two TCI states are activated for at least one CORESET, support the following configuration of RS for BFD   * Down-select one alternative for implicit configuration   + **Alt 1-2**: RS of CORESETs with both single and two TCI states are used   + **Alt 1-3**: RS of CORESETs with only two TCI states are used * Down-select one alternative for explicit configuration   + **Alt 2-1**: Support defining CSI-RS resource or SSB pairs as BFD RS     - FFS other details   + **Alt 2-2**: Reuse the existing Rel-15/Rel-16 approach for BFD RS configuration * Note: down-selection can be done separately for Rel-15/16 cell specific BFR and Rel-17 TRP-specific BFR, Rel-17 TRP-specific BFR to be discussed under AI 8.1.2.3 |

**RAN1#106e meeting**

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| **Agreement**  Support the following combination of the transmission schemes   * Single-TRP PDCCH + Rel-17 Scheme 1 PDSCH * Single-TRP PDCCH + Rel-17 TRP-based pre-compensation PDSCH * FFS: Other combinations of the transmission scheme   Note: The PDSCH corresponds to the PDSCH scheduled by DCI formats 1\_1 and 1\_2.  **Agreement**  For Rel-17 TRP-based pre-compensation scheme, indication of carrier frequency for uplink transmission (Doppler frequency reporting) in TRP-based pre-compensation scheme is supported using   * **Option 1** Implicit from RAN1#102-e agreement   + FFS enhancements to SRS (e.g multiple SRS resource in a set) to improve the accuracy of frequency estimation   For Option1, some companies raised concerns that there is no consensus on the benefit and the applicability of this scheme in FDD.  For Option1, some companies raised concerns that there is no benefit in low SNR scenarios.  **Agreement**  For TRP -based pre-compensation   * Alt-1: QCL parameters are dropped from the second TCI state of the indicated TCI codepoint containing two TCI states   **Conclusion**  For Variant A and B (if supported)   * For frequency offset pre-compensation QCL -like association of the resource(s) received in the 1st step with UL signal transmitted in the 2nd step is supported by implementation without specification impact   **Agreement**  Confirm working assumption from RAN1#105e meeting without modification:  For TRP -based pre-compensation, Variant A (based on RAN1#103-e meeting agreement) is supported as QCL types/assumption, when the same DMRS port(s) are associated with two TCI states.   * FFS: Support of Variant B   **Agreement**  In CA scenario support RRC configured set of the serving cells which can be addressed by a single MAC CE for activation of two TCI states of CORESET with the same CORESET ID for all the BWPs in the indicated CCs set   * FFS: Whether to reuse Rel-16 RRC parameters or introduce new RRC parameters. * FFS: UE capability * FFS: Whether/How to update the CORESET that is not configured to SFN scheme in the indicated CCs set   **Agreement**  If enableTwoDefaultTCI-States is configured and at least one TCI codepoint indicates two TCI states and time offset between the reception of the DL DCI and the PDSCH is less than the threshold timeDurationForQCL, default beam(s) for Rel-17 enhanced SFN PDSCH (scheme 1 or if supported TRP-based pre-compensation) reception:   * **Alt 1**: Reuse rule to determine TCI states as defined for Rel-16 PDSCH scheme-1a   This is a UE optional feature  **Agreement**  For PDSCH reception scheduled by DCI format 1\_0, [1\_1 and 1\_2], if the time offset between the reception of the DL DCI and the corresponding PDSCH is equal or larger than the threshold *timeDurationForQCL*   * Support configuration when there is no TCI field in the DCI scheduling PDSCH   + UE applies the state(s) of the scheduling CORESET when receiving the PDSCH     - if there are two active TCI states for the CORESET, UE applies the both QCL assumption of the CORESET that schedules the PDSCH when receiving the PDSCH     - otherwise, UE applies the one active TCI state of the CORESET when receiving the PDSCH * FFS if the time offset between the reception of the DL DCI and the corresponding PDSCH is smaller than the threshold *timeDurationForQCL*   This is a UE optional feature.  **Agreement**  If enhanced SFN PDCCH transmission scheme (scheme 1 or if TRP-based pre-compensation is supported in FR2) is configured and CORESET is indicated with two TCI states, and scheduling offset for AP CSI-RS is less than the threshold and *enableTwoDefaultTCIStates* is not configured   * If there is no other DL signal on the same symbol, use one of two TCI states as default beam for aperiodic CSI-RS reception, i.e.   + using one TCI state of the CORESET with the lowest CORESET ID in the latest slot as default beam for aperiodic CSI-RS reception. If there are two activated TCI states for the CORESET with the lowest CORESET ID, one of two TCI states will be selected, i.e. always selects the first TCI state if the CORESET has two TCI states * If there is other DL signal on the same symbol, reuse Rel-15/16 mechanism   **Agreement**  If enhanced SFN PDCCH transmission scheme (scheme 1 or TRP-based pre-compensation) is configured and two TCI states are activated for at least one CORESET, support the following configuration of RS for BFD   * For implicit configuration   + **Alt 1-2**: RS of CORESETs with both single and two TCI states are used   FFS: The maximum number of BFD RS and details on RS determination  **R1-2108548** Summary#3 of AI: 8.1.2.4 Enhancements on HST-SFN deployment Moderator (Intel Corporation)  **Agreement**  If enhanced SFN PDCCH transmission scheme (scheme 1 or if TRP-based pre-compensation is supported in FR2) is configured, and if the CORESET with the lowest ID in the active DL BWP is indicated with two TCI states   * If PL-RS and spatial relation information are not configured for PUCCH and enableDefaultBeamPL-ForPUCCH is configuredin FR2   + For single-TRP PUCCH transmission, select the first TCI state of the CORESET as default beam and PL RS * If PUSCH scheduled by DCI format 0\_0 and *enableDefaultBeamPL-ForPUSCH0-0* is configured in FR2, and if PUCCH resource is not configured on active UL BWP in the cell or if spatial relation is not configured in any PUCCH resource on active UL BWP in the cell,   + For single-TRP PUSCH transmission scheduled by DCI format 0\_0, select the first TCI state of the CORESET as default beam and PL RS * If PL-RS and spatial relation information are not configured for SRS and *enableDefaultBeamPL-ForSRS* is configured in FR2   + For single-TRP SRS resource, select the first TCI state of the CORESET as default beam and PL RS * FFS other details, if any * These are UE optional features   **Agreement**  When a CORESET is activated with two TCI states which overlaps with another CORESET, support extension of Rel-15 prioritization rule for PDCCH monitoring of PDCCH candidates in overlapping monitoring occasions with different QCL-TypeD   * FFS: Prioritization rule considers CORESETs indicated with 1 and/or 2 TCI states * Supports identifying two QCL-TypeD properties for multiple overlapping CORESETs   + UE capability is introduced * FFS other details * FFS: Strive to have same / similar solution as discussed under AI 8.1.2.1   **Conclusion**  No RAN1 specification impact on how to calculate hypothetical BLER for BFD |

**RAN1#106b-e meeting**

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| **Working Assumption**  Reuse legacy Rel-16 RRC parameters *simultaneousTCI-UpdateList1, simultaneousTCI-UpdateList2* to define set of the serving cells which can be addressed by a single MAC CE for activation of two TCI states of CORESET with the same CORESET ID for all the BWPs.  **Agreement**  If CSI-RS other than those configured with repetition set to 'on' is overlapping in the time domain with CORESET with two TCI states, support the first TCI state of the CORESET as the default TCI assumption for the CSI-RS.  **Agreement**  Support combination of Rel-17 SFN PDCCH scheme 1 and single-TRP PDSCH   * This is optional UE feature * Note: The support of such combination scheme is for URLLC use-case only.   **Agreement**  Enhanced SFN (scheme 1 or TRP-based pre-compensation scheme) for PDCCH and PDSCH is configured by using separate per-BWP RRC parameters   * In Rel-17, all downlink BWPs (except initial BWP and FFS: BWP-DownlinkCommon) within a CC should be the same configuration of SFN scheme   **Agreement**  When SFN PDSCH is not configured by RRC, for PDSCH reception scheduled by DCI format 1\_0, 1\_1, 1\_2, if the time offset between the reception of the DL DCI and the corresponding PDSCH is smaller than the threshold *timeDurationForQCL,*   * For DCI format 1\_1/1\_2, support both configurations with and without TCI state field. * [If *enableTwoDefaultTCIStates* is not configured,] for both cases with and without TCI state field,   + If enhanced SFN PDCCH transmission scheme 1 is configured and the lowest CORESET ID in the latest slot is indicated with two TCI states, select the 1st TCI state of the two TCI states of the CORESET as default beam for the PDSCH reception     - FFS: Whether above applies for TRP-based pre-compensation if TRP-based pre-compensation is agreed to be support in FR2   + Otherwise, UE applies the one active TCI state of the CORESET with the lowest *controlResourceSetId* in the latest slot when receiving the PDSCH   **Agreement**  For CSS associated with SFN CORESET, study the following alternatives and down-select in RAN1#107e:   * Alt 2: UE doesn’t expect PDCCH candidates in CSS to be associated with CORESET activated with two TCI states, except for CSS type 3 associated with CORESET configured with scheme 1 * Alt 3: If PDCCH candidates in CSS 0/0A/1/2/3 are associated with CORESET that activated with two TCI states, the first TCI state is applied for the CSS reception, except for CSS type 3 associated with CORESET configured with scheme 1.   + For CSS type 3 associated with CORESET configured with scheme 1,  both TCI states can be applied for the CSS reception.     **Agreement**  When CORESET is indicated with two TCI states   * One BFD RS pair for SFN CORESET is counted as two BFD RSs * FFS: Increase the maximum number of monitored BFD RSs to X.   + X is UE capability   + X = 2, 3, 4, FFS other values of X   **Agreement**  When two TCI states are activated for a CORESET, NBI RS can be configured as follows   * **Alt 4-1**: Using the existing Rel-15 NBI configuration based on single SSB / CSI-RS resource * **FFS addition support of** **Alt 4-2**: two new beam identification CSI-RS resource sets / new beam identification CSI-RS resource pairs or SSB pairs |