**3GPP TSG RAN WG1 #105-e R1-21xxxxx**

**e-Meeting, May 10th – 27th, 2021**

**Source: Moderator (Intel Corporation)**

**Title: 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 transmissionii. 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 company’s and moderator’s proposals.

# Possible enhancements for HST-SFN deployment

The section summarizes company proposals regarding enhancements that can be supported for HST-SFN deployment. The proposals are based on the contributions [2]-[23] submitted to RAN1#105-e meeting.

## UE-based solutions

1.

### Issue #1-1 (Identification/Configuration of scheme 1 for PDSCH)

Regarding remaining details of identification/configuration of scheme 1. In RAN1#104b-e meeting dynamic switching for scheme 1 was agreed as UE optional feature. In addition, new RRC parameter for configuration of scheme 1 with indication of two TCI states were agreed for identification of scheme 1. One of the remaining issues is granularity of new RRC parameter configuration, i.e., per BWP, CC or UE. Based on contributions submitted to RAN1#105‑e meeting the following altertives were identified.

**Issue#1-1:** New RRC parameter for identification of scheme 1 PDSCH is configured

* **Alt 1**: Per BWP
	+ **Supported by**: CATT, Nokia/NSB, …
* **Alt 2**: Per CC
	+ **Supported by**: Qualcomm, …

#### Round-1

Companies are invited to provide their preference on the remaining details of identification / configuration of scheme 1 for PDSCH.

**Proposal #1-1:**

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| **Company** | **Comment** |
| Moderator | More inputs are required |
| InterDigital | Support Alt2 |
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### Issue #1-2 (Semi-static switching of scheme 1 with single-TRP)

Regarding remaining details of switching of scheme 1 and single-TRP. One company mentioned that UE not capable of supporting dynamic switching should not expect indication of two TCI states per TCI codepoint, while other company propose to introduce RRC parameter to support enabling/disabling of dynamic switching. The company’s proposals regarding remaining details for scheme 1 switching are summarized below.

**Issue #1-2:**

* **Alt. 1:** UE is not expected higher-layer configuration of a single TCI state per TCI codepoint, if UE is configured with scheme 1 PDSCH, but not capable to support dynamic switching with single-TRP
	+ **Supported by**: Apple
* **Alt. 2:** Dynamic switching of scheme 1 and single-TRP is configured by RRC.
	+ **Supported by:** CATT

Companies are invited to provide their preference on the remaining details of semi-static switching of single-TRP and scheme 1 for PDSCH.

#### Round-1

**Proposal #1-2:**

* TBD

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| **Company** | **Comment** |
| Moderator | More inputs are required |
| InterDigital | Support Alt1 |
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### Issue #1-3 (Dynamic switching of scheme 1 and scheme-1a)

Regarding support of dynamic 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#1-3:** Whether or not to support dynamic switching of scheme 1 and Rel-16 scheme-1a

* **Alt 1**: Dynamic (DCI-based) is not supported
	+ **Supported by**: Qualcomm, OPPO, NEC, Nokia, Lenovo/MotMobility…
* **Alt 2**: Dynamic (DCI-based) is supported
	+ **Supported by**: Huawei, HiSilicon, CATT?, …

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

#### Round-1

**Proposal #1-3 (for conclusion):**

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

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| **Company** | **Comment** |
| InterDigital | Support FL proposal |
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### Issue #1-4 (Additional source RS in TCI for scheme 1)

In RAN1#104b-e meeting all Rel-15/Rel-16 source RS types supported for TCI states were agreed as working assumption for Rel-17 scheme 1. Several companies proposed to confirm the working assumption in this meeting.

**Issue#1-4:** Whether or not to confirm working assumption on QCL source RS types?

* **Alt-1**: Confirm working assumption
	+ **Supported by**: Nokia/NSB, Lenovo/MotMobility,
* **Alt-2**: Not confirm working assumption
	+ **Supported by**: …

Based on the inputs above, it is proposed to confirm working assumption from RAN1#104b-e meeting.

#### Round-1

**Proposal #1-4:**

* Confirm 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.

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| **Company** | **Comment** |
| InterDigital | Support FL proposal |
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### Issue #1-5 (Support of scheme 2)

Regarding support of scheme 2. Several companies expressed their preference regarding support of scheme 2 in Rel-17. Some companies have also provided LLS evaluation results comparing performance of scheme 2 with scheme 1 and the baseline scheme. Summary of the company’s views are provided below:

**Issue#1-5:** 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, …

Since there is no clear majority to support scheme 2 in Rel-17, it is recommended to make the following conclusion on Issue #1-5.

#### Round-1

**Proposal #1-5 (for conclusion):**

* Scheme 2 is not supported in Rel-17

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| **Company** | **Comment** |
| Moderator | No more discussion on this issue |
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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 #2-1 (QCL types/assumptions when TRS is source)

Regarding new QCL types/assumption for TRS, when TRS resource(s) is used as source RS in the TCI state. The following preference on the QCL Variants (A, B, C and E agreed in RAN1#103-e meeting) were provided by companies for TRP-based pre-compensation schemes. In addition, one company proposed a new option (captured as Variant F) for QCL types/assumption.

**Issue#2-1:** For TRP-based pre-compensation, 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

* **Variant A**
	+ **Supported by**: Huawei / HiSilicon, OPPO, Spreadtrum, CATT, Futurewei, ZTE, CMCC, Ericsson, Samsung, Lenovo/Motorola Mobility, Nokia/NSB, LGE, …
* **Variant B**
	+ **Supported by**: CATT, Intel, Ericsson, Qualcomm, …
* **Variant C**
	+ **Supported by**: vivo, CMCC, …
* **Variant E**
	+ **Supported by**: Futurewei, Samsung …
* **Variant F (new)**
	+ One of the TCI state can be associated with {average delay, delay spread, [Doppler spread]} and another TCI state can be associated with {average delay, delay spread, Doppler shift, Doppler spread} (i.e., QCL-TypeA)
	+ **Supported by**: Apple

Based on the company’s preference the following proposal is made.

#### Round-1

**Proposal #2-1:**

* 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 containing TRS as source reference signal.
	+ FFS support of other Variant(s)

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| **Company** | **Comment** |
| InterDigital | * Don’t support the proposal.
* We believe variant E is a better choice as it has a symmetric QCL type for both TRP1 and TRP2. As a UE moves from TRP1 to TRP2, for other variants, we have to alternate the association of QCL Type A as the source of Doppler estimation; hence unnecessary signaling.
* With variant E, we could assume that each UE has sufficient intelligence to know which of TRPs should be used as the source of Doppler estimation, and what parameters should be dropped.
* Also to make a sound decision on this issue, it may be better to first discuss and agree on whether TRS is going to be pre-compensated or not.
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### Issue #2-2 (New QCL types/assumption)

Regarding signalling of QCL type/assumptions for TRP-based pre-compensation scheme. The following two approaches were identified by companies for TRP-based pre-compensation scheme as captured in Alt 1 and Alt 2.

**Issue#2-2:** For TRP-based pre-compensation QCL assumptions is provided to the UE by using

* **Alt-1**: New QCL type
	+ **Supported by**: Huawei / HiSilicon, Lenovo/MotMobility, Intel, Vivo, Futurewei, Qualcomm, Ericsson, [CATT]
* **Alt-2**: 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
	+ **Supported by**: ZTE, Sony, Nokia/NSB, OPPO, LGE, NEC, Samsung, Apple, …

Companies are invited to share their preference regarding signaling option of QCL types/assumptions for TRP-based pre-compensation scheme.

#### Round-1

**Proposal #2-2:**

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| **Company** | **Comment** |
| Moderator | More inputs are required |
| InterDigital | Should be discussed later. |
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### Issue #2-3 (Indication of the carrier frequency for UL)

Regarding indication of the carrier frequency for UL transmission. In RAN1#104b-e it was agreed to support at least one option based on implicit and explicit approaches for indication of the carrier frequency for UL. Companies preference regarding the above options are summarized below.

**Issue#2-3:** Indication of carrier frequency for uplink transmission in TRP-based pre-compensation schemes

* **Option 1** Implicit from RAN1#102-e agreement
	+ **Supported by**: Futurewei, OPPO, CATT, CMCC, ZTE, Qualcomm (with loose QCL type E), Intel (with RAN4 tests to address FO pre-compensation errors), Samsung, …
	+ **Companies with concerns**: Nokia/NSB,
* **Option 2** Explicit from RAN1#102-e agreement
	+ **Supported by**: Futurewei, Ericsson, Sony, ZTE (specification impact should be as small as possible), Intel, Qualcomm (only if UE optional feature), Nokia / NSB, NTT DOCOMO, …
	+ **Companies with concerns**: Huawei/HiSilicon, CATT, OPPO?, Lenovo/MotMobility

Companies are invited to share their views regarding indication option of the carrier frequency for UL transmission.

#### Round-1

**Proposal #2-3:**

* TBD

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| **Company** | **Comment** |
| Moderator | More inputs are required |
| InterDigital | Both should be supported, where the baseline should be the Implicit indication but to be assisted by explicit if needed. |
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### Issue #2-4 (QCL-like association between DL and UL RS)

Regarding support of QCL-like association between DL and UL RS, e.g., for carrier frequency indication in UL. Several companies provided their views whether carrier frequency requires specification support for indication or can be selected by the UE based on implementation. Company’s preferences on this issue are summarized below:

**Issue#2-4:** Whether to support QCL-like association between DL and UL RS?

* **Option 1**: QCL-like association of the resource(s) received in the 1st step with UL signal transmitted in the 2nd step is supported by specification. FFS between the following alternatives:
	+ **Alt-1**: Explicit indication of the DL RS for QCL-like association
	+ **Alt-2**: Implicit indication of DL RS for QCL-like association
	+ **Supported by**: Futurewei, CMCC, Qualcomm, …
* **Option 2**: 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
	+ **Supported by**: vivo, CATT, Ericsson, Samsung, Intel, OPPO, Sony, LGE, Nokia/NSB, …

Based on the company’s preference above, the following proposal is made.

#### Round-1

**Proposal #2-4 (for conclusion):**

* For Variant A, B or C (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

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| **Company** | **Comment** |
| InterDigital | Support Option 2. It should not be indicated; for a UE in pre-compensation mode it should be assumed by definition. |
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### Issue #2-5 (Switching of TRP pre-compensation scheme)

Some companies have provided their views regarding switching of TRP pre-compensation scheme with legacy Rel-15/Rel-16 and new Rel-17 transmission schemes. Company’s views on this issue are summarized below:

**Issue#2-5:** How to support switching of TRP pre-compensation with other Rel-15/Rel-16/Rel-17 schemes?

* Switching of TRP-based frequency offset pre-compensation and Rel-15 singe-TRP
	+ **Alt. 1-1**: Dynamic (DCI-based)
		- **Supported by**: Spreadtrum (with UE capability), Nokia/NSB, Lenovo/MotMobility,
	+ **Alt. 1-2**: Semi-static (RRC-based)
		- **Supported by**: Apple, Qualcomm…
* Switching of TRP-based frequency offset pre-compensation and Rel-16 scheme 1a/2a/2b/3/4
	+ **Alt. 2-1**: Dynamic (DCI-based)
		- **Supported by**: …
	+ **Alt. 2-2**: Semi-static (RRC-based)
		- **Supported by**: Apple, Qualcomm, Lenovo/MotMobility,…
* Switching of TRP-based frequency offset pre-compensation and Rel-17 scheme 1
	+ **Alt. 3-1**: Dynamic (DCI-based)
		- **Supported by**: Spreadtrum?, Lenovo/MotMobility,…
	+ **Alt. 3-2**: Semi-static (RRC-based)
		- **Supported by**: Apple, Qualcomm,

Companies are invited to share their preference regarding switching of TRP pre-compensation scheme with other transmission schemes. One possible option is to support the same switching options as were agreed for scheme 1 (PDSCH). In addition to support semi-static switching of Rel-17 scheme and TRP pre-compensation.

#### Round-1

**Proposal #2-5:**

* 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
* 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)

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| **Company** | **Comment** |
| InterDigital | We don’t think dynamic indication for switching to S-TRP is needed, as occasional reception by only one TRP should be natural to a M-TRP system.Support 2nd and 3rd bullets. |
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### Issue #2-6 (Configuration/Identification of TRP pre-compensation scheme)

Some companies have provided their views regarding configuration/identification of TRP pre-compensation scheme for PDSCH. Company’s views on this issue are summarized below:

**Issue#2-6:** TRP pre-compensation scheme for PDSCH is identified by

* **Alt-1**: Number of TCI states
	+ **Supported by**: …
* **Alt-2**: New RRC parameter and number of TCI states
	+ **Supported by**: Nokia/NSB, …

#### Round-1

Companies are invited to provide their preference on the above alternatives. One possible option is to support the same configuration/identification approach as for scheme 1 (PDSCH) as captured in the proposal below.

**Proposal #2-6:**

* RRC parameter and number of TCI states are used for identification of TRP-based frequency offset pre-compensation scheme
	+ FFS other details

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| **Company** | **Comment** |
| InterDigital | Support FL proposal |
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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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## SFN transmission of PDCCH

### Issue #3-1 (Remaining FFS issues)

In RAN1#104b-e meeting several issues related to support of enhanced SFN PDCCH transmission were agreed for further study. Several companies provided their preference regarding these FFS issues. Based on the discussion, the following proposal is made:

**Issue #3-1:**

* In CA scenario additionally support RRC configured set of the serving cells which can be addressed by a single MAC CE
	+ **Supported**: Qualcomm, Lenovo/MotMobility, …
	+ **Not supported**: …
* Enhanced MAC CE signaling is applicable to a CORESET configured with CORESETPoolindex
	+ **Supported**: …
	+ **Not supported**: Qualcomm, Nokia/NSB, Lenovo/MotMobility, …
* For a CORESET that is RRC-configured with only two TCI states, the UE assumes that the DM-RS antenna port associated with PDCCH receptions in the CORESET are QCLed with the DL RSs in the two TCI states
	+ **Supported**: Qualcomm, …
	+ **Not supported**: …

#### Round-1

Companies are invited to provide their preference on the proposals above.

**Proposal #3-1:**

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| **Company** | **Comment** |
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### Issue #3-2 (Identification of SFN PDCCH transmission)

Several companies have mentioned the issue of identification of the Rel-17 enhanced SFN PDCCH transmission scheme (i.e., scheme 1 and TRP-based pre-compensation).

**Issue #3-2:**

* Enhanced SFN PDCCH transmission scheme (scheme 1 and TRP-based pre-compensation) is identified by
	+ **Alt 1a**: RRC parameter and number of TCI states, where RRC parameter is defined for PDCCH only
		- **Supported by**: Qualcomm, Intel, …
	+ **Alt 1b**: RRC parameter and number of TCI states, where RRC parameter is the same as used for identification of scheme 1 or TRP based pre-compensation for PDSCH
		- **Supported by**: vivo, …
	+ **Alt 2**: Number of TCI states
		- **Supported by**: vivo, Ericsson, …
	+ FFS other details including whether RRC parameter is common or separate between scheme 1 and TRP-based pre-compensation schemes

#### Round-1

Companies are invited to provide their views regarding the above options.

**Proposal #3-2:**

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| **Company** | **Comment** |
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### Issue #3-3 (Default TCI for single-beam PDSCH)

Regarding default beam assumption for PDSCH reception. When two TCI states are indicated for CORESET, several companies proposed to enhance rule(s) to determine default beam (TCI state) for PDSCH reception. In particular, whether and which default TCI state should be used for Rel-15 single-TRP and Rel-16 scheme 3/4 PDSCH reception. Based on the company’s contributions the following alternatives were identified.

#### Round-1

**Issue #3-3:**

* If a CORESET is indicated with two TCI states and time offset between the reception of the DL DCI and the corresponding PDSCH is less than the threshold *timeDurationForQCL*
	+ **Alt 1:** New rule(s) to determine one of the TCI states of the CORESET as default beam for Rel-15 single-TRP and Rel-16 scheme 3/4 PDSCH reception is supported
	+ If neither of *enableDefaultTCIStatePerCoresetPoolIndex* and *enableTwoDefaultTCI-States* is configured down-select one alternative
		- **Alt 1-1**: gNB ensures the lowest CORESET ID in the latest slot only configured one TCI state by implementation
		- **Alt 1-2**: Modify the definition of the lowest CORESET ID in the latest slot, e.g. the lowest CORESET ID among the CORESETs associated with one TCI state in the latest slot.
		- **Alt 1-3**: QCL assumption associated with one of TCI states, e.g. always selects the first or the second TCI state or the TCI state with a lower ID
		- **Supported by**: vivo, Xiaomi, ZTE, Ericsson, OPPO, Qualcomm, Spreadtrum, CATT, Convida Wireless, …
	+ **Alt 2:** The default TCI state for Rel-15 single-TRP and Rel-16 scheme 3/4 PDSCH is not specified / supported
		- **Supported by**: Nokia/NSB, Intel, …

Based on the companies view the following proposal is made.

**Proposal #3-3:**

* If a CORESET is indicated with two TCI states and time offset between the reception of the DL DCI and the corresponding PDSCH is less than the threshold *timeDurationForQCL*
	+ If neither of *enableDefaultTCIStatePerCoresetPoolIndex* and *enableTwoDefaultTCI-States* is configured down-select one alternative
		- **Alt 1-1**: gNB ensures the lowest CORESET ID in the latest slot only configured one TCI state by implementation
		- **Alt 1-2**: Modify the definition of the lowest CORESET ID in the latest slot, e.g. the lowest CORESET ID among the CORESETs associated with one TCI state in the latest slot.
		- **Alt 1-3**: QCL assumption associated with one of TCI states, e.g. always selects the first or the second TCI state or the TCI state with a lower ID

Companies are invited to provide their views regarding the above options.

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### Issue #3-4 (Default TCI for Rel-17 SFN PDSCH)

Several companies have proposed to define new rule for determination of default TCI states for reception of Rel-17 enhanced SFN PDSCH, when PDSCH is scheduled by PDCCH transmitted from CORESET indicated with two TCI states. Based on the company’s contributions the following alternatives were identified.

#### Round-1

**Proposal #3-4:**

* If a CORESET is indicated 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*, the following rule is used to determine default beam(s) for Rel-17 SFN PDSCH reception:
	+ **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
		- FFS other details

Companies are invited to provide their views regarding the above options.

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### Issue #3-5 (TCI states of PDSCH with absent TCI field)

Several companies discussed the issue of PDSCH reception when TCI field is not present in DCI scheduling PDSCH. Based on the discussion the following alternatives were identified for the following discussion.

#### Round-1

**Proposal #3-5**:

* For Rel-17 enhanced SFN PDSCH reception, when the time offset between the reception of the DL DCI and the corresponding PDSCH is equal or larger than the threshold *timeDurationForQCL*
	+ **Alt 1:** Support configuration when there is no TCI field in the DCI scheduling PDSCH
	+ **Alt 2:** Configuration when there is no TCI field in the DCI scheduling PDSCH is not supported

Companies are invited to provide their views regarding the above options.

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### Issue #3-6 (Default TCI for aperiodic CSI-RS)

Regarding default beam for aperiodic CSI-RS reception. Several companies proposed to define new rule to determine default beam for aperiodic CSI-RS reception in Rel-17, when CORESET is indicated with two TCI states. Based on the company’s contributions the following proposal is made.

#### Round-1

**Proposal #3-6:**

* If a 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 overlapping DL signal with indicated TCI state
		- Use one of two TCI states as default beam for aperiodic CSI-RS reception using the same principles as for default TCI state for Rel-15 single TRP PDSCH case
	+ If there is other overlapping DL signal, the default TCI of the AP CSI-RS follows one TCI state of the other signal
		- FFS other details

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### Issue #3-7 (Default spatial / PL RS for single-TRP PUSCH/PUCCH/SRS)

In the context of supporting two TCI states for CORESET, several companies have mentioned the issue of default uplink beam(s) and PL-RS determination for dedicated-PUSCH/PUCCH/SRS transmission to a single TRP. Based on the company’s contributions the following proposal is made.

#### Round-1

**Proposal #3-7:**

* If a CORESET is indicated with two TCI states for PUSCH/PUCCH/SRS transmission to a single-TRP
	+ If PL-RS and spatial relation information are not configured and default beam is enabled for the PUCCH transmission
		- For single-TRP PUCCH transmission define rule(s) to determine one of the TCI states of the CORESET used as default beam and PL RS
		- FFS the exact rule
	+ If PUSCH scheduled by DCI format 0\_0 and default beam is enabled for the PUSCH transmission
		- For single-TRP PUSCH transmission define rule(s) to determine one of the TCI states of the CORESET used as default beam and PL RS
		- FFS the exact rule
	+ If PL-RS and spatial relation information are not configured and default beam is enabled for the SRS transmission
		- Define rule(s) for mapping of TCI states from CORESET to SRS resource sets to determine default beam and PL-RS

Companies to provide their preference on the proposal above.

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### Issue #3-8 (Default spatial / PL RS for Rel-17 multi-TRP PUSCH/PUCCH)

If a CORESET is indicated with two TCI states, several companies proposed to define rule to determine default beams for Rel-17 multi-TRP PUSCH/PUCCH transmission schemes with repetition. Based on the discussion the following proposal is made.

#### Round-1

**Proposal #3-8:**

* If a CORESET is indicated with two TCI states, support two TCI states of the CORESET used as default beams and PL RS for Rel-17 Multi-TRP PUSCH/PUCCH repetition scheme
	+ FFS the exact rule

Companies to provide their views on the proposal above.

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### Issue #3-9 (PDCCH monitoring 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. Based on the discussion the following proposal is made.

#### Round-1

**Proposal #3-9:**

* When a CORESET is activated with two TCI states which overlaps with other CORESET, support new prioritization rule for PDCCH monitoring of PDCCH candidates in overlapping monitoring occasion with different QCL-TypeD
	+ **Alt 1**: Prioritization rule considers only CORESETs indicated with same number of TCI states (e.g., 2)
	+ **Alt 2**: Prioritization rule considers CORESETs indicated with the same and different number of TCI states
	+ FFS other details including whether new RRC parameter is required to indicate PDCCH monitoring assumptions using single TCI state or up to two TCI states

Companies to provide their views on the proposal above.

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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

### Issue #4-1 (Configuration of RS for BFD)

Several companies have discussed the issue of reference signals configuration for beam failure detection (BFD), when two TCI states are activated for CORESET. Based on the company’s contributions the following alternatives were proposed.

**Issue #4-1:**

* When two TCI states are activated for a CORESET, support the following configuration of RS for BFD
	+ Implicit configuration
		- **Alt 1-1**: RS of CORESETs with only single TCI states are used
			* **Supported by**: Nokia/NSB, …
		- **Alt 1-2**: RS of CORESETs with both single and two TCI states are used
			* **Supported by**: Lenovo/MotMobility, …
		- **Alt 1-3**: RS of CORESETs with only two TCI states are used
			* **Supported by**: Qualcomm, Xiaomi?, Ericsson, …
	+ Explicit configuration
		- **Alt 2-1**: Support defining CSI-RS resource or SSB pairs as BFD RS
			* FFS other details
			* **Supported by**: NEC, Xiaomi, …
		- **Alt 2-2**: Reuse the existing Rel-15/Rel-16 approach for BFD RS configuration
			* **Supported by**: Qualcomm, Nokia/NSB, Lenovo/MotMobility, …

Companies are invited to provide their views regarding the above alternatives.

#### Round-1

**Proposal #4-1:**

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### Issue #4-2 (Hypothetical BLER calculation for BFD)

Several companies have discussed the issue of hypothetical BLER calculation using measurements from beam failure detection (BFD) RS, when two TCI states are activated for CORESET. Based on the company’s contributions the following alternatives were proposed.

**Issue #4-2:**

* When two TCI states are activated for a CORESET, hypothetical BLER for BFD calculated as follows
	+ **Alt 3-1**: UE calculates hypothetical BLER using BFD RS assuming single-TRP transmission
		- **Supported by**: Nokia/NSB, Ericsson …
	+ **Alt 3-2**: UE calculates hypothetical BLER using BFD RS pairs assuming SFN transmission for multiple-TRPs
		- **Supported by**: Qualcomm, NEC, Lenovo/MotMobility, LGE, …

Companies are invited to provide their views regarding the above alternatives.

#### Round-1

**Proposal #4-2:**

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| **Company** | **Comment** |
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### Issue #4-3 (NBI RS)

Several companies have discussed the issue of configuration of new beam identification reference signals, when two TCI states are activated for CORESET. Based on the company’s contributions the following alternatives were proposed.

**Issue #4-3:**

* When two TCI states are activated for a CORESET, NBI RS are configured as follows
	+ Alt 4-1: Reuse the existing Rel-15 NBI configuration based on single CSI-RS resource
		- **Supported by**: Qualcomm, Nokia/NSB, Intel …
	+ Alt 4-2: Introduce two new beam identification CSI-RS resource sets or new beam identification CSI-RS resource pairs
		- **Supported by**: NEC, Xiaomi, Lenovo/MotMobility,

#### Round-1

Companies are invited to provide their views regarding the above alternatives.

**Proposal #4-3:**

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### Issue #4-4 (Applicability of the BFR enhancements)

Several companies have discussed the issue of applicability of beam failure enhancements for different BFD procedures (specified in different releases), when two TCI states are activated for CORESET. Based on the company’s contributions the following alternatives were proposed.

**Proposal #4-4:**

* When two TCI states are activated for a CORESET, BFR enhancements are applicable to
	+ Rel-15 BFR
		- **Supported by**: Qualcomm, NEC, Nokia/NSB, Lenovo/MotMobility,
	+ Rel-16 BFR
		- **Supported by**: Qualcomm, NEC, Nokia/NSB, Lenovo/MotMobility,
	+ Rel-17 BFR
		- **Supported by**: NEC,

Companies are invited to provide their views regarding the above alternatives.

#### Round-1

**Proposal #4-4:**

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## Other issues

This section contains other issues the companies want to highlight for discussion regarding support of beam failure detection.

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## Issue #5-1 (Other non-categorized proposals)

The proposals supported by one company are provided below for consideration in the next RAN1 meetings.

* *A new definition on QCL association relationship of one antenna port and one antenna port group*
* *Support of small delay CDD with a properly adjusted delay offset between TRPs*
* *QCL assumptions between the TRS/CSI-RS and SSB reference RS for scheme 1*
* *Support configuration of combination of SFN and TDM based PDCCH simultaneously*
* *Introduce new QCL type-E with loose Doppler shift relationship between the target and source RS.*
* *Study zone-based configuration for TCI/QCL information to mitigate potential high signaling overhead.*
* *Support variable-rate TRS transmission for HST deployment scenario.*
* *TCI states configured in non-serving cell(s) with PCI either explicitly configured or implicitly associated*
* *DMRS adaptation for HST SFN scenario*
* *UE assisted DMRS adaptation for DL, in which UE provides an indication of the most convenient DMRS configuration*
* *Define new value of CORESETPoolIndex for CORESET with two TCI states*
* *Study PTRS design in case of SFN transmission scheme*
* *Dynamic DMRS configuration signaling to enable DMRS adaptation*
* *New SRS pattern for UL Doppler estimation purpose*
* *SRS allocation for Doppler measurements multiplexing with any UL or DL channel for the addressed UE*
* *Efficient triggering method for SRS transmission*
* *Study TA issue in HST scenario*
* *Support configuration/activation of one or two TCI States for different search spaces in a CORESET for PDCCH SFN transmission.*

# 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] R1-2104203, Enhancement to support HST-SFN deployment scenario, FUTUREWEI.

[3] R1-2104269, Enhancements on high speed train for multi-TRP in Rel-17, Huawei, HiSilicon.

[4] R1-2104295, Further Discussion on HST-SFN, InterDigital, Inc.

[5] R1-2104346, Further discussion and evaluation on HST-SFN schemes, vivo.

[6] R1-2104414, Discussion on enhancements on HST-SFN deployment, Spreadtrum Communications.

[7] R1-2104487, Discussion on HST-SFN transmission schemes, CATT.

[8] R1-2104588, Discussion on Multi-TRP HST enhancements, ZTE.

[9] R1-2104602, Enhancements on HST-SFN deployment, CMCC.

[10] R1-2104657, Enhancements on HST-SFN deployment, Qualcomm Incorporated.

[11] R1-2104735, Enhancements on HST-SFN deployment, OPPO.

[12] R1-2104892, Enhancements to HST-SFN deployments, Intel Corporation.

[13] R1-2105090, Views on Rel-17 HST enhancement, Apple.

[14] R1-2105154, Enhancement on HST-SFN deployment, Sony.

[15] R1-2105249, Discussion on HST-SFN deployment, NEC.

[16] R1-2105276, Enhancements for HST-SFN deployment, Nokia, Nokia Shanghai Bell.

[17] R1-2105294, Enhancements on HST-SFN, Samsung.

[18] R1-2105543, Enhancements on HST-SFN operation for multi-TRP PDCCH transmission, Xiaomi.

[19] R1-2105586, Enhancement on HST-SFN deployment, Ericsson.

[20] R1-2105591, On Enhancements for HST-SFN deployment, Convida Wireless.

[21] R1-2105686, Discussion on HST-SFN deployment, NTT DOCOMO, INC.

[22] R1-2105761, Enhancements for HST-SFN deployment, Lenovo, Motorola Mobility.

[23] R1-2105782, Enhancements on HST-SFN deployment, LG Electronics.

# Appendix (Summary of the agreements)

The agreements made in RAN1#102e, RAN1#103e and RAN1#104e 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.
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**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
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