**3GPP TSG-RAN WG1 Meeting #117 R1-24xxxxx**

**Fukuoka, Japan, May 20 – 24, 2024**

**Agenda Item: 9.3.3**

**Source: Moderator (Huawei)**

**Title: Summary #1 of CLI handling**

**Document for: Discussion and Decision**

1. **Introduction**

In this contribution, the proposals based on the technical documentation submitted in RAN1#117 and the discussion on CLI handling schemes are summarized.

1. **Adjacent channel CLI handling**

The following was agreed in RAN1#116bis with respect to adjacent channel CLI handling

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| **For future RAN1 meetings:**For the down-selection of gNB-to-gNB CLI handling scheme(s) and UE-to-UE CLI handling scheme(s), companies are encouraged to check whether the candidate co-channel CLI handling scheme can be applicable for inter-operator and/or intra-operator adjacent channel CLI handling.* Note: Whether flexible symbol(s)/slot(s) with SBFD subband configurations can be convert into DL/UL symbols by *TDD-UL-DL-ConfigDedicated* is discussed under AI 9.3.1.
* Note: Whether UE-specific SBFD subband time domain location indication is supported is discussed under AI 9.3.1.
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* 1. **Submitted proposals**

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| **Company** | **Description** |
| **Ericsson** | 1. Most schemes in TR 38.858 either require RAN3 signaling for inter-gNB information exchange of channel measurement, configuration of reference signals or both.
2. For inter-operator case, co-channel CLI mitigation schemes summarized in the table cannot address the CLI from adjacent channels. Disallowing SBFD operation in legacy UL symbols or slot alleviates the impact to legacy networks.
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| **Nokia** | Observation 1: For adjacent channel inter-site gNB-gNB CLI handling with intra-operator deployment, exchange of semi-static time and frequency information of SBFD slots can be supported. Observation 5: The applicability of beam nulling to combat adjacent channel interference is unclear due to the fact that gNBs measurements should occur across carriers. |
| **NTT DOCOMO** | *Observation 1: CLI handling schemes with exchanging information of measurement and reporting is not applicable for inter-operator adjacent channel CLI handling, and one possible solution can be CLI measurement with RSSI.* |
| **OPPO** | *For adjacent-channel CLI handling:* ***Observation*** *1: CLI measurement based on RS sequence signature is not applicable to adjacent-channel CLI handling. The following CLI schemes and functional components that are currently discussed in AI9.3.3 for co-channel CLI do not require CLI measurement using RS sequence signature:* * *Inter-UE CLI-RSSI measurement within DL subband (for inter-UE CLI)*
* *Inter-gNB CLI measurement using transparent UL resource muting (for inter-gNB CLI)*
* *Coordinated scheduling of time-frequency resource (for both inter-UE CLI and inter-gNB CLI)*
* *Beam nulling (for inter-gNB CLI)*
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| **Qualcomm** | ***Proposal*** *22: There is no UL performance impact on UL symbols due to inter-operator adjacent channel inter-gNB CLI when restricting SBFD to D symbols and F symbols. Therefore, there is potentially no need for RAN1 to discuss inter-operator adjacent channel inter-gNB CLI handling schemes.* ***Proposal*** *23: Open to discuss schemes for resolving intra-operator adjacent channel CLI based on the co-channel CLI handling schemes as baseline.* |
| **Tejas Networks** | Proposal 1: RAN1 should consider the study techniques for mitigation of Adjacent channel CLI ,if possible, as part of this Rel-19 work item.Proposal 2: RAN1 should further discuss on sending a LS to RAN-4 to trigger the feasibility study on adjacent channel blocker mitigation due to adjacent channel CLI in view of relaxed roll off requirements considering {D,U,D} for SBFD.Proposal 3: Further study the impact of adjacent channels on network throughput with the {D, U, D} SBFD configurations.Proposal 4 : Co-channel gNB-gNB CLI handling schemes are applicable for intra-operator adjacent channel CLI.Proposal 5 : For intra-operator adjacent channel CLI we support beam nulling based on steering vector between gNB-gNB for adjacent channel CLI.Proposal 6 : For intra-operator adjacent channel CLI we support the non-transparent UL resource muting scheme due to better UL performance compared to transparent UL resource muting scheme.Proposal 7: Schemes for inter-operator adjacent channel CLI handling requires further study due to absence of signalling between inter-operator gNB’s. |

* 1. **Summary**

**Ericsson, Nokia, NTT DOCOMO, OPPO, Tejas Networks and Qualcomm** discussed adjacent channel CLI handling in the context of Rel-19 SBFD.

**Ericsson** thinks for inter-operator case, co-channel CLI mitigation schemes summarized in the table cannot address the CLI from adjacent channels.

**Nokia** thinks for adjacent channel inter-site gNB-gNB CLI handling with intra-operator deployment, exchange of semi-static time and frequency information of SBFD slots can be supported. While, the applicability of beam nulling to combat adjacent channel interference is unclear due to the fact that gNBs measurements should occur across carriers.

**NTT DOCOMO** thinks CLI handling schemes with exchanging information of measurement and reporting is not applicable for inter-operator adjacent channel CLI handling, and one possible solution can be CLI measurement with RSSI.

**OPPO** thinksCLI measurement based on RS sequence signature is not applicable to adjacent-channel CLI handling. The following CLI schemes and functional components that do not require CLI measurement using RS sequence signature can be considered.

* Inter-UE CLI-RSSI measurement within DL subband (for inter-UE CLI)
* Inter-gNB CLI measurement using transparent UL resource muting (for inter-gNB CLI)
* Coordinated scheduling of time-frequency resource (for both inter-UE CLI and inter-gNB CLI)
* Beam nulling (for inter-gNB CLI)

**Tejas Networks** thinks Co-channel gNB-gNB CLI handling schemes are applicable for intra-operator adjacent channel CLI, such as beam nulling based on steering vector between gNB-gNB for adjacent channel CLI, non-transparent UL resource muting scheme. However, Schemes for inter-operator adjacent channel CLI handling requires further study due to absence of signalling between inter-operator gNB’s.

**Qualcomm** thinks there is potentially no need for RAN1 to discuss inter-operator adjacent channel inter-gNB CLI handling schemes, but open to discuss schemes for resolving intra-operator adjacent channel CLI based on the co-channel CLI handling schemes as baseline.

Companies discussed about the applicability to candidate co-channel CLI handling scheme for inter-operator and/or intra-operator adjacent channel CLI handling. The moderator thinks that these aspects can be taken into account in the down-selection of the CLI handling schemes. Based on companies’ input, the following observations are provided

**Proposal 2-1**

**Observations:**

The following schemes can be applicable for intra-operator adjacent channel CLI handling

* Beam nulling
* UL resource muting
* Coordinated scheduling of time-frequency resource

The following schemes can be applicable for inter-operator adjacent channel CLI handling

* UL resource muting

**Companies are invited to provide views on the above observation if any.**

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| **Companies** | **Views** |
| Tejas Networks | The leakage into adjacent channel will also be proportional to the beam strength , we think beam nulling schemes are applicable for intra-operator adjacent channel handling. We support beam nulling with steering vector as the adjacent channel measurement can be avoided here. Additionally, we recommend UL non-transparent muting especially to mitigate the impact of adjacent channel side-lobes. Information exchange for CLI handling is possible for intra-operator gNB’s.Current Co-Channel CLI schemes is not applicable for inter-operator CLI’s requires further study as it requires inter-operator co-ordination and information exchange.  |
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1. **gNB-to-gNB CLI handling schemes**

In RAN1#116 and RAN1#116bis, the following agreements were made for gNB-to-gNB CLI handling.

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| **Agreement**Consider the following candidate gNB-to-gNB co-channel CLI handling schemes for further down-selection* gNB-to-gNB co-channel CLI and/or channel measurements
* Spatial domain based schemes
	+ Beam nulling
	+ Beam pairing
* Coordinated scheduling in time and/or frequency
* Power control based schemes
	+ gNB Tx power control
	+ UE Tx power control

Note: gNB-to-gNB co-channel CLI and/or channel measurements can be the enablers for some of the above CLI handling schemes.**Agreement**gNB Tx power control based schemes are not considered in the down-selection of gNB-to-gNB co-channel CLI handling schemes.**Agreement**UL Tx power control based schemes are not considered in the down-selection of gNB-to-gNB CLI handling and UE-to-UE CLI handling schemes.* + Note: Support of UL Tx power control enhancements can be discussed in AI 9.3.1 and 9.3.2 (for PRACH only).
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* 1. **Submitted proposals**

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| **Company** | **Description** |
| ***CATT*** | ***Observation 1:*** *Beam nulling can be enabled by gNB-gNB CLI measurement.****Proposal 1:*** *Support gNB-to-gNB co-channel CLI measurement.****Proposal 2:*** *Non-transparent UL resource muting is not supported.****Proposal 3:*** *The potential spec impact of gNB-to-gNB co-channel CLI measurement includes information exchange of CLI measurement resource configuration (NZP CSI-RS/NCD-SSB).****Proposal 4:*** *Support exchange of semi-static SBFD time and frequency configuration among gNBs to enable coordinated scheduling for time/frequency resources.****Proposal 5:*** *Support beam pairing method and recommended/not-recommended DL beam information indication via measurement resource ID (e.g. SSB index and/or CSI-RS ID).* |
| **CMCC** | ***Observation 1****: gNB Tx-Beam Nulling scheme is beneficial to reduce receiver blocking issue at victim BS especially when sub-band RF filter is not applied.* ***Observation 2****: gNB Tx-Beam Nulling scheme may degrade DL performance due to loss of degrees of freedom in spatial domain.****Observation 3****: Whether information exchange of channel measurement is needed or not is up to the possible measurement procedures. For Alt.1, information exchange of channel measurement is needed, and for Alt.2, information exchange of channel measurement is not needed.****Observation 4****: The time/frequency domain based coordinated scheduling scheme cannot be used for SBFD Deployment Case 1 (Non-coexistence case with single SBFD subband configuration).****Observation 5****: SBFD Deployment Case 2 (Non-coexistence case with multiple SBFD subband configurations) is out of the WID scope of Rel-19 SBFD.****Observation 6****: The time/frequency domain based coordinated scheduling scheme is beneficial for SBFD Deployment Case 3 (Co-channel co-existence for semi-static SBFD and legacy static TDD).****Observation 7****: The time/frequency domain based coordinated scheduling scheme cannot be used for SBFD Deployment Case 4 (Adjacent-channel co-existence case).****Observation 8****: For time/frequency domain based coordinated scheduling scheme, the motivation of information exchange of dynamic scheduling information over OTA gNB-to-gNB signalling is not clear.****Observation 9****: gNB-to-gNB co-channel CLI and/or channel measurement is an enabler for other gNB-gNB CLI handling schemes, e.g., beam nulling, beam pairing, coordinated scheduling in time and/or frequency, etc., and the specification impacts for different gNB-gNB CLI handling schemes are different.****Observation 10****: The motivation of non-transparent UL resource muting for gNB-to-gNB CLI measurement is not clear.****Observation 11****: Symbol level transparent UL resource muting via gNB scheduling may cause large resource overload.****Observation 12****: RE level transparent UL resource muting via legacy DMRS configuration has less or no spec impact, and it introduces less overhead.****Proposal 1****: For gNB-to-gNB co-channel CLI handling, support specification enhancement of gNB Tx-Beam Nulling scheme.****Proposal 2****: For gNB Tx-Beam Nulling scheme for SBFD Deployment Case 1, consider the following measurement procedures:** *Alt.2 (aggressor measures channel): gNB A (e.g., aggressor gNB) performs measurement on the RS transmitted from gNB B (e.g., victim gNB).*
	+ *gNB B (e.g., victim gNB) transmits RS for gNB-gNB channel measurement, and gNB A (e.g., aggressor gNB) performs channel measurement and derive the channel information from gNB A to gNB B based on TDD channel reciprocity. gNB B requests for gNB-gNB CLI mitigation via backhaul. In response to the request, gNB A performs Tx-Beam Nulling scheme based on its measured channel information.*
	+ *The following information is exchanged between gNBs for Alt.2. FFS details:*
		- *Configuration of the reference signals for gNB-gNB channel measurement: gNB A (e.g., aggressor gNB) may obtain the RS configuration of gNB B (e.g., victim gNB) via OAM configuration, or via backhaul signalling from gNB B to gNB A.*
		- *Requests for gNB-gNB CLI mitigation via backhaul signalling from gNB B to gNB A.*
	+ *Note: channel reciprocity can be achieved based on gNB implementation.*

***Proposal 3****: For gNB-to-gNB co-channel CLI handling, compared with steering vector based beam nulling method, channel measurement based beam nulling method can be studied with higher priority.****Proposal 4****: Regrading the reference signals for gNB-gNB channel measurement for gNB Tx-Beam Nulling, NZP CSI-RS can be used. CSI-RS port expansion with up to 128 ports can be further studied.****Proposal 5****: Support information exchange of CLI-mitigation request from the victim gNB to the aggressor gNB to trigger on-demand CLI mitigation.****Proposal 6****: For gNB-to-gNB co-channel CLI handling, support specification enhancement for beam paring between gNBs.****Proposal 7****: Regrading the reference signals for gNB-gNB CLI measurement for beam paring, NZP CSI-RS and NCD-SSB can be used.****Proposal 8****: To enable time/frequency domain based coordinated scheduling scheme for SBFD Deployment Case 3 (Co-channel co-existence for semi-static SBFD and legacy static TDD), information exchange of semi-static SBFD time and frequency configuration between SBFD gNB and the legacy TDD gNB can be supported.****Proposal 9****: For interference covariance matrix measurement for gNB-to-gNB CLI handling, RE level transparent UL resource muting via legacy DMRS configuration can be considered as a starting point.****Proposal 10****: Before agreeing non-transparent UL resource muting, RAN1 should first clarify that whether the pre-requisite of non-transparent UL resource muting for interference covariance matrix measurement is that the whole symbols overlapping with UL DMRS should be muted in DL subbands to guarantee the detection performance of UL DMRS.* |
| **Deutsche Telekom** | ***Observation*** *2: Aggressor and victim gNBs can be determined by a radio network planning tool.* ***Proposal*** *1: Aggressor and victim gNBs are set via the O&M. Each SBFD cell receives a list of potential aggressor cells and required parameters (PCIs, CSI-RS Ports …)****Proposal*** *2: The victim gNB verifies by measurements if the top aggressor gNBs according to the list are really the true top aggressor gNBs.* ***Observation*** *3: TX beam nulling at aggressor gNBs in a macro layer will reduce the coverage in a significant part of the macro cell.* ***Proposal*** *4: In order to avoid coverage reduction TX beam nulling at marco gNBs is not the preferred CLI reduction technique.* ***Proposal*** *5: RAN1 should concentrate on gNB-gNB CLI reduction at the victim gNB.*  |
| **Ericsson** | [*Observation 3 The simulation studies in TR examined gNB-gNB CLI mitigation schemes in narrow, controlled settings without considering the broader implications of deploying SBFD.*](#_Toc166256482)[*Observation 4 The process for identifying an aggressor and/or victim gNB is not defined and very challenging.*](#_Toc166256483)[*Observation 5 Assigning a dynamic order for the gNBs to transmit reference signals and ensuring synchronization among gNBs to measure these reference signals is complex.*](#_Toc166256484)[*Observation 6 It is unclear how the coordination between gNBs determines which ones are the aggressors and which are the victims.*](#_Toc166256485)[*Observation 7 The receiver blocking requirements for adjacent channel CLI in SBFD BS are already stricter and demonstrate a capability to handle blocking in challenging scenarios more effectively than what is required for co-channel CLI mitigation using TX beam nulling.*](#_Toc166256486)[*Observation 8 The design of reference signal resources and procedures for inter-gNB interference measurement and mitigation needs to consider that the actual interference channel and that the measured reverse channel involves completely different pairs of hardware. This requires SBFD gNBs to be able to transmit and receive using the same panel which adds additional hardware cost.*](#_Toc166256487)[*Observation 9 Performance gains from Tx beam nulling varies based on whether self-interference and inter-sector interference was suppressed to the point of 1dB desensitization purely by spatial isolation or not.*](#_Toc166256488)[*a. Nulling gains are lower with realistic isolation assumptions, where spatial isolation alone doesn't achieve 1dB desensitization, compared to optimistic assumptions that do.*](#_Toc166256489)[*Observation 10 Under realistic isolation assumptions where 1 dB desense is not achieved purely by spatial isolation, some degrees of freedom are used for nulling towards self/co-sited base stations. In contrast, with optimistic isolation assumptions, these degrees of freedom could be directed towards nulling other sites.*](#_Toc166256490)[*Observation 11 For beam nulling, under both realistic and optimistic assumptions, there are UL gains (3%-17% for realistic, 3%-40% for optimistic, varying by load), but significant DL losses are observed (12%-45% for realistic, 10%-26% for optimistic, also varying by load). Therefore, Proposal 1 becomes even more relevant.*](#_Toc166256491)[*Observation 12 For Tx beam nulling that relies on gNB-gNB channel estimation through RS measurement, the gNB measuring the RS must pause or mute its DL transmissions to be able to receive the RS in the DL subband.*](#_Toc166256492)[*Observation 13 OAM system ensures that the CSI-RS configurations for multiple gNBs in a network are orthogonal in time and frequency.*](#_Toc166256493)[*Observation 14 It is not straightforward to determine which gNBs to establish an Xn interface to and there are constraints on the number of Xn interfaces for a node.*](#_Toc166256494)[*Observation 15 For gNB-gNB channel measurement, it is not clear how to report CSI when the aggressor and victim gNBs have different antenna configuration and use different CSI-RS ports, especially in HetNets where, a WA Macro gNB could be the aggressor and the victim could be a MR or LA outdoor/indoor/factory gNB.*](#_Toc166256495)[*Observation 16 Beam nulling can be effectively implemented when gNBs periodically monitor the RS transmitted by neighboring gNBs. If a gNB receives strong reference signals from its neighbors, yet its own uplink transmission in the SBFD slot is not interfered significantly, it can identify itself as a potential source of interference (an "aggressor"). In response, the gNB can choose to apply beam nulling techniques to minimize its impact on neighboring networks.*](#_Toc166256496)[*Observation 17 For beam pairing, use of CD-SSBs for gNB-gNB CLI measurement may have impact on initial access, cell search and RRM measurement performance.*](#_Toc166256497)[*Observation 18 It should be noted that the non-transparent UL resource muting methods only help CLI suppression if the interference is weak enough not to saturate (block) the gNB receiver.*](#_Toc166256498)[*Observation 19 Power boosting of the OFDM symbol with muted REs could be considered to mitigate the power control issues if RE-level UL resource muting is introduced.*](#_Toc166256499)[*Observation 20 DFT-s-OFDM aspects of non-transparent UL resource muting are important and would require special investigations, e.g. resource mapping as well as impact from the cubic-metric (CM) increase.*](#_Toc166256500)[*Observation 21 Comb-2 RE-level muting is not expected to significantly increase the PAPR/CM any more than doubling the sub-carrier spacing or halving the transmission bandwidth.*](#_Toc166256501)[*Observation 22 Interference estimation based on muting of a single OFDM symbol may completely miss DL interference spanning only part of the slot, resulting in poor performance compared to legacy configurations with similar overhead (2 DMRS per slot).*](#_Toc166256502)[*Observation 23 By muting REs in multiple UL OFDM symbols in a slot, instead of just one, performance in the presence of DL interference spanning only a few OFDM symbols could likely be substantially improved. The fraction of muted REs per OFDM symbol would be reduced to ensure that the total muting overhead in a slot is not increased.*](#_Toc166256503)[*Observation 24 For the low cubic metric DFT-S-OFDM waveform, the proposed ZP PTRS method use time domain sample muting instead of frequency domain RE muting. This solution will not cause cubic metric to increase.*](#_Toc166256504)[*Observation 25 The PTRS has a well-defined structure in multiple OFDM symbols within a slot. This allows multiple measurement opportunities to estimate the correct interference characteristics.*](#_Toc166256505)[*Observation 26 The proposed ZP PTRS introduces minimal necessary modification to existing PTRS structure or configuration to enable efficient RE muting for SBFD gNB-gNB CLI and/or channel measurement.*](#_Toc166256506)[*Observation 27 In LLS with full-slot DL allocation (apart from 1 muted symbol), ZP PTRS gives similar performance as single-symbol non-transparent UL resource muting. With partial-slot DL allocation, ZP PTRS would be expected to outperform single-symbol muting.*](#_Toc166256507)[*Observation 28 UE-UE CLI is a lesser problem than gNB-gNB CLI and optimizations for the former is not expected to increase SBFD performance drastically.*](#_Toc166256508)[*Observation 29 UE-UE CLI only becomes severe when the devices are in close proximity to each other.*](#_Toc166256509)[*Observation 30 L1 RSSI measurements offer limited insight because they fail to distinguish between co-channel and adjacent channel CLI for UE-UE CLI mitigation. This information would be useful to make a more effective scheduling decision oriented to avoid CLI.*](#_Toc166256510)[*Observation 31 For UE-UE CLI measurements, there is a need for SBFD-aware UEs to ignore the SBFD configuration while doing these measurements, especially for Methods #2, #3, and #4.*](#_Toc166256511)[*Proposal 3 It is not clear whether a victim gNB or an aggressor gNB transmits the reference signals, for a given interference scenario.*](#_Toc166256514)[*Proposal 4 If Tx beam nulling is supported, RAN1 agrees to support only the framework for gNBs to transmit reference signals that could be used by other gNBs to determine the channel, i.e. only support Alt 2.*](#_Toc166256515)[*Proposal 5 If RAN4 blocking requirements account for adjacent channel gNB-gNB CLI, then SBFD gNBs are already equipped to handle high power, and beam nulling would not offer extra protection against blocking. Therefore, we suggest minimizing specification changes if beam nulling is to be supported.*](#_Toc166256516)[*Proposal 6 For gNB-gNB channel measurements, an SBFD gNB should be able to receive RS from another gNB in the DL subband.*](#_Toc166256517)[*Proposal 7 If Tx beam nulling is supported, RAN1 agrees to adopt periodic NZP CSI-RS configurations with longer periodicity values than existing periodicities. The specific periodicity will depend partly on the rate at which the gNB-gNB channel conditions change.*](#_Toc166256518)[*Proposal 8 For Tx beam nulling, RAN1 agrees that the gNBs exchanging information are based on already established connections via the Xn interface i.e., no new connections are established solely for the purpose of CLI mitigation.*](#_Toc166256519)[*Proposal 9 Do not support beam nulling schemes that require information exchange of channel measurements/reports.*](#_Toc166256520)[*Proposal 10 Do not support beam nulling schemes that require information exchange of CLI-mitigation requests.*](#_Toc166256521)[*Proposal 11 If beam pairing is agreed to be supported, only support exchange of NCD-SSB measurement resource configuration.*](#_Toc166256522)[*Proposal 12 RAN1 should evaluate if the NCD-SSB and NZP CSI-RS information in the RRC MeasurementTimingConfiguration inter-node message adequately supports the purpose of CLI mitigation. If any essential information is deemed missing, RAN1 should identify any other RRC IE that could potentially include the missing information and consider incorporating them into the current MeasurementTimingConfiguration inter-node message.*](#_Toc166256523)[*Proposal 13 If beam pairing is agreed to be supported, do not specify exchange of recommended/non-recommended beams.*](#_Toc166256524)[*Proposal 14 For coordinated scheduling for time/frequency resources, RAN1 agrees to enhance the existing IE Intended TDD DL-UL Configuration NR to include semi-static cell-specific SBFD time and frequency location.*](#_Toc166256525)[*Proposal 15 If non-transparent UL resource muting is standardized, it should be ensured that it works well also for DFT-s-OFDM. Comb-2 RE muting could be a good compromise solution in terms of performance and impact to PAPR/CM.*](#_Toc166256526)[*Proposal 16 RAN1 to agree the proposed ZP PTRS that introduces minimal necessary modification to existing PTRS structure or configuration to enable efficient RE muting for SBFD gNB-gNB CLI and/or channel measurement. FFS: the time density and frequency density.*](#_Toc166256527)[*Proposal 17 Regardless of the UE-UE CLI mitigation schemes, it may be beneficial to leverage Rel-18 Positioning enhancements to identify position of UEs. This can help identify UEs at risk of causing or being affected by UE-UE CLI. Enhancing RSSI reports with positional data could aid in implementing effective UE-UE CLI mitigation strategies.*](#_Toc166256528)[*Proposal 18 RAN1 to reuse existing L3 based UE-UE CLI measurement with relevant enhancements for SBFD operation in measurement resources and reporting.*](#_Toc166256529)[*Proposal 19 If L1 based measurement reporting is agreed to be specified for UE-UE CLI measurement, prefer Alt2 or considerably minimize specification effort in Alt1 or Alt3.*](#_Toc166256530)[*Proposal 20 For UE-UE CLI mitigation schemes, do not support information exchange of SRS configuration and/or UE timing information.*](#_Toc166256531) |
| **ETRI** | ***Observation 2:*** *Timing alignment between the two gNBs for gNB-to-gNB CLI and/or channel measurement can be conducted at a low frequency.****Proposal 7:*** *For gNB-to-gNB co-channel CLI handling, at least gNB-to-gNB co-channel CLI and/or channel measurements should be supported.****Proposal 8:*** *For gNB-to-gNB co-channel CLI handling, at least coordinated scheduling in time and/or frequency should be further supported.****Proposal 9:*** *SSB dedicated to gNB-to-gNB co-channel CLI and/or channel measurements (e.g., NCD-SSB) can be considered.* |
| **Google** | ***Proposal 1:*** *Beam pairing and beam nulling are both supported and specified in Rel-19: Beam nulling for FR1 and beam pairing for FR2.****Proposal 2:*** *Information exchange of CLI-mitigation request and report via backhaul between the aggressor gNB and the victim gNB are supported.****Proposal 3:*** *Coordinate CSI-RS configurations between different gNBs to reduce impact on CLI estimation performance at the victim gNB.* ***Proposal 4:*** *Non-transparent UL resource muting is not supported for gNB-to-gNB co-channel CLI handling in Rel-19 as it increases the UE implementation complexity, the signalling overhead and has high specification impact.* |
| **Huawei** | ***Observation 1****: Beam nulling is beneficial to reduce the blocking at gNB sides.****Observation 2****: The specification impacts of beam pairing and beam nulling are similar, i.e., information exchange of measurement resource configuration and the normative work is mostly in RAN3.****Observation 3****: Transparent UL resource muting by either not scheduling certain UL symbols or based on muted REs in UL DMRS symbols is not flexible and very inefficient for gNB-to-gNB co-channel CLI handling which leads to worse performance, larger processing delay and/or increased memory requirements compared to non-transparent UL resource muting.* ***Observation 4****: UL resource muting based schemes is beneficial for SBFD and non-transparent UL resource muting based schemes can achieve larger gain than transparent UL resource muting based schemes.****Observation 5****: For CP-OFDM, UL resource muting does not have adverse impact on PAPR, no matter which the existing reference signal time-frequency resource pattern, e.g., PT-RS, CSI-RS, is reused.****Observation 6****: For DFT-s-OFDM, UL resource muting with com-2 pattern in frequency domain does not have adverse impact on PAPR.****Observation 7****: For DFT-s-OFDM, UL resource muting with com-2 pattern in frequency domain does not have any impact on transmit signal quality/MPR requirement.****Observation 8****: For DFT-s-OFDM, up to 2 symbols can be configured for UL resource muting for a PUSCH transmission in a slot.****Observation 9****: UL resource muting should be performed on the symbols except DMRS symbols of the PUSCH transmission.****Observation 10****: gNB can avoid configuring UL resource muting collide* *with PT-RS, or if UL resource muting is overlapped with PT-RS, PT-RS can be prioritized.****Observation 11:*** *The PUSCH transmission should perform rate matching on the UL muting resource.****Observation 12:*** *The UCI transmission multiplexing in PUSCH should perform rate matching on the UL muting resource.****Observation 13:*** *For the symbols with muted REs, power boosting should be performed on the unused REs of the PUSCH transmission to keep the total transmit power of these symbols with muting REs unchanged with symbols without muting REs.****Observation 14:*** *For the PUSCH transmission with UL resource muting, the TB size can be determined without excluding UL muting REs.****Proposal 1:*** *For gNB-to-gNB co-channel CLI handling, support beam nulling based scheme.** *Support information exchange of measurement resource configuration, i.e., periodic NZP CSI-RS.*

***Proposal 2:*** *Support CSI-RS overhead reduction considering the gNB-to-gNB channel characteristics:** *gNB-to-gNB channel has a larger coherent time than gNB-UE channel.*
* *gNB-to-gNB channel has a larger coherent bandwidth than gNB-UE channel.*

***Proposal 3:*** *For gNB-to-gNB co-channel CLI handling, support beam pairing based scheme.** *Support information exchange of measurement resource configuration, i.e., SSB and/or periodic NZP CSI-RS*

***Proposal 4:*** *For both gNB-to-gNB and UE-to-UE CLI handling, support information exchange of semi-static cell-specific SBFD time and frequency location configuration.****Proposal 5****: For gNB-to-gNB CLI handling, support non-transparent UL resource muting* * *For DFT-s-OFDM, support comb-2 pattern in frequency domain and up to 2 symbols in time domain*
* *For CP-OFDM, support {1, 2, 4} REs every {1, 2} RBs in frequency domain and up to 2 symbols in time domain*
 |
| **Interdigital** | [2.2 gNB-to-gNB CLI Handling]***Observation 15****. The gNB-to-gNB co-channel CLI mitigation can be based on spatial domain coordination, where the CLI measurement can be based on beam sweeping at both victim and aggressor gNBs.****Observation 16****. The victim gNB could monitor to detect one or more events to trigger gNB-to-gNB co-channel CLI measurement.****Proposal 14****. Support coordinated scheduling for gNB-to-gNB CLI handling, where at least semi-static time and frequency configuration are exchanged between gNBs.* ***Proposal 15****. In gNB-to-gNB co-channel CLI measurement and mitigation, support beam-pairing based spatial domain coordination, where the victim gNB measures beam-swept CLI and sends, to the aggressor gNB, information on the SSB index or the CRI of the aggressor beams with the highest and/or lowest CLI in addition to the measured CLI.****Proposal 16****. In gNB-to-gNB co-channel CLI measurement, support defining the events that may trigger the gNB-to-gNB CLI measurement.* |
| **Interdigital** | [2.2 gNB-to-gNB CLI Handling]***Observation 15****. The gNB-to-gNB co-channel CLI mitigation can be based on spatial domain coordination, where the CLI measurement can be based on beam sweeping at both victim and aggressor gNBs.****Observation 16****. The victim gNB could monitor to detect one or more events to trigger gNB-to-gNB co-channel CLI measurement.****Proposal 14****. Support coordinated scheduling for gNB-to-gNB CLI handling, where at least semi-static time and frequency configuration are exchanged between gNBs.* ***Proposal 15****. In gNB-to-gNB co-channel CLI measurement and mitigation, support beam-pairing based spatial domain coordination, where the victim gNB measures beam-swept CLI and sends, to the aggressor gNB, information on the SSB index or the CRI of the aggressor beams with the highest and/or lowest CLI in addition to the measured CLI.****Proposal 16****. In gNB-to-gNB co-channel CLI measurement, support defining the events that may trigger the gNB-to-gNB CLI measurement.* |
| **Lenovo** | CLI/channel measurement (inter-gNB CLI)*Observation 2-1: RAN1 is spending a disproportionate amount of the limited time on non-transparent UL resource muting, which is merely an optimization for inter-gNB CLI measurements. Meanwhile, important discussions on how to use the measurements for CLI mitigation is not sufficiently discussed, which inevitably will lead to leaving it to proprietary signalling, which is highly undesirable.**Proposal 2-1: Do not support inter-gNB CLI measurement optimizations such as non-transparent UL resource muting until RAN1 decides how the CLI measurements are to be used. It is strongly discouraged to leave CLI mitigation to proprietary signalling.**Proposal 2-2: Consider downlink reference signals such as NCD-SSB and CSI-RS for inter-gNB CLI measurement. Further consider SRS transmission by gNBs for unified CLI/ICI measurement by gNBs and UEs.**Proposal 2-3: Specify inter-gNB signalling for exchanging information of the reference signals for inter-gNB CLI measurements.**Observation 2-2: Victim-side CLI mitigation does not require further inter-gNB signalling. However, victim-side CLI mitigation alone may be too constraining for scheduling and beamforming.**Proposal 2-4: Specify further inter-gNB signalling to enable aggressor-side CLI mitigation. The information exchanged can include high-interference beams and the amount of excess CLI.**Proposal 2-5: Study inter-gNB over-the-air (OTA) signalling as a low-latency alternative to complement backhaul information exchange.**Proposal 3-1: In order for each gNB to have a chance to measure CLI from any other gNB in its vicinity, support gNB-specific patterns for transmitting SSBs dedicated to CLI measurements. The SSBs can be configured as NCD-SSB.**Proposal 3-2: If SSB (CD or NCD) is used for gNB-to-gNB CLI measurements, the issue with timing misalignment at the victim gNB between SSB reception from aggressor gNBs and UL reception from served UEs can be handled by implementation.**Observation 3-1: Periodic RS (such as NZP CSI-RS and SSB) are not optimal for gNB-to-gNB CLI measurements. Using periodic RS without enhancements is wasteful and not easily scalable, especially for beam-based CLI measurement at FR2.**Proposal 3-3: Study enhancements to periodic RS for resource efficiency, scalability, and flexibility of gNB-to-gNB CLI measurement. Consider gNB-specific patterns of RS transmission and CLI measurement.**Proposal 3-4: Support exchange of reference signal configuration information among gNBs for the purpose of inter-gNB CLI measurement.* *Proposal 3-5: Support victim gNB indicating high-interference (non-preferred) beams to the aggressor gNB or the core network. Additionally, support the victim gNB reporting the amount/level of excess interference corresponding to the high-interference beams.**Proposal 3-6: Support victim gNB indicating preferred and high-priority Tx beams to the aggressor gNB.**Proposal 3-10: Study and address Tx-Rx antenna mismatch in order to enable aggressor-side CLI measurements. For example, apply correction to the measured CLI to take the antenna mismatch into account or transmit additional downlink reference signals from the full-duplex antennas.**Proposal 3-11: Study unified inter-cell CLI handling through transmitting SRS by aggressor gNB/UE and measuring interference by victim gNB/UE.**Proposal 3-12: Support assigning priorities to victim gNBs so that the aggressor gNB will be able to limit or avoid the CLI towards at least high-priority victim gNBs.**Proposal 3-13: The impact on the PUSCH reception when receiving CLI measurement RS can be solved by gNB implementation.*Coordinated scheduling and beamforming (inter-gNB CLI)*Observation 2-3: Dynamic inter-gNB coordination for scheduling and beamforming over the backhaul is impractical with the current backhaul implementations.**Proposal 2-7: RAN1 to specify inter-gNB signalling that allows the gNBs to coordinate on resource configuration and beamforming with backhaul signalling that may experience latencies in the scale of tens of milliseconds or longer.**Observation 2-4: The agreement in RAN1#116-bis on beam nulling was a mere result of insufficient discussion on the subject. Exchanging information of reference signals is absolutely insufficient for beam nulling. We strongly discourage leaving the rest of the beam nulling to inter-gNB proprietary signalling.**Proposal 2-8: Specify backhaul information exchange for beam and resource coordination among gNBs.** *Example 1: Indication of downlink beam usage from aggressor gNB to victim gNB.*
* *Example 2: Matching DL/UL resource configurations on select slots among nearby cells.*

*Proposal 2-9: Specify OTA signalling to complement backhaul information exchange for beam and resource coordination at lower latencies.**Proposal 3-7: Further study inter-gNB CLI handling by aggressor gNBs selection.**Proposal 3-8: Support aggressor gNB indicating information of using high-interference beams to victim gNBs.**Proposal 3-9: To enable coordinated scheduling/beamforming, support coordination/matching of DL/UL on certain slots/symbols for use of high-interference beams.* *This information can be exchanged by adding spatial parameters to the Intended SBFD/TDD Configuration IE.* |
| **LG** | *Observation 1. following metric is used to compare UL resource muting schemes** *UL latency and/or throughput*
* *Signaling overhead to indicate UL resource muting*
* *Timing alignment of uplink reception timing from the UE and the aggressor gNB*
* *Potential impact on UL channel estimation*

*Observation 2. For gNB-to-gNB co-channel CLI and/or channel measurement, transparent UL resource muting can be enabled by following methods** *gNB scheduling (i.e., not scheduling)*
* *UL CI(uplink cancellation indication) introduced in Rel-16 URLLC*
* *Muting CDM group of DMRS*

*Observation 3. Muting CDM group of DMRS for transparent UL resource muting has following pros and cons** *UL latency is not increased and UL throughput is not reduced due to muted resource*
* *No additional signaling overhead*
* *Uplink reception timing from the UE and the aggressor gNB needs to be aligned*
* *UL channel estimation may be degraded due to the Tx power difference of UE and gNB*

*Observation 4. The listed potential specification impacts are not influenced by whether the existing reference signal time-frequency resource pattern is used for UL resource muting pattern or not.**Proposal 1. For gNB-to-gNB co-channel CLI and/or channel measurement, non-transparent UL resource muting can be enabled by following methods** *Part or whole of existing reference signal (PTRS) is muted*
* *Specific group of REs are muted*

*Observation 5. Zero-power PTRS for non-transparent UL resource muting has following pros and cons** *UL latency is not increased and UL throughput is not reduced due to muted resource*
* *Additional signaling overhead to activate/deactivate UL resource muting is negligible*
* *Uplink reception timing from the UE and the aggressor gNB does not need to be aligned*
* *UL channel estimation is degraded due to the absence of PTRS for FR2*

*Proposal 2. For gNB-to-gNB co-channel CLI and/or channel measurement, if non-transparent muting is supported,** *Existing reference signal(zero-power PTRS) has minimum specification impact*
* *Non-transparent muting is semi-static event*

*Proposal 3. For spatial domain-based solution for gNB-to-gNB CLI handling, both beam nulling and beam pairing are supported.**Proposal 4. For the signaling of information exchange of measurement resource configuration to support beam nulling, intended TDD DL-UL configuration is considered as baseline.**Proposal 5. For the information exchange recommended/not-recommended DL beam information and associated resource configuration, restricted and recommended beam indication for IAB is considered as baseline.**Proposal 6. For gNB-to-gNB CLI handling and UE-to-UE co-channel CLI handling, coordinated scheduling is supported** *For the signaling, intended TDD DL-UL configuration is considered as baseline.*
	+ *The SBFD time and frequency location configuration are included*
 |
| **MediaTek** | ***Observation 10:*** *Muting the first symbol in a SBFD slot succeeding a DL-only slot avoids the resource overlap between uplink and downlink resources. This removes the possibility of any uplink transmission on the SBFD slot interference with downlink reception on the DL-only slot.****Proposal 8:*** *Do not support non-transparent UL resource muting for gNB-to-gNB CLI measurement.* |
| **NEC** | ***Observation 1:****Power control enhancements may have different requirements for different use case** *UEs performing UL Tx during SBFD symbols may be required to increase their Tx power to counter the gNB self-interference.*
* *UEs may also be required to increase their Tx power when gNB is experiencing large CLI from neighbor gNBs DL transmissions.*
* *For UE-UE CLI handling, Tx power reduction is required for interfering UEs (without significantly affecting their throughput performance).*

***Observation 2:**** *Exact impact of some proposals on the tables presented in R1-240635*

***Proposal 1:*** *Consider single-port CSI-RS per TRP as the baseline for CSI-RS configuration exchange between the gNBs for CLI measurement.** *Different TRPs of a gNB can use different ports of the same CSI-RS resource.*

***Proposal 2:*** *Different gNBs can share the same set of CSI-RS resources for CLI measurements but using different non-CDMed ports.* ***Proposal 3:*** *Consider aperiodic or semi-persistent CSI-RS and periodic CSI-RS for gNB-gNB CLI measurements.* ***Proposal 4:*** *Support non-transparent UL rate matching/puncturing procedures at least for CLI measurement for periodic CSI-RS.****Proposal 5:*** *Consider the following approaches for indicating the puncturing/rate matching resources to Ues.** *Option 1: A new RS type, e.g., zero power (ZP) SRS, can be configured to the UE for rate-matching resources which follow the CSI-RS resource pattern.*
* *Option 2: Puncturing resources (pattern-based) can be configured to the UE.*
* *Option 3: ZP-CSI resources, which are applied for rate-matching UL transmissions, are defined.*

***Proposal 6:*** *Define CLI threshold level as a measurement metric for gNB-gNB CLI measurements. In which different channels will require different CLI thresholds to continue transmission.* ***Proposal 7:*** *Support at least beam nulling based mechanism for inter-gNB coordination. Support the following mechanism for beam nulling:** *Victim gNB performs CLI measurements and shares the list of interfering/preferred beams with the aggressor gNB along with any additional assistance information.*
* *The aggressor gNB takes corrective action based on the provided information.*

***Proposal 8:*** *For beam nulling, specify information exchange of interfering or non-preferred beams measured by victim gNB for inter-gNB coordination.* ***Proposal 9:*** *The following information exchange between gNB is supported for coordinated inter-gNB scheduling.* * + *Semi-static DL beam scheduling information of victim/aggressor gNB*
	+ *DL transmission power information of aggressor gNB*

***Proposal 10:*** *For inter-gNB CLI mitigation, gNBs exchange the UL subband frequency resource configuration and SBFD time occasions with each other.****Proposal 11:*** *For inter-gNB CLI mitigation, gNBs exchange RO PRB locations with each other in case neighbours are willing to help in the RO process by self-muting.****Proposal 12:*** *aggressor gNB obtains the PRB information of victim gNB UL and can choose to self-mute.* ***Proposal 13:*** *In the information exchange for CLI, the current gNB SBFD status should be exchanged to allow for greater CLI performances.* |
| **New H3C** | *Proposal 1 Besides SBFD time/frequency configurations, other configurations such as frame structure, SSB, CSI-RS, PxSCH DMRS and time domain allocation, and so on should be exchanged between gNBs. The information exchange among several gNBs can be handled by a central controller. The central controller can be a CU, a master gNB, or OAM.**Proposal 2: The NZP-CSI-RS used for CLI measurement can be periodic, aperiodic or semi-persistent.**Proposal 3: The NZP-CSI-RS for different aggressor gNBs should be different, and the configuration of the NZP-CSI-RS should be exchanged between gNBs by Xn interface, or handled by a central controller.**Proposal 4: Both options on the transparent/non-transparent UL resource muting method should be considered, different options can be used in different cases. Comparing with transparent UL resource muting, the non-transparent UL resource muting achieves better UL performance.**Proposal 5: In victim gNB, the PRACH/PUCCH/SRS should not use any resource that are overlapping with CSI-RS for CLI measurement, the PUSCH can perform rate matching around CSI-RS for CLI measurement.**Proposal 6: A measurement window can be introduced for improving the energy efficiency of the victim gNB. For the victim gNB, it can only measure the CLI measurement signals in the measurement windows, and ignore all the CLI measurement signals out the range of the measurement windows. Several measurement window can be configured, but only one is active. The measurement window is periodic, and its position is determined by the length, periodicity and offset.**Proposal 7: The reported CLI results can be short term or long term. The report can be full report or partial report, and can be event-triggered or periodic.**Proposal 8: The beam information exchange can be handled by a central controller. The beam information consists of gNB ID+CLI measurement configuration which including the signal resource ID.* *Proposal 9: For CSI-RS for CLI measurement, a dedicated indication, such as cli-info, can be introduced in the CSI-RS resource configuration to indicate the usage of this CSI-RS resource.**Proposal 10: The CLI results of all beams should be reported in full report mode, while both preferred beam set and non-preferred beam set are reported in partial report mode. The periodic or event-triggered report can be also used for the beam based CLI report.**Proposal 11: The central controller determines the non-preferred beam or preferred beam for aggressor gNB according to the dedicated algorithms. The number of the non-preferred beam for one aggressor gNB should not exceed a maximum number.**Proposal 12: A restriction window can be introduced, where the aggressor gNB cannot use the non-preferred beams, but the victim gNB can use any beam. Several restriction window can be configured, but only one is active. The measurement window is periodic, and determined by the length, periodicity and offset.**Proposal 13: The new RAN measurement abilities should be introduced for supporting the CLI measurement and reporting: CLI-RSSI and/or CLI RSRP.* |
| **Nokia** | [*Proposal 1: Prioritize the gNB-to-gNB co-channel CLI and channel measurements, time/frequency coordination, spatial coordination as the candidate schemes for the gNB-to-gNB CLI handling.*](#_Toc166244917)[*Proposal 2: Extend the existing* Intended TDD-DL-UL Configuration NR *to support the exchange of SBFD time and frequency configuration.*](#_Toc166244918)[*Observation 1: For adjacent channel inter-site gNB-gNB CLI handling with intra-operator deployment, exchange of semi-static time and frequency information of SBFD slots can be supported.*](#_Toc166244919)[*Observation 2: For TX beam nulling, Alt 2 is efficient only when channel reciprocity is supported for both victim and aggressor gNBs. Alt 2 can be supported for RX beam nulling.*](#_Toc166244920)[*Observation 3: TX beam nulling using the gNB-to-gNB channel obtained from DL-to-DL subbands decreases the impact of the direct interference, and by extension, the impact of the leakage to the UL subband.*](#_Toc166244921)[*Proposal 3: Support TX Beam nulling based on gNB-to-gNB CLI measurement. Also, support Xn/F1 signaling for victim gNB to inform CLI level to strong aggressor gNBs.*](#_Toc166244922)[*Observation 4: Beam nulling at the victim gNB (Rx beam nulling) can also help handling the gNB-to-gNB CLI based on gNB-to-gNB CLI measurement. No further specification impact is expected other than CLI measurement.*](#_Toc166244923)[*Observation 5: The applicability of beam nulling to combat adjacent channel interference is unclear due toto the fact that gNBs measurements should occur across carriers.*](#_Toc166244924)[*Observation 6: The NZP-CSI-RS information exchange over the Xn/F1 interface should be enable both beam pairing and beam nulling.*](#_Toc166244925)[*Observation 7: Victim gNB should perform per-beam CLI measurements with all possible combinations of aggressor Tx beams and victim Rx beams.*](#_Toc166244926)[*Proposal 4: Xn/F1 interface to be used to exchange the needed information to enable beam pairing.*](#_Toc166244927)[*Proposal 5: As part of the reporting over the Xn/F1 interface, victim gNBs should include the Rx beam ID, Tx beam ID and measured CLI level.*](#_Toc166244928)[*Proposal 6: Study the possibility of exchanging beam-usage information as part of the* Intended TDD dL-UL configuration](#_Toc166244929)[*Observation 8: The applicability of beam pairing to combat adjacent channel interference is unclear due toto the fact that gNBs measurements should occur across carriers.*](#_Toc166244930)[*Observation 9: Aggressor gNB symbol-level DL muting over neighbour cell UL DMRS helps the UL channel estimation at the victim gNB*](#_Toc166244931)[*Proposal 7: If DL muting is supported, introduce additional exchange of information between cells to coordinate the DMRS and muting resources.*](#_Toc166244932)[*Observation 10: Non-transparent muting with ZP-SRS pattern has big specification impact as well as the UL performance degradation due to non-linearity at the UE’s RF chain. The equivalent pattern can be supported by transparent gNB scheduling method by using DMRS with single CDM group and the number of CDM group without data to be 2.*](#_Toc166244933)[*Observation 11: PT-RS like pattern introduce high complexity in both UE and gNB because its pattern is dependent on the scheduling parameters (MCS, bandwidth) and UE capabilities. Also, the frequency domain density is too low to obtain correct interference measurement.*](#_Toc166244934)[*Proposal 8: UL muting based transparent method is supported without RAN1 specification impact. FFS: inter-gNB signalling for exchange of DMRS configurations.*](#_Toc166244935)[*Proposal 9: NCD-SSB and NZP-CSI-RS are preferred for CLI measurement purposes.*](#_Toc166244936)[*Proposal 10: gNB-to-gNB CLI/channel measurements occur over the configured CLI-RS resources. Measurements of leakage CLI is not preferred given its complexity and lack of aggressor gNB identification.*](#_Toc166244937)[*Proposal 11: gNB-to-gNB CLI measurements should be based on RSRP. The existing definition of SS-RSRP and CSI-RSRP should be re-used for gNB-to-gNB CLI measurements.*](#_Toc166244938)[*Observation 12: Additional exchange of messages, e.g., CLI-mitigate Request/Response, may reduce the gNB complexity and measurement overhead by triggering CLI measurement only when necessary.*](#_Toc166244939) |
| **NTT DOCOMO** | ***Proposal 1:*** *Semi-static information exchange for spatial domain CLI handling i.e., beam nulling and beam pairing should be supported.****Proposal 2:*** *Non-transparent UL resource muting scheme should not be supported.****Proposal 3:*** *Information exchange of semi-static cell-specific SBFD time and frequency location configuration should be supported.* |
| **OPPO** | *For gNB-to-gNB co-channel CLI handling:* *Proposal 5: To support coordinated scheduling between gNBs, SBFD time/frequency configuration that is exchanged over Xn/F1 has periodicity up to 160ms.**Proposal 6: Both Tx-beam nulling and Rx-beam nulling are considered in spatial-domain based CLI handling schemes.** *CLI mitigation request-and-response handshake signaling helps both to work jointly and efficiently.*

*Proposal 7: Support transparent UL resource muting for inter-gNB CLI measurement.* |
| **Samsung** | *Proposal 1: For gNB-to-gNB CLI handling, prioritize spatial domain based schemes.**Proposal 2: For gNB-to-gNB CLI handling based on spatial domain schemes, support Alt.2.**Proposal 3: For gNB-to-gNB CLI handling based on spatial domain schemes, no new/additional gNB-side measurements are specified in 38.215.**Proposal 4: For gNB-to-gNB CLI handling based on spatial domain schemes, support a 2-way signaling exchange over Xn/F1 to indicate recommended/restricted beams based on RS resource ID.**Proposal 5: For gNB-to-gNB CLI measurement support information exchange of measurement resource configuration (SSB, NZP CSI-RS).**Proposal 6: Non-transparent UL resource muting is not supported for interference covariance matrix measurement for gNB-to-gNB CLI handling.**Proposal 7: For gNB-to-gNB co-channel CLI handling, support 1-way indication of the intended SBFD cell-common configuration over Xn/F1* |
| **Sony** | *Proposal 1: Support using CD-SSB, NCD-SSB and CSI-RS for gNB-gNB measurement and the exchange of their configurations among gNB.* *Proposal 2: For UL resource muting to improve gNB-gNB CLI measurements, use non-transparent UL resource muting, where the gNB semi-statically configures one or more RE muting patterns (following existing RS, such as PT-RS, SRS and CSI-RS) for the UE, i.e., the UE is aware of which REs are muted.**Proposal 3: The gNB dynamically enables/disables RE muting for an UL/DL transmission and if multiple RE patterns are configured, the gNB indicates which RE muting pattern to apply in the dynamic grant.**Proposal 4: RE muting on REs containing gNB RS is conditional upon the transmission parameters, such as the L1 priority or MCS of the UL transmission.**Proposal 5: Support OTA gNB-gNB signaling to exchange dynamic scheduling information such as L1 priority among gNBs.* *Proposal 6: The L1 priority OTA indicator uses CSI-RS, and can be implemented using the following two options:** *Option 1: A WUS-like indicator, where the presence and absence of the CSI-RS L1 priority OTA indicator, indicate whether the gNB has a High L1 priority reception or not, in NL1 slots after the transmission of the OTA indicator.*
* *Option 2: Two CSI-RS are used where:*
	+ *A 1st CSI-RS sequence indicates that the gNB has a High L1 priority reception in NL1 slots after the transmission of the OTA indicator*
	+ *A 2nd CSI-RS sequence indicates that the gNB does not have any High L1 priority reception in NL1 slots after the transmission of the OTA indicator*

*The configuration of NL1 value is exchange between gNBs**Proposal 7: Beam nulling can be supported together with L1 priority OTA indication.**Proposal 8: Beam pairing is not practical over a slow gNB-gNB interface and is not considered further.* |
| **Panasonic** | *Proposal 1: For UL muting resource for gNB-to-gNB CLI measurement, transparent UL resource muting method should be sufficient.* *Proposal 2: For gNB-to-gNB/UE-to-UE CLI handling, exchange of SBFD time and frequency configuration over Xn/F1 interfaces should be support.* |
| **Qualcomm** | *Observation 4: Transparent UL muting via gNB scheduling or ULCI can achieve the benefits for gNB-to-gNB co-channel CLI measurement, channel measurement already. Whether there is benefit for introducing non-transparent UL resource muting needs further discussion:** *A cell can contain legacy Ues and SBFD aware Ues and if there is a gain, the gain is only for SBFD aware Ues but not legacy Ues.*
* *RAN1 needs to take into consideration impact on UL waveform in terms of increased PAPR and phase discontinuity across PUSCH symbols in non-contiguous UL transmissions caused by introducing non-transparent UL resource muting.*
* *RAN1 needs to take into consideration both spec impact and UE HW/SW complexity for supporting different UL procedures in non-contiguous UL transmissions caused by introducing non-transparent UL resource muting.*
	+ *The indication of the muting pattern*
	+ *Mapping to virtual resources for PUSCH*
	+ *UCI resource determination*
	+ *Configuration and definition of UL-muting pattern*
	+ *Collision with PTRS and/or DMRS*

*Proposal 15: Propose certain changes related to gNB-to-gNB co-channel CLI and/or channel measurement related to Proposal 2-2a (gNB-gNB CLI handling) in R1-2401635:** *Change 1): gNB-to-gNB co-channel CLI and/or channel measurement can be achieved by transparent UL resource muting. And if non-transparent UL muting is applied, then spec impact will be discussed.*
* *Change 2): In addition, we suggest removing last two bullets in potential spec impact column, which shall belong to spatial domain scheme.*
* *Change 3): UCI resource determination shall also be captured under potential spec impact for non-transparent UL resource muting. And similar bullets shall be captured for operational details on UE implementation complexity.*

*The suggested edits are highlighted in yellow:*

|  |  |  |  |
| --- | --- | --- | --- |
| gNB-to-gNB co-channel CLI and/or channel measurement | * If non-transparent UL resource muting is applied, e.g., comb-2 RE-level or RB level UL resource muting pattern for PUSCH including indication of the muting pattern, potential impact on PUSCH rate-matching, UCI resource determination and power allocation, collision handling with DMRS/PTRS
* Information exchange of channel measurement
* Reference signals for channel measurement
* Information exchange of measurement resource configuration (NZP CSI-RS/NCD-SSB)
* ~~Information exchange of DL beam indication~~
* ~~Information exchange of preferred/restricted DL beam information and associated resource configuration~~
 | **Section 7.4.2.2.3 of TR38.858**- Non-Transparent UL resource muting based IRC assuming UL OH: 1 symbol and DL OH: 1 symbol has similar mean DL Average-UPT for low and medium load level, lower mean DL Average-UPT for high load level and higher or similar 5% DL Average-UPT for all load levels. - Non-Transparent UL resource muting based IRC assuming UL OH: 1 symbol and DL OH: 1 symbol has higher mean UL Average-UPT and similar 5% UL Average-UPT for all load levels. | * Beneficial for leakage interference suppression
* Increase UE implementation complexity, e.g. rate matching, power allocation, UCI resource determination, collision handling with DMRS/PTRS
* Increased PAPR for DFT-S-OFDM for some UL resource muting patterns

Note: If gNB-to-gNB co-channel CLI and/or channel measurement is used as an enabler for spatial domain based schemes, the operational details for those schemes also applies.  |

*Proposal 16: Support following schemes in the table:** *Spatial domain based schemes: Tx/Rx beam nulling, beam pairing*
* *gNB-to-gNB co-channel CLI and/or channel measurement, with transparent UL resource muting*
* *Coordinated scheduling in time and frequency domain*
* *UE power control based scheme*

*Proposal 17: Support to specify information exchange between gNBs of NZP CSI-RS and/or SSB resource configurations for gNB-to-gNB co-channel CLI/channel measurement.**Proposal 18: Not support RAN1 to introduce non-transparent UL muting for inter-gNB CLI measurement. Transparent UL muting without spec impact can already achieve the purpose for inter-gNB CLI measurement.**Proposal 19: Support to specify information exchange between gNBs on semi-static SBFD time and frequency configuration.**Proposal 20: For spatial domain coordination, support to specify the information exchange of beam related information among gNB(s) (e.g., victim gNB(s) and aggressor gNB(s)) for inter-gNB co-channel CLI management.** *Support to specify example 2 (from victim gNB to aggressor gNB), preferred/restricted DL beam and associated resource configuration, beam based inter-gNB co-channel CLI measurement result from victim gNB*

*For spatial domain enhancement of gNB-to-gNB co-channel CLI handling, DL Tx beam information of the gNB can be exchanged between gNBs. Reference signal resource ID (e.g., NZP-CSI-RS resource ID, SSB index) can be used as beam information exchange between gNBs.**Proposal 21: Inter-gNB CLI can be mitigated by coordinating and configuring slot-specific power control parameters for slots with CLI and without CLI** *For SBFD, power control parameters configured for SBFD slots can be different from those configured for HD slots.*
* *For dynamic TDD, power control parameters configured for slots where the two cells have different traffic direction can be different from those configured for slots with aligned traffic directions in the two cells.*
* *Support to specify semi-static configured PC parameters with less overhead.*
 |
| **Spreadtrum** | *Proposal 1: Transparent UL resource muting is preferred compared to non-transparent UL resource muting.**Proposal 2: For the Alt2 of beam nulling based scheme, feasibility and practicability of antenna panel mapping relationship change and dedicated period for measurement should be comprehensively considered before down-selection.**Proposal 3: For beam pairing based scheme, clarification on information exchange of associated resource configuration is needed.**Proposal 4: RAN1 needs to study and guide the normative work on information exchange among gNBs to RAN3.**Proposal 5: Spatial domain based CLI handling schemes can be considered in Rel-19.**Proposal 6: Coordinated scheduling based gNB-to-gNB CLI handling schemes can be considered in Rel-19.* |
| **Tejas Networks** | *Proposal 8: Comb-2 SRS like muting pattern can be adapted to enable RE level UL resource muting for non-transparent UL resource muting scheme.**Proposal 9: Rate matching around the muted RE’s should be used instead of puncturing the input symbols.**Proposal 10: specify the time location of UL symbol(s) with RE muting relative to DMRS symbol(s) location to avoid collision with DMRS symbol(s).**Proposal 11: In case of PTRS collision with RE muting, prioritize PTRS over RE muting. FFS: Impact on PAPR due to prioritization of PTRS over RE muting.**Proposal 12: Further study the requirement for more than one UL symbol with RE muting to estimate the gNB-gNB CLI accurately.**Proposal 13: Consider the following as the additional specification impact for beam nulling based on steering vector between gNB-gNB.* *• Enhanced measurement resource configuration based on NZP CSI-RS/NCD-SSB.**• Enhanced measurement report.**• Information exchange of measurement report configuration including CLI measurement window and periodicity, RSRP/RSRQ, DL beam indication.**Proposal 14: Consider Alt-2 (gNB-A performs measurement on the RS transmitted from gNB B and identifies the beam-ID) for CLI measurement.**FFS: Impact of Alt-2 on micro gNB as a victim**Proposal 15: Enhance measurement and reporting configuration using NZP-CSI-RS and/or SSB to include aggressor gNB information.**• FFS: The exact details of aggressor gNB information to be included in measurement configuration.**Proposal 16: CLI measurement for spatial domain coordination can be periodic or aperiodic.* *• FFS: Periodicity of CLI measurement & reporting.**Proposal 17: Consider the following as the additional specification impact for beam nulling based on channel measurement between gNB-gNB.**• Reference signal for measurement of CLI* *• Information exchange of channel measurement associated cell-id’s**• Information exchange of CLI-mitigation request and indication**Proposal 18: Consider the following as a potential specification impact for transparent UL resource muting.**• Signaling of assistance information for interference/channel estimation over Xn interface.**• Signaling of DL muting pattern to eliminate contamination of UL DMRS.**• Signaling of DL muting pattern to UE for de-ratematching.**Proposal 19: Consider the following as a potential additional specification impact for non-transparent UL resource muting.**• Signaling of assistance information for interference/channel estimation over Xn interface.**• Signaling of DL muting pattern to eliminate contamination of UL DMRS.**• Signaling of UL muting pattern to eliminate the contamination of DL DMRS.**Proposal 20: For gNB-gNB CLI handling, both the UL resource muting scheme and the spatial domain coordination scheme should be considered.**Proposal 21: Beam nulling scheme based on steering vector should be prioritized.**Proposal 22: Considering specification impact and UE complexity, transparent-based UL resource muting methods can be considered under UL resource Muting Mode-1.**Proposal 23: Considering the UL throughput gain of the non-transparent UL muting compared to transparent UL muting , non-transparent UL muting should be considered as UL Muting Mode-2.* *Proposal 24: Non-transparent UL muting should be prioritized over transparent muting.* |
| **Transsion Holdings** | *Proposal 3: For beam nulling schemes, information exchange of channel measurement, and information exchange of CLI-mitigation request among aggressor gNBs and victim gNBs should be specified.* |
| **Xiaomi** | *Proposal 14: If gNB-to-gNB measurement and reporting is supported, periodic reporting for gNB-to-gNB CLI mitigation should be supported.**Observation 2: The gNB-to-gNB CLI level may be varied among different Tx-Rx beam pairs.**Proposal 15: Both Option 1 and Option 2 can be considered for gNB-to-gNB CLI mitigation.* *Proposal 16: The key point of spatial domain enhancement for gNB-to-gNB CLI handling is information exchange between victim gNB and aggressor gNB, which has no RAN1 specification impact.*  |
| **ZTE** | *Proposal 2: A common understanding of the overall framework of gNB-to-gNB CLI handling should be clarified firstly.**Observation 1: For CLI handling, the specification impacts include the configuration and exchange of measurement resource, measurement results exchange, and the CLI feedback between the gNBs.* *Proposal 3: Rel-19 SBFD should support the following framework for CLI management,* * *Step 0: The victim gNB identifies gNB-to-gNB CLI based on measurement of reference signal from the aggressor gNB (e.g., SSB, CSI-RS or other measurement resource);*
* *Step 1: The victim gNB indicates interference information identified from Step 0, e.g., index of high-interference beam, channel state information for the interference channel, etc, to the aggressor gNB via either air interface or backhaul;*
* *Step 2: The aggressor gNB and/or victim gNB start to perform CLI handling schemes;*
* *Step 3: The victim gNB measures the reference signals sent by the aggressor gNB to evaluate the CLI handling effect;*
* *Step 4: The victim gNB feedbacks the CLI mitigation effect of the different CLI handling schemes.*

*Proposal 4: For gNB-to-gNB co-channel CLI measurement, both RSRP measurement and RSSI measurement should be supported.* * *The existing measurement resource configuration for SSB/CSI-RS based RRM can be applied as baseline for gNB-to-gNB co-channel RSRP measurement.*
* *The existing configuration of RSSI measurement resource can be applied as baseline for gNB-to-gNB co-channel RSSI measurement.*

*Proposal 5: For inter-gNB co-channel inter-subband CLI, the following measurement methods should be supported,* * *Method 1: victim gNB measures RSSI of aggressor gNB within UL subband*
* *Method 2: victim gNB measures RSRP of aggressor gNB within DL subband*

*For inter-gNB co-channel intra-subband CLI, victim gNB measures RSRP/RSSI of aggressor gNB within UL subband.* * *Note: if RSSI measurement is used, the measurement result also includes inter-gNB co-channel inter-subband CLI.*

*Observation 2: The existing CSI-RS can be configured with up to 32 ports, which is not sufficient for the gNB-to-gNB co-channel channel measurement for gNBs equipped with 64 antenna ports in the practice.**Proposal 6: In order to perform the gNB-to-gNB co-channel channel measurement for CLI handling for gNBs equipped with 64 antenna ports, support to group two 32-port CSI-RS resources, which is similar to the CSI-RS pairing defined in Rel-17 Multi-TRP CSI.** *It is also noted that CSI resource with up to 128 ports will be specified in Rel-19 MIMO enhancements.*

*Observation 3: Based on the field test, a clear timing difference is observed between the symbol boundary and the arrival time of the reference signal received at the victim gNB for gNB-to-gNB co-channel CLI measurement and/or channel measurement.**Proposal 7: RAN1 further discusses potential solutions to address the timing misalignment issue for gNB-gNB CLI measurement.* *Proposal 8: Non-transparent UL resource muting is supported for gNB-to-gNB CLI measurement for gNB-to-gNB CLI handling** *CSI-RS-like pattern should be supported.*

*Proposal 9: Regarding UL resource muting pattern, a certain guard band need to be reserved around the measurement resources for avoiding adjacent frequency interference (e.g., leakage from the adjacent RBs).* *Observation 4: Beam pairing can bring significant UL UPT gains with acceptable DL UPT losses for cell edge UEs under different RU cases.* *Proposal 10: Support beam pairing for spatial domain coordination of gNB-to-gNB CLI handling.**Observation 5: Beam nulling can significantly reduce the co-channel blocking interference by more than 10 dB.* *Observation 6: Beam nulling can bring clear UL UPT gain for cell edge UEs for all RU cases for both SBFD and dynamic TDD.* *Proposal 11: Support beam nulling for spatial domain coordination of gNB-to-gNB CLI handling.**Observation 7: The scheduling mechanism can be optimized for interference mitigation if the related configuration (e.g., SBFD time/frequency, dynamic TDD) of the neighbouring gNB is obtained.* *Observation 8: The gNB-to-gNB CLI can be accurately measured and effectively coordinated only after the related configuration (e.g., SBFD time/frequency, dynamic TDD) of the neighbouring gNB is obtained.* *Proposal 12: The related configuration (e.g., SBFD time/frequency, dynamic TDD) exchange among gNBs should be supported for more accurate CLI measurement and more effective CLI handling.* |
| **Vivo** | *Proposal 1: For gNB-to-gNB co-channel CLI handling, beam nulling based on gNB-gNB channel measurement can be supported.**Proposal 2: For gNB-to-gNB co-channel CLI handling, beam pairing based on gNB-gNB channel measurement can be supported.**Proposal 3: For gNB-to-gNB co-channel CLI handling, non-transparent UL resource muting based scheme is not preferred.**Proposal 4: Coordination on SBFD configuration between gNBs can be supported for gNB-to-gNB co-channel CLI handling.* |
| **WILUS** | *Proposal 1: For UE non-transparent UL muting for gNB-to-gNB co-channel CLI handling, UE behaviours on UL muting resources should be further investigated with respect to the UL signal/channel and PHY priority.* |

* 1. **Summary**

Companies shared their views on gNB-to-gNB co-channel CLI handling schemes. Based on the companies’ input, spatial domain based schemes, coordinated scheduling in time and/or frequency and gNB-to-gNB co-channel CLI and/or channel measurements were discussed. For discussion in this meeting, moderator recommends to focus on the down-selection of CLI handling schemes taking into account the guidance concluded in RAN1#116 and RAN1#116bis.

* + 1. **Spatial domain based schemes**

Two kinds of spatial domain solutions are discussed: beam nulling and beam paring.

* **Beam nulling**

In this meeting, beam nulling are proposed by **CATT, CMCC, Ericsson, Google, Huawei, LG, NEC, Nokia, NTT DOCOMO, OPPO, Samsung, Sony, Tejas Networks, Transsion Holdings, Spreadtrum, Xiaomi, ZTE, Vivo**.

Among these companies, most company propose to consider Tx beam nulling. While, **Deutsche Telekom proposes that** in order to avoid coverage reduction, TX beam nulling is not the preferred CLI reduction technique.

In addition to Tx-beam nulling, **Nokia** **and** **OPPO** also propose to consider Rx-beam nulling. While, **Nokia** thinks no further specification impact is expected other than CLI measurement for Rx-beam nulling.

**Lenovo** proposes to study and address Tx-Rx antenna mismatch in order to enable aggressor-side CLI measurements. Apply correction to the measured CLI to take the antenna mismatch into account or transmit additional downlink reference signals from the full-duplex antennas.

**Enhancement of Measurement source, i.e., periodic NZP CSI-RS**

For the measurement source, i.e., periodic NZP CSI-RS, **CMCC, ZTE and Huawei** propose to consider **CSI-RS port expansion up to 128 ports**.

In addition, **Ericsson** **and** **Huawei** also propose to consider periodic NZP CSI-RS configurations with **longer periodicity values than existing periodicities**.

**Specification impact**

For beam nulling, the following agreement has been made until RAN1#116bis.

|  |
| --- |
| **Agreement**If beam nulling is supported for gNB-to-gNB CLI handling, the following are recommended to be specified* Information exchange of measurement resource configuration, i.e., periodic NZP CSI-RS
 |

For information exchange, in addition to measurement resource configuration**, CMCC, OPPO, Google, Tejas Networks and Transsion Holdings** also propose to consider information exchange of **CLI-mitigation requests**. While, Ericsson objects to it.

For information exchange, in addition to Xn/F1, **Sony** and **Lenovo** also propose to consider information exchange over **OTA signaling**.

**Proposal 3-1**

Update the agreement in RAN1#116bis (changes mark in red) as follows

If beam nulling is supported for gNB-to-gNB CLI handling, the following are recommended to be specified

* Information exchange of measurement resource configuration, i.e., periodic NZP CSI-RS
* Information exchange of CLI-mitigation request

**Companies are invited to provide views on the above proposal.**

|  |  |
| --- | --- |
|  | **Companies** |
| Support | Tejas Networks |
| Not support |  |

|  |  |
| --- | --- |
| **Companies** | **Views** |
| Tejas Networks | Information exchange of CLI-mitigation request should be considered as additional specification impact.  |
|  |  |
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* **Beam paring**

In this meeting, beam pairing are proposed by **CATT, CMCC, Google, Huawei, Interdigital, Lenovo, LG, Nokia, NTT DOCOMO, Samsung, Qualcomm, Spreadtrum, Xiaomi, ZTE, Vivo**. However, **Sony** thinks beam pairing is not practical over a slow gNB-gNB interface and is not considered further.

**Qualcomm** provides the following example for the procedure of beam pairing between gNBs.

* For spatial domain coordination, support to specify the information exchange of beam related information among gNB(s) (e.g., victim gNB(s) and aggressor gNB(s)) for inter-gNB co-channel CLI management.
* Support to specify example 2 (from victim gNB to aggressor gNB), preferred/restricted DL beam and associated resource configuration, beam based inter-gNB co-channel CLI measurement result from victim gNB
	+ Step 1. DL RS related configuration for victim gNB(s) and aggressor gNB(s)
	+ Step 2. Measurement by victim gNB(s)
	+ Step 3. Victim gNB reports the feedback (e.g. preferred/restricted DL beam and associated preferred/restricted time/frequency resource) to the aggressor gNB(s)
	+ Step 4. Aggressor gNB can use/restrict the time/frequency resource association with DL beam

**Interdigital** proposes to support defining the events that may trigger the gNB-to-gNB CLI measurement.

**Specification impact**

For beam paring, the following agreement has been made until RAN1#116bis.

|  |
| --- |
| **Agreement**If beam pairing is supported for gNB-to-gNB CLI handling, the following are recommended to be specified* Information exchange of measurement resource configuration, i.e., SSB and/or periodic NZP CSI-RS
* Information exchange of recommended/not-recommended DL beam information and associated resource configuration
 |

The potential specification impact mentioned by companies includes information exchange of measurement resource configuration and information exchange of recommended/not-recommended DL beam information and associated resource configuration, which have been agreed in RAN1#116bis. **LG** proposes to consider restricted and recommended beam indication for IAB as baseline.

* + 1. **Coordinated scheduling in time and/or frequency**

Most companies think coordinated scheduling in time and/or frequency mainly up to gNB implementation.

**CMCC thinks** it cannot be used for SBFD Deployment Case 1 (Non-coexistence case with single SBFD subband configuration) and SBFD Deployment Case 4 (Adjacent-channel co-existence case). SBFD Deployment Case 2 (Non-coexistence case with multiple SBFD subband configurations) is out of the WID scope of Rel-19 SBFD. It is only beneficial for SBFD Deployment Case 3 (Co-channel co-existence for semi-static SBFD and legacy static TDD).

**Specification impact**

For coordinated scheduling in time and/or frequency, the following agreement was made in RAN1#116bis.

|  |
| --- |
| **Agreement**If coordinated scheduling in time and/or frequency is supported for gNB-to-gNB CLI handling and UE-to-UE CLI handling, the following is recommended to be specified* Information exchange of semi-static cell-specific SBFD time and frequency location configuration
 |

In addition, **Sony and Lenovo** propose to consider information exchange over **OTA signaling**, where, **Sony** also proposes to use CSI-RS as the L1 priority OTA indicator to exchange dynamic scheduling information. However, **CMCC** thinks the motivation of information exchange of dynamic scheduling information over OTA gNB-to-gNB signalling is not clear.

**ZTE** thinks the information exchange is helpful, such as the related configuration (e.g., SBFD time/frequency) of the neighbouring gNB, Power control parameters.

* + 1. **gNB-to-gNB co-channel CLI and/or channel measurements**

gNB-to-gNB co-channel CLI and channel measurement are widely discussed by companies. The main specification impact is to enable the aforementioned spatial domain based schemes, advanced receiver based schemes, coordinated scheduling in time and/or frequency based schemes.

* **Measurement signal(s)/channel(s)/resources**

For measurement channels/signals, NZP CSI-RS/SSB were proposed by most companies for gNB-to-gNB co-channel CLI and channel measurement.

For SSB, both CD-SSB and NCD-SSB are discussed by companies.

For NZP CSI-RS, in addition to periodic NZP CSI-RS, some companies also propose to consider aperiodic or semi-persistent NZP CSI-RS.

**Lenovo** also propose to study unified inter-cell CLI handling through transmitting SRS by aggressor gNB/UE and measuring interference by victim gNB/UE.

* **UL resource muting**

For UL resource muting, the following agreements were made in RAN1#116bis.

|  |
| --- |
| **Agreement**If non-transparent UL resource muting is supported for interference covariance matrix measurement for gNB-to-gNB CLI handling, the following are recommended to be specified* Definition and indication of UL resource muting pattern
* Collision with DMRS/PTRS
* PUSCH resource mapping, i.e., rate-matching around the muted REs
* UCI resource determination
* Power allocation in symbols with muted REs considering potential impact to phase continuity
* TB size determination

Note: The existing reference signal time-frequency resource pattern, e.g., PT-RS, comb-2 SRS, are the candidates for the UL resource muting pattern.Note: Consider pattern without adverse impact on PAPRNote: The potential impact on transmit signal quality/MPR requirement may need to checked with RAN4.Note: The above does not apply for PUSCH transmission during random access procedures.**Agreement**If non-transparent UL resource muting is supported for gNB-to-gNB CLI handling, the following are recommended to be specified* Definition and indication of UL resource muting pattern
* Collision with DMRS/PTRS
* PUSCH resource mapping, i.e., rate-matching around the muted REs
* UCI resource determination
* Power allocation in symbols with muted REs considering potential impact to phase continuity
* TB size determination
* Exchange of information across gNBs on measurement resources

Note: The existing reference signal time-frequency resource pattern, e.g., CSI-RS, are used to determine the UL resource muting pattern.Note: Consider pattern without adverse impact on PAPRNote: The potential impact on transmit signal quality/MPR requirement may need to checked with RAN4.Note: The above does not apply for PUSCH transmission during random access procedures. |

In this meeting, UL resource muting are widely discussed by companies. Based on the inputs, the following issues are discussed

**Definition and indication of UL resource muting pattern**

For non-transparent UL resource muting, companies discussed several UL resource muting patterns mainly based on existing signal time-frequency resource pattern, e.g., PT-RS, comb-2 SRS and CSI-RS. One key point discussed by companies is the impact on PAPR. According to moderator’s understanding, the PAPR issue is mainly for DFT-S-OFDM.

For DFT-s-OFDM, **Ericsson, NEC, Sony, Tejas Networks, Huawei, Hisilicon** proposed comb-2 SRS pattern. The theoretical analysis and evaluation results from **Huawei, HiSilicon** demonstrates UL resource muting with comb-2 pattern does not have adverse impact on PAPR for DFT-s-OFDM.

For CP-OFDM, **Huawei, Hisilicon** proposedtosupport {1, 2, 4} REs every {1, 2} RBs in frequency domain and up to 2 symbols in time domain.

Some companies proposed to support CSI-RS-like pattern. The moderator’s understanding is that it is not applicable for DFT-S-OFDM since there will be adverse impact on PAPR. For CP-OFDM, it can be applicable to improve the gNB-to-gNB CLI measurement accuracy. However, it was also pointed out by **vivo** that different from interference covariance matrix measurement, where UL muting is needed for every PUSCH transmission. For gNB-to-gNB CLI measurement, since gNB does not need to perform CLI measurement frequently, UL muting is only needed in some certain positions. In addition, it should be noted that the CSI-RS pattern depends on number of port(s), frequency density, CDM type. If all existing CSI-RS patterns are supported, the number of CSI-RS pattern will be large. If CSI-RS-like pattern is supported for CP-OFDM, the moderator suggests to pick one pattern.

Some companies proposed to support PT-RS pattern. The moderator’s understanding is that it is not applicable for DFT-S-OFDM for interference covariance matrix estimation since the insertion of zero-power PTRS is pre-DFT. After DFT, there will be UL signals on the frequency locations of PT-RS. However, the MIMO equalization is performed in frequency domain at the receiver, i.e., before IDFT. With ZP PT-RS, after “RE-demapping”, there is no UL “muted resources” in frequency domain. Again, it can be applied for CP-OFDM for interference covariance matrix estimation. However, it was also pointed out by **Nokia** that PT-RS like pattern introduce high complexity in both UE and gNB because its pattern is dependent on the scheduling parameters (MCS, bandwidth) and UE capabilities. Also, the frequency domain density is too low to obtain correct interference measurement.

Based on companies input and moderator’s understanding, the following is proposed

**Question 3-2**

If non-transparent UL resource muting is supported for gNB-to-gNB CLI handling, which option do you prefer?

* **Option 1**: Comb-2 for both DFT-S-OFDM and CP-OFDM
* **Option 2**: Comb-2 for DFT-S-OFDM and one CSI-RS-like pattern for CP-OFDM

**Companies are invited to provide views on the above question.**

|  |  |
| --- | --- |
| **Companies** | **Views** |
| Tejas Networks | We support Comb-2 for both DFT-S-OFDM and CP-OFDMComb-2 SRS pattern should be used along with Rate matching around the muted RE’s should be used instead of puncturing the input symbols. Only with this condition PAPR degradation + is minimized. |
|  |  |
|  |  |

**Collision with DMRS/PTRS**

For collision with DMRS, **Tejas Networks and Huawei, Hisilicon** propose the UL resource muting should avoid colliding with DMRS symbol(s) in order to guarantee the channel estimation accuracy.

For collision with PTRS, **Tejas Networks and Huawei, Hisilicon** propose if UL re is overlapped/collide with PT-RS, PT-RS can be prioritized.

**Power allocation in symbols with muted REs**

For power allocation in symbols with muted REs, **Ericsson and Huawei, Hisilicon** propose power boosting should be performed on the unused REs of the PUSCH transmission to keep the total transmit power on symbol(s)with muting REs unchanged, in order to guarantee phase continuity and reduce the impact caused by muting resource overhead.

**Potential impact on transmit signal quality/MPR requirement**

For the potential impact on transmit signal quality/MPR requirement, initial evaluation results from one source [5] show **UL resource muting with comb-2 pattern also does not have negative impact on transmit signal quality/MPR requirement**.

**Transparent UL resource muting versus non-transparent UL resource muting**

Some companies also propose to consider **transparent UL resource muting**. For transparent UL resource muting, one solution proposed by **Samsung** is that the gNB does not schedule the first and the last symbol of the slot. Another solution proposed by **CMCC** is RE level transparent UL resource muting via legacy DMRS configuration. While, **Huawei, Hisilicon** thinks that these two possible solutions based transparent UL resource muting are not flexible and inefficient which leads to degraded UL performance, larger processing delay and/or increased memory requirements compared to non-transparent UL resource muting.

The concerns on non-transparent UL resource muting mainly include UE implementation complexity, signalling overhead and specification impact. According to moderator’ understanding, the UE implementation complexity may depend on UE implementation. And in the existing specification, PUSCH will also perform rate matching on the REs with UCI transmission or DMRS. These procedures seem to be similar. For signalling overhead and specification impact, the moderator shares the view that these aspects should be considered when the down-selection is performed even though it should be a general principle for all candidate CLI handling schemes. For example, of only one or two UL resource muting patterns can be considered, the specification impact can be reduced. Regarding the signaling overhead, one may discuss whether the UL resource muting is configured in a semi-static manner or a dynamic manner.

* **Issue#3: Timing alignment issue for gNB-to-gNB co-channel CLI and channel measurement**

**Support/prioritize: ETRI, ZTE**

**ETRI:** It is necessary to consider the timing misalignment between victim gNB’s UL reception timing and reception timings of CLI-RS from aggressor gNBs as a potential specification impact.

* Timing alignment between the two gNBs for gNB-to-gNB CLI and/or channel measurement can be conducted at a low frequency.

**ZTE**: RAN1 further discusses potential solutions to address the timing misalignment issue for gNB-gNB CLI measurement.



**Figure-6: Timing difference between different gNBs**

In order to obtain the accurate channel state information, the following methods focusing on the main part of timing difference, i.e., NTA\_offset can be considered.

* Method#1: gNB sets the NTA\_offset as 0us since NTA\_offset is the main contributor of the timing difference. In this case, gNB may need to reserve one symbol as the transition gap for each UL-to-DL switch.
* Method#2: Victim gNB extracts the samples for the reference signal by deferring the starting point by 13us by implementation. This will impact the reception of signal from UE on the first symbol after the end of the reference signal, i.e., symbol 13 in Figure-5, because UE is not expected to change its UL transmission timing. Thus, one additional symbol after the reference signal needs to be muted.
* Method#3: Introduce extended CP to cover the maximum time difference.

**Not support/deprioritize: Lenovo**

**Lenovo:** the issue with timing misalignment at the victim gNB between SSB reception from aggressor gNBs and UL reception from served UEs can be handled by implementation.

* + 1. **others**

**Apple**: DL CLI indication, e.g., based on DL-PI, indicates which symbols were impacted by cross-link interference from aggressor UE(s).

**Qualcomm**: Inter-gNB CLI can be mitigated by coordinating and configuring slot-specific power control parameters for slots with CLI and without CLI

* For SBFD, power control parameters configured for SBFD slots can be different from those configured for HD slots.
* For dynamic TDD, power control parameters configured for slots where the two cells have different traffic direction can be different from those configured for slots with aligned traffic directions in the two cells.
* Support to specify semi-static configured PC parameters with less overhead.
1. **UE-to-UE CLI handling schemes**

In RAN#116 and RAN1#116bis, the following agreements were made for UE-to-UE CLI handling.

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| --- |
| **Agreement**Consider the following candidate UE-to-UE co-channel CLI handling schemes for further down-selection* UE-to-UE co-channel CLI measurement and reporting
* Coordinated scheduling in time and/or frequency
* Spatial domain based schemes
* Power control based schemes
* Note: UE-to-UE co-channel CLI measurement and reporting can be the enablers for some of the above CLI handling schemes.

**Agreement*** UL Tx power control based schemes are not considered in the down-selection of gNB-to-gNB CLI handling and UE-to-UE CLI handling schemes.
	+ Note: Support of UL Tx power control enhancements can be discussed in AI 9.3.1 and 9.3.2 (for PRACH only).
 |

* 1. **Submitted proposals**

|  |  |
| --- | --- |
| **Company** | **Description** |
| **Apple** | ***Proposal 1****: UE is RRC configured with M (M is subject to UE capability) CLI resources per active BWP within the SBFD symbol, where time domain CLI measurement resource configuration shall indicate at which slots and which symbols within that slot, CLI measurement is expected.****Proposal 2****: UE is indicated about which CLI measurement resource(s) or resource set(s) are activated/triggered as follows:** *through DL MAC-CE for semi-persistent CLI resources*
* *through UE specific DCI or GC-DCI for aperiodic CLI resource(s)*

***Proposal 3****: If UE is aperiodically indicated to report CLI, each CLI report occasion may cover O CLI measurement occasions, where O>=1 and is subject to UE capability****Proposal 4****: AP-CLI reporting can be indicated through DL-DCI scheduling PDSCH, where CLI report and HARQ-ACK for PDSCH are sent over the same PUCCH resource indicated by DL DCI****Proposal 5****: DL CLI indication, e.g., based on DL-PI, indicates which symbols were impacted by cross-link interference from aggressor UE(s).* ***Proposal 6****: To assure symbol level alignment at victim UEV, aggressor UEA is indicated to hold two different TAs:** *one TA for symbols on which TRP is doing legacy TDD, another TA for symbols on which TRP is doing SBFD or dynamic TDD.*
 |
| **CATT** | ***Observation 2:*** *RSRP/RSSI measurements within UL subband /DL subband/guard band can be supported by existing specification.****Observation 3:*** *The existing specifications is sufficient for UE-UE CLI-RSSI measurement/report across downlink subbands.****Proposal 6:*** *Support L1 UE-to-UE CLI measurement and report with Alt.1.****Proposal 7:*** *Support exchange of semi-static SBFD time and frequency configuration to enable coordinated scheduling for time/frequency resources****.******Proposal 8:*** *Spatial domain coordination to avoid/mitigate UE-to-UE CLI is not supported.* |
| **CEWiT** | ***Observation*** *1: Rel. 16 CLI management does not specify relevant information exchange among gNBs for UE-to-UE CLI management, e.g., SRS configuration parameters.**Proposal 1: Relevant information exchange, e.g. SRS configuration parameter among gNBs is supported for efficient UE-to-UE CLI management.****Observation*** *2: In case of partial overlap of BWPs, the victim UE receives only a part of the SRS transmitted by the aggressor UE for measurement of CLI RSRP leading to mismatch in how the SRS sequence is filled by the aggressor and how SRS sequence is interpreted by the victim.****Observation*** *3: When aggressor and victim UE are operating at different numerology, discrepancy arises in the transmitted and received SRS numerologies that will affect the accuracy of CLI RSRP measurement.****Proposal*** *2: Further study the following SRS related information exchange between gNBs for efficient UE-to-UE CLI measurement: a. Numerology of transmission of SRS and b. A reference point for CLI RSRP measurement.****Observation*** *4: In Rel. 16, the gNB cannot configure a UE to measure/report CLI using beam sweeping/ different Rx beams.****Proposal*** *3: Support gNB configuring different Rx beams for UE-to-UE CLI RSSI/RSRP measurement.**Observation 5: Rel. 16 UE-to-UE CLI does not support SRS with dedicated usage for CLI measurement.* ***Proposal*** *4: Support SRS with dedicated usage for CLI measurement.**Proposal 5: Support separate UE-to-UE CLI measurement report corresponding to different receive beams.****Observation*** *6: Alt. 1 gives the provision to measure and report CLI explicitly. Also, it allows to identify aggressor UEs since RSRP can be measured and reported. Alt. 3 incorporates elements from both Alt. 1 and Alt. 2.****Proposal*** *6: For L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework, downselect Alt.3.****Proposal*** *7: Support L2 based UE-to-UE CLI measurement and reporting based on event triggered reporting.****Proposal*** *8: Support UE-to-UE CLI RSSI measurement where the RSSI resources are restricted only within DL subband overlapping with the DL BWP.****Proposal*** *9: For UE-to-UE CLI RSRP measurement, the reporting of CLI can be done in the following ways:** *The UE reports RSRP measured in the uplink subband*
* *The UE reports a CLI metric for the downlink subbands that is derived from the RSRP measured in the uplink subband. This is based on a UE capability to derive the CLI metric for the downlink subbands from the RSRP measured in the uplink subband.*

***Proposal*** *10: For UE-to-UE CLI RSSI measurement, support separate CLI-RSSI measurement resources and reports in each downlink subband.****Proposal*** *11: Support repetition of CLI RSSI resources for UE-to-UE CLI measurement for allowing UE to measure CLI-RSSI on different receive beams.* |
| **CMCC** | ***Observation 13****: For Alt. 1 of L1 based UE-to-UE CLI measurement and reporting, it is unnecessary for victim UEs to know the resource type of SRS/RSSI resources for aggressor UEs.****Observation 14****: For Alt. 1 of L1 based UE-to-UE CLI measurement and reporting, it should be guaranteed by gNB implementation that there is(are) aggressor UE(s) transmitting on the resources where the victim UE measures the UE-to-UE CLI.****Observation 15:*** *For Alt. 2 of L1 based UE-to-UE CLI measurement and reporting, it should be clarified how to use CLI-IMR in the CSI measurement procedure integrating CLI measurement, and the relationship/interaction between CLI-IMR and the existing IMR used for CSI reporting in the current specification.****Proposal 11****: Consider new L1 measurement resource configurations for Alt. 1 of L1 based UE-to-UE CLI measurement and reporting.****Proposal 12****: For Alt. 1 of L1 based UE-to-UE CLI measurement and reporting, regarding measurement resource configurations, SRS resource sets with a new usage, e.g., “CLI measurement” can be configured to victim UEs, where each SRS resource set consists of one or multiple SRS resources which are associated with the SRS transmitted by the aggressor UEs.****Proposal 13****: For UE-to-UE CLI measurement in SBFD, exclude Method#1, i.e., victim UE measures RSSI within DL subband. It is unnecessary to discuss the potential enhancements for UE-to-UE CLI measurement and report regarding non-contiguous measurement resources in DL subbands in the WI phase.****Proposal 14:*** *For L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework, Alt. 1 can be supported, and Alt. 3 can also be considered.****Proposal 15****: Similar to CMR and IMR resources configured in IE CSI-ReportConfig, define a new resource set for CLI measurement, e.g., named “resourcesForCLI-Measurement” in IE CSI-ReportConfig and link it to SRS/RSSI measurement resources, e.g., the SRS resource set with usage “CLI measurement”.****Proposal 16****: Aperiodic CLI reporting on aperiodic SRS/RSSI resources is not preferred because gNB not only needs to trigger the SRS/signal transmission of aggressor UE, but also needs to trigger the CLI measurement and reporting of victim UE.* |
| **Deutsche Telekom** | ***Observation*** *4: The properties of burst traffic makes UE-UE CLI techniques challenging. The measurement effort is high and the observation might be outdated once the CLI mitigation techniques is adapted for the observed set the interfering UEs.* ***Observation*** *5: For the likely SBFD uses cases UE-UE CLI might be not such relevant and legacy techniques such as e.g. scheduling based on ACK/NACK can be used to further reduce the impact of CLI.****Proposal*** *6: RAN1 should stop the work on UE-UE CLI interference mitigation.*  |
| **Ericsson** | [*Observation 1 Most schemes in TR 38.858 either require RAN3 signaling for inter-gNB information exchange of channel measurement, configuration of reference signals or both.*](#_Toc166256480)[*Observation 2 For inter-operator case, co-channel CLI mitigation schemes summarized in the table cannot address the CLI from adjacent channels. Disallowing SBFD operation in legacy UL symbols or slot alleviates the impact to legacy networks.*](#_Toc166256481)[*Observation 3 The simulation studies in TR examined gNB-gNB CLI mitigation schemes in narrow, controlled settings without considering the broader implications of deploying SBFD.*](#_Toc166256482)[*Observation 4 The process for identifying an aggressor and/or victim gNB is not defined and very challenging.*](#_Toc166256483)[*Observation 5 Assigning a dynamic order for the gNBs to transmit reference signals and ensuring synchronization among gNBs to measure these reference signals is complex.*](#_Toc166256484)[*Observation 6 It is unclear how the coordination between gNBs determines which ones are the aggressors and which are the victims.*](#_Toc166256485)[*Observation 7 The receiver blocking requirements for adjacent channel CLI in SBFD BS are already stricter and demonstrate a capability to handle blocking in challenging scenarios more effectively than what is required for co-channel CLI mitigation using TX beam nulling.*](#_Toc166256486)[*Observation 8 The design of reference signal resources and procedures for inter-gNB interference measurement and mitigation needs to consider that the actual interference channel and that the measured reverse channel involves completely different pairs of hardware. This requires SBFD gNBs to be able to transmit and receive using the same panel which adds additional hardware cost.*](#_Toc166256487)[*Observation 9 Performance gains from Tx beam nulling varies based on whether self-interference and inter-sector interference was suppressed to the point of 1dB desensitization purely by spatial isolation or not.*](#_Toc166256488)[*a. Nulling gains are lower with realistic isolation assumptions, where spatial isolation alone doesn't achieve 1dB desensitization, compared to optimistic assumptions that do.*](#_Toc166256489)[*Observation 10 Under realistic isolation assumptions where 1 dB desense is not achieved purely by spatial isolation, some degrees of freedom are used for nulling towards self/co-sited base stations. In contrast, with optimistic isolation assumptions, these degrees of freedom could be directed towards nulling other sites.*](#_Toc166256490)[*Observation 11 For beam nulling, under both realistic and optimistic assumptions, there are UL gains (3%-17% for realistic, 3%-40% for optimistic, varying by load), but significant DL losses are observed (12%-45% for realistic, 10%-26% for optimistic, also varying by load). Therefore, Proposal 1 becomes even more relevant.*](#_Toc166256491)[*Observation 12 For Tx beam nulling that relies on gNB-gNB channel estimation through RS measurement, the gNB measuring the RS must pause or mute its DL transmissions to be able to receive the RS in the DL subband.*](#_Toc166256492)[*Observation 13 OAM system ensures that the CSI-RS configurations for multiple gNBs in a network are orthogonal in time and frequency.*](#_Toc166256493)[*Observation 14 It is not straightforward to determine which gNBs to establish an Xn interface to and there are constraints on the number of Xn interfaces for a node.*](#_Toc166256494)[*Observation 15 For gNB-gNB channel measurement, it is not clear how to report CSI when the aggressor and victim gNBs have different antenna configuration and use different CSI-RS ports, especially in HetNets where, a WA Macro gNB could be the aggressor and the victim could be a MR or LA outdoor/indoor/factory gNB.*](#_Toc166256495)[*Observation 16 Beam nulling can be effectively implemented when gNBs periodically monitor the RS transmitted by neighboring gNBs. If a gNB receives strong reference signals from its neighbors, yet its own uplink transmission in the SBFD slot is not interfered significantly, it can identify itself as a potential source of interference (an "aggressor"). In response, the gNB can choose to apply beam nulling techniques to minimize its impact on neighboring networks.*](#_Toc166256496)[*Observation 17 For beam pairing, use of CD-SSBs for gNB-gNB CLI measurement may have impact on initial access, cell search and RRM measurement performance.*](#_Toc166256497)[*Observation 18 It should be noted that the non-transparent UL resource muting methods only help CLI suppression if the interference is weak enough not to saturate (block) the gNB receiver.*](#_Toc166256498)[*Observation 19 Power boosting of the OFDM symbol with muted REs could be considered to mitigate the power control issues if RE-level UL resource muting is introduced.*](#_Toc166256499)[*Observation 20 DFT-s-OFDM aspects of non-transparent UL resource muting are important and would require special investigations, e.g. resource mapping as well as impact from the cubic-metric (CM) increase.*](#_Toc166256500)[*Observation 21 Comb-2 RE-level muting is not expected to significantly increase the PAPR/CM any more than doubling the sub-carrier spacing or halving the transmission bandwidth.*](#_Toc166256501)[*Observation 22 Interference estimation based on muting of a single OFDM symbol may completely miss DL interference spanning only part of the slot, resulting in poor performance compared to legacy configurations with similar overhead (2 DMRS per slot).*](#_Toc166256502)[*Observation 23 By muting REs in multiple UL OFDM symbols in a slot, instead of just one, performance in the presence of DL interference spanning only a few OFDM symbols could likely be substantially improved. The fraction of muted REs per OFDM symbol would be reduced to ensure that the total muting overhead in a slot is not increased.*](#_Toc166256503)[*Observation 24 For the low cubic metric DFT-S-OFDM waveform, the proposed ZP PTRS method use time domain sample muting instead of frequency domain RE muting. This solution will not cause cubic metric to increase.*](#_Toc166256504)[*Observation 25 The PTRS has a well-defined structure in multiple OFDM symbols within a slot. This allows multiple measurement opportunities to estimate the correct interference characteristics.*](#_Toc166256505)[*Observation 26 The proposed ZP PTRS introduces minimal necessary modification to existing PTRS structure or configuration to enable efficient RE muting for SBFD gNB-gNB CLI and/or channel measurement.*](#_Toc166256506)[*Observation 27 In LLS with full-slot DL allocation (apart from 1 muted symbol), ZP PTRS gives similar performance as single-symbol non-transparent UL resource muting. With partial-slot DL allocation, ZP PTRS would be expected to outperform single-symbol muting.*](#_Toc166256507)[*Observation 28 UE-UE CLI is a lesser problem than gNB-gNB CLI and optimizations for the former is not expected to increase SBFD performance drastically.*](#_Toc166256508)[*Observation 29 UE-UE CLI only becomes severe when the devices are in close proximity to each other.*](#_Toc166256509)[*Observation 30 L1 RSSI measurements offer limited insight because they fail to distinguish between co-channel and adjacent channel CLI for UE-UE CLI mitigation. This information would be useful to make a more effective scheduling decision oriented to avoid CLI.*](#_Toc166256510)[*Observation 31 For UE-UE CLI measurements, there is a need for SBFD-aware UEs to ignore the SBFD configuration while doing these measurements, especially for Methods #2, #3, and #4.*](#_Toc166256511)[*Proposal 17 Regardless of the UE-UE CLI mitigation schemes, it may be beneficial to leverage Rel-18 Positioning enhancements to identify position of UEs. This can help identify UEs at risk of causing or being affected by UE-UE CLI. Enhancing RSSI reports with positional data could aid in implementing effective UE-UE CLI mitigation strategies.*](#_Toc166256528)[*Proposal 18 RAN1 to reuse existing L3 based UE-UE CLI measurement with relevant enhancements for SBFD operation in measurement resources and reporting.*](#_Toc166256529)[*Proposal 19 If L1 based measurement reporting is agreed to be specified for UE-UE CLI measurement, prefer Alt2 or considerably minimize specification effort in Alt1 or Alt3.*](#_Toc166256530)[*Proposal 20 For UE-UE CLI mitigation schemes, do not support information exchange of SRS configuration and/or UE timing information.*](#_Toc166256531) |
| **ETRI** | ***Observation 1:*** *To ensure accurate RSRP and channel measurement using CLI-RS, it is necessary to consider adjusting the aggressor UE’s transmission timing of CLI-RS and/or victim UE’s reception timing of CLI-RS.****Proposal 1:*** *For UE-to-UE co-channel CLI handling, at least UE-to-UE co-channel CLI measurement and reporting should be supported.****Proposal 2:*** *For UE-to-UE co-channel CLI handling, at least coordinated scheduling in time and/or frequency based schemes should be further supported.****Proposal 3:*** *For UE-to-UE CLI handling in SBFD operation, both RSSI and RSRP can be considered as CLI measurement quantities, and for CLI reference signal (CLI-RS), at least SRS should be introduced for its ability to estimate timing difference.****Proposal 4:*** *L1/L2-based UE-to-UE CLI measurement and reporting based on existing CSI framework should be supported.****Proposal 5:*** *SRS resource(s) for UE-to-UE CLI measurement should be configured to be cell-specific as the baseline.****Proposal 6:*** *It is necessary to investigate specification impacts for timing alignment issues for UE-to-UE CLI measurement and reporting (e.g., timing synchronization between victim UE and aggressor UE for CLI-RSRP measurement, victim UE’s two different reception timings for CLI-RS and DL).* |
| **Google** | ***Proposal 5:*** *Define new resources and new configurations for the Rel-19 L1-SRS-RSRP and CLI-RSSI.****Proposal 6:*** *Define new “L1-CLI” usage parameter under SRS-ResourceSet or under SRS-ResourceConfigCLI-r16 if existing IEs are re-used.****Proposal 7:*** *Study the behaviour of the victim UE when the SRS transmission is dropped by the aggressor UE, e.g. due to collision with other UL signals.****Proposal 8:*** *The UE to report a specified/configurable number N of the highest L1-SRS-RSRPs from all the measured SRS resources of different potential agressor UEs.****Proposal 9:*** *The network to configure an SRS resource subset restriction and the UE to report the L1-SRS-RSRP based on the SRS resources in the SRS resource subset.****Proposal 10:*** *If a multiple ports SRS resource is configured for L1-SRS-RSRP measurement, the UE can measure/report the L1-SRS-RSRP for each SRS port.****Proposal 11:*** *Allow CLI reporting on PUCCH/PUSCH and allow PUCCH to be transmitted on UL SBFD sub-bands.****Proposal 12:*** *Inter-UE CLI measurement and reporting mechanisms should prioritize UE complexity reduction. This includes minimizing CLI measurement and reporting frequency and optimizing signaling overhead.* |
| **Huawei** | ***Observation 15****: L3 based UE-to-UE CLI measurement based coordinated scheduling has similar DL average-UPT gain compared to L1 based UE-to-UE CLI measurement based coordinated scheduling for all load levels.****Observation 16****: If L1 based UE-to-UE CLI measurement and reporting is supported, there is a need to limit the scope of the specification impact.****Observation 17****: For L2 based UE-to-UE CLI measurement and reporting based on even triggered based reporting, the mechanism of notification to the gNB about CLI measurement reporting needs to be studied.****Proposal 6****: Spatial domain coordination is deprioritized for UE-to-UE co-channel CLI handling.****Proposal 7****: Support L3 based UE-to-UE CLI measurement and reporting by reducing the candidate values of ReportInterval.****Proposal 8****: For UE-to-UE CLI measurement, support Method #1 and Method #2.** *Method#1: UE measures RSSI within DL subband*
* *Method#2: UE measures RSRP of aggressor UE within UL subband*

***Proposal 9****: Fo*r *UE-to-UE CLI-RSSI measurement/report across downlink subbands, consider Alt #1 or Alt #3.** *Alt #1: Separate CLI-RSSI measurement resources/reports in each DL subband*
* *Alt #3: CLI-RSSI measurement/report based on non-contiguous CLI-RSSI resource across downlink subbands*
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| **Interdigital** | [2.1.1.1 L1-based UE-to-UE CLI measurement and reporting]***Observation 1.*** *L1-based UE-to-UE CLI measurement could be used for performance enhancement by properly accommodating short-term CLI nature, for facilitating gNB adjusting UE scheduling, and for low latency.****Proposal 1.*** *Support CSI reporting framework as baseline for L1-based UE-to-UE CLI measurement and reporting.****Proposal 2:*** *Support UE to be configured with a flexible CLI measurement hypothesis for reporting, e.g., with or without cell-wise UL muting, to aid gNB to identify strong interferers either from the same cell or a neighbour cell, or based on a UE group.*[2.1.1.2 Performance analysis on L1-based CLI measurement and reporting]**Observation 2:** Use of CLI measurement and reporting schemes can help the gNB schedule downlink and uplink UEs to reduce the effects of UE-to-UE CLI on downlink UE performance. ***Proposal 3.*** *Support at least Alt.1 and Alt.3 in RAN1#116bis for L1-based UE-to-UE CLI measurement and reporting, where Alt.1 (Scheme 2) is essential for aggressor UE identification and Alt.3 (Scheme 3) further improves performance including link adaptation, based on utilizing a SINR-type metric for the CLI reporting.*[2.1.2.1.1 Subband-edge-specific CLI Measurement]***Observation 3.*** *Inter-subband UE-to-UE CLI measurement in SBFD DL subbands based on measuring over configured RB resources and averaging may result in down-estimation, as the subband-edge RBs experience higher CLI compared to RBs in the middle of the subband.* ***Proposal 4.*** *In UE-to-UE CLI measurement techniques, support all Methods agreed to be considered in RAN1 #116 (i.e., Methods #1-4)****Proposal 5.*** *In UE-to-UE CLI-RSSI measurement techniques within active DL BWP,**support measuring and reporting delta-CLI-RSSI based on differences in measured CLI-RSSI in**subband-edge or guard-bands with measured CLI-RSSI in the middle of the DL subband.* [2.1.2.1.2 Frequency resource configuration for CLI-RSSI]***Observation 4.*** *Considering the configuration of CLI-RSSI resources, separate resource configurations (Method #1) for non-contiguous resources would unnecessarily increase the configuration overhead for at least two times in supporting SBFD operations.****Observation 5.*** *Considering the configuration of CLI-RSSI resources, measuring and reporting CLI-RSSI in only one DL subband (Method #2) may result in down-estimation or over-estimation of overall CLI-RSSI, in case of non-symmetrical scheduling of UL resources.****Observation 6.*** *Considering the configuration of CLI-RSSI resources, measuring and reporting CLI-RSSI in non-contiguous resources across DL subbands (Method #3) allows different configuration of CLI-RSSI measurement such as frequency-selective and subband-edge specific CLI measurements.****Observation 7.*** *Considering the configuration of CLI-RSSI resources, measuring and reporting CLI-RSSI in non-contiguous resources across DL subbands (Method #3) allows flexible CLI-RSSI reporting configurations such as single report, separate report, reporting only the DL subband with higher CLI-RSSI, or reporting differential value for the DL subband with lower CLI.* ***Proposal 6.*** *Support measuring and reporting CLI-RSSI in non-contiguous resources across DL subbands (Method #3), in order to enable more accurate and flexible CLI measurement and reporting configurations.*  [2.1.2.1.3 L2-event based CLI reporting]***Observation 8.*** *Techniques based on victim UE-initiated CLI reporting based on a configured condition or event could be used to enhance UE-to-UE interference mitigation.****Proposal 7.*** *In addition to periodic type of CLI reporting, support L2-event based CLI reporting.* [2.1.2.2 Distinguishing aggressor UEs]***Observation 9.*** *CLI estimation and reporting at a potential victim UE based on distinguishing aggressor UEs can be used for enhancing CLI mitigation at the UE and further optimal scheduling at the gNB.* ***Proposal 8.*** *Support enhancements to UE-to-UE co-channel CLI measurement based on supporting CLI measurement and reporting at the potential victim UE that includes distinguishing aggressor UEs.* [2.1.3.1 Joint beam management]***Observation 10.*** *In spatial domain coordination, there are two aspects to be considered:** *Preventive aspects, that is determining the victim and aggressor UEs beam pairs to be avoided.*
* *Beam pairing aspects, that is determining the gNB and victim UE beam pairs to be used based on directional CLI from the aggressor UEs.*

***Proposal 9.*** *Support preventive aspects in spatial domain coordination by determining the most and least favourable beam pairings between the victim and aggressor UEs.****Proposal 10.*** *Support CLI mitigation aspects in spatial domain coordination by determining beam pairing between victim UE and gNB based on directional CLI.*[2.1.3.2 UL directional beam coordination at the aggressor UE]***Observation 11****. Restricting one or more UL beam directions at the aggressor UE due to causing CLI on victim UEs, throughout all occasions of a configured UL transmission, could degrade the UL performance, as the aggressor UE may be restricted to transmit based on suboptimal UL beam directions.****Observation 12****. Restricting one or more UL beam directions at the aggressor UE due to causing CLI on victim UEs, throughout all occasions of a configured UL transmission, could be unnecessary as the respective victim UEs may not be scheduled for DL reception in all corresponding configured UL occasions.****Proposal 11.*** *Support methods to restrict UL beam directions for a configured UL transmission at an aggressive UE based on scheduled victim UEs, that is only for the occasions that a respective victim UE is scheduled for DL reception.*[2.1.3.3 CLI mitigation via monitoring beams]***Observation 13.*** *Since a general CSI/beam reporting in NR is not based on dynamic CLI-related information, a victim UE may unpredictably experience DL performance degradation if a UE-to-UE CLI occurs especially when an aggressor UE is served by a different serving gNB/TRP.* ***Observation 14.*** *An aggressor UE can be configured with a first UL beam direction and a second candidate UL beam direction, where the first UL beam direction can be used in case no CLI is caused, and the second candidate UL beam direction can be used in case CLI is caused.* ***Proposal 12.*** *Support a conditional CLI handling behaviour based on monitoring the beams at the victim UE side, where the condition can at least include a case when the victim UE detects a PDSCH reception failure, which initiates a subband-wise CLI measurement/reporting for a subband switching to avoid the CLI.****Proposal 13.*** *Support CLI mitigation techniques based on configuring a second candidate UL beam direction at the aggressor UE to be used in case the UL transmission based on the first UL beam direction could cause CLI to other UEs.* |
| **Lenovo** | Inter-UE CLI handling*Observation 2-5: Inter-cell inter-UE CLI measurement and reporting is an essential enabler for inter-UE CLI mitigation at the aggressor side.**Proposal 2-10: Support Alt.3 of the agreement reached in the last RAN1#116bis meeting for L1 based UE-to-UE CLI measurement and reporting.* *Proposal 2-11: RAN1 to study an adaptive L1-L3 UE-to-UE CLI measurements and reporting approach to optimize the inter-UE CLI reporting overhead. For example, the explicit/implicit L1-based UE-to-UE CLI measurements and reporting is only enabled based on some explicit/implicit conditions and/or indication*/*signaling.**Observation 2-6: If inter-cell inter-UE CLI measurement and reporting is specified, the gNBs can reuse inter-gNB resource and beam coordination schemes for handling inter-UE CLI as well.**Proposal 2-12: RAN1 to discuss inter-gNB information exchange for inter-cell inter-UE CLI measurement and reporting even as further discussions on down-selection among candidate schemes are still in progress.**Proposal 3-14: Study to introduce coordination of SRS configurations for SRS-RSRP measurement.* *Proposal 3-15: Study benefits and mechanisms for sharing SRS resources among UEs in the aggressor cell.**Proposal 3-16: For the UE-to-UE inter-cell co-channel and inter-subband CLI measurement, common schemes on coordination of SRS configurations should be studied.**Proposal 3-17: To handle SRS reception timing misalignment in UE-to-UE CLI measurements, support signaling and information exchange for assisting the victim UE with SRS reception timing and/or indicating to the aggressor UE the SRS transmission timing.**Observation 3-2: Observed interference level may vary significantly depending on Rx beams and Rx antenna panels.**Proposal 3-18: Support* *spatially differentiated CLI measurement and reporting.* *Proposal 3-19: For UE-to-UE CLI-RSSI measurement/report across downlink subbands, support Alt#3 of the agreement made in TR 38.858.* * *Alt#3: CLI-RSSI measurement/report based on non-contiguous CLI-RSSI resource across downlink subbands*

*Proposal 3-20: For L1/L2 based UE-to-UE co-channel CLI measurement and reporting, study periodic/aperiodic/semi-persistent CLI reporting over PUCCH or PUSCH.* *Proposal 3-21: Support inter-UE CLI handling by joint aggressor UEs and preferred Tx beams indication.* |
| **LG** | *Observation 6. L3 based CLI measurement and repot has following drawbacks** *Outdated CLI measurements for short-term characteristics due to the L3 reporting latency which cannot be ensured or estimated*
* *Lack of the flexibility for resource and report configuration*

*Observation 7. When the reporting latency of L1 based CLI measurement is similar to that of CSI report, gNB can aware of channel variation of the UE due to the short-term characteristics of UE-to-UE CLI, which cannot be supported by L3 based CLI measurement and report.**Proposal 7. L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework is recommended for normative work in Rel-19 DE.**Proposal 8. For L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework, at least L1-SRS-RSRP is introduced for new report quantity.** *FFS: L1-CLI-RSSI*

*Observation 8. Each of alternatives agreed in RAN1#116bis for L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework is understood as follows;** *For Alt. 1, CSI report for beam management is used with newly defined report quantities*
* *For Alt. 2, both of CSI report for beam management and CSI acquisition are used with existing report quantities*
* *For Alt. 3, both of CSI report for beam management and CSI acquisition are used with both newly defined report quantities and existing report quantities*

*Proposal 9. For L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework, at least Alt. 2 is deprioritized and Alt. 1 is preferred.**Proposal 10. For L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework, CSI report when report quantity is L1-SINR and L1-RSRP is considered as baseline.**Proposal 11. For L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework, at least following enhancement is deprioritized.** *UCI bits generation*
* *UCI omission rule*
* *CSI measurement procedure integrating CLI measurement*
* *Timeline and related UE behaviors*

*Observation 9. Compared to the sub-case#1 (i.e, no inter-UE CLI handling), packet size with 0.5Mbytes for DL, about 40-45 DL resource utilization,** *with inter-UE CLI handling based on L1 based CLI measurement and report, mean, 5%ile, 10%ile, 15%ile, 50%ile and 95%ile values of DL UE average throughput is enhanced 0.33%, 19.7%, 23.75%, 8.24%, 0.39% and 0.67%, respectively.*

*Observation 10. Compared to the inter-UE CLI handling based on L3 CLI measurement and report, packet size with 0.5Mbytes for DL, about 40-45 DL resource utilization,** *with inter-UE CLI handling based on L1 based CLI measurement and report, mean, 5%ile, 10%ile, 15%ile, 50%ile and 95%ile values of DL UE average throughput is enhanced or degraded 0.44%, 15.98%, 20.50%, 10.23%, -0.04% and 0.46%, respectively.*

*Observation 11. In Urban Macro scenario, DL UE average throughput of 5%ile, 10%ile and 15%ile of UE is enhanced when inter-UE CLI is handled based on L1 based CLI measurement and report.**Observation 12. When performing scheduling for victim DL UEs to avoid UL UEs causing severe CLI,** *Using inter-UE CLI handling based on L1 based CLI measurement and report is beneficial to improves the DL throughput performance of DL UEs.*
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| **MediaTek** | 1. *It is possible to have a scenario where SRS transmission toward the gNB is not frequent enough to allow up to date CLI measurement and reporting in SBFD operation.*
2. *Having dedicated SRS transmissions solely for the purpose of CLI measurement can support fast, reliable, and more accurate SRS-RSRP measurement and reporting.*
3. *With dedicated SRS resources for UE-to-UE CLI measurement, reusing the existing SRS power control loop can result in a higher transmit power consumption*
4. *Allowing low power SRS transmissions intended for CLI measurement can reduce power consumption as well as inter-cell interference.*
5. *The resource overhead cost is avoided when uplink subband resources of a SBFD slot is used for CLI-RSSI measurement*
6. *CLI-RSSI measurement on UL subband can help to identify individual aggressor UEs by allowing measurements on finer RB Groups of the UL subband.*
7. *Allowing L2 based* *autonomous detection and reporting of UE-to-UE CLI can ensure faster and more reliable CLI reporting in SBFD operation.*
8. *L2 based autonomous monitoring, detection and reporting of UE-to-UE CLI can serve as a mechanism for a UE to protect itself against potential blockage caused by nearby aggressor UEs.*
9. *Muting the first symbol in a SBFD slot succeeding a DL-only slot avoids the resource overlap between uplink and downlink resources. This removes the possibility of any uplink transmission on the SBFD slot interference with downlink reception on the DL-only slot.*
10. *Support configuration of dedicated SRS Resource solely for the purpose of SRS transmission for UE-to-UE CLI measurement.*
11. *Support low power SRS transmission for inter-UE CLI measurement when using dedicated SRS resources for UE-to-UE CLI measurement.*
12. *For low power SRS transmission, allow the UE to adjust the measured UE-to-UE CLI value for efficient CLI reporting.*
13. *Support CLI measurement on finer RB Groups on the UL subband of SBFD slots.*
14. *Support CSI-IM based inter-UE CLI-RSSI measurement.*
* *For this method, the UE measures the total interference in the CSI-IM resources in SBFD slot and its preceding DL-only slot and report difference between them as the actual inter-UE CLI experienced by the UE.*
1. *Support mechanisms to enable L2 based autonomous reporting of UE-to-UE CLI by a SBFD aware UE.*
2. *Support muting of the first UL symbol in the first SBFD slot after a non-SBFD (DL-only) slot.*
 |
| **NEC** | ***Observation 1:****Power control enhancements may have different requirements for different use case** *UEs performing UL Tx during SBFD symbols may be required to increase their Tx power to counter the gNB self-interference.*
* *UEs may also be required to increase their Tx power when gNB is experiencing large CLI from neighbor gNBs DL transmissions.*
* *For UE-UE CLI handling, Tx power reduction is required for interfering UEs (without significantly affecting their throughput performance).*

***Observation 2:**** *Exact impact of some proposals on the tables presented in R1-240635*

***Proposal 14:*** *Specify L1 based UE-UE CLI measurements and reporting.****Proposal 15:*** *The configuration information for UE-to-UE L1 CLI measurement should include a list of TCI states for beam-based CLI measurements.****Proposal 16:*** *The UE-to-UE L1 CLI report configuration/indication information should include K (K>=1) TCI states with the highest L1-SRS-RSRP, L1-SINR, or L1-CLI-RSSI.****Proposal 17:*** *Unified design for CLI RS for gNB-to-gNB and UE-to-UE measurement should be considered to reduce the RS overhead. The RS for UE-UE and gNB-gNB interference measurement can be orthogonal in order to achieve this goal.****Proposal 18:*** *Only consider Method#1 (victim UE measures RSSI within DL subband) and Method#2 (victim UE measures RSRP of aggressor UE within UL subband) for inter-UE CLI handling schemes specification.****Proposal 19:*** *Only consider Alt#1 (separate CLI-RSSI measurement resources/reports in each DL subband) and Alt #2 (CLI-RSSI measure/report in one DL subband only) for specification for CLI measurement methodologies.****Proposal 20:**** *Consider the CSI report size enhancement for SBFD operation and different types of CLI interference.*
* *Consider the non-uniform CLI bandwidth in inter-subband CLI measurement/report.*

***Proposal 21:**** *Consider following steps to specify inter-gNB coordination requirements for UE-UE CLI handling.*
	+ *Request from gNB1 to gNB2 to trigger CLI-RS transmissions from one or more UEs connected to gNB2.*
	+ *Indication from gNB2 to gNB1 about CLI measurement resources to use for identifying the interfering UEs.*
	+ *Indication from gNB1 to gNB2 about the identity of the interfering UEs of gNB2.*

***Proposal 22:**** *Differentiation of the BFR caused by CLI with the beam blockage is needed.*
* *Eliminating the effect of the CLI on BFR for BFD and NBI should be considered.*
 |
| **New H3C** | *Proposal 14: A new usage of the SRS resource can be introduced during the configuration of the SRS resource, which is CLI measurement, the SRS resource used for CLI can be configured to periodic, aperiodic and semi-persistent.**Proposal 15: The central controller can be used to coordinate the SRS resource configuration between different gNBs, the SRS resource is identified by gNB ID + SRS resource set ID + SRS ID or gNB ID + SRS resource ID.**Proposal 16：The SRS resource for CLI can be configured to cell-specific, UE-specific or group-common. There should be a trade-off between the resource efficiency and the measurement precision.**Proposal 17: The CLI reporting can be an independent reporting or a joint reporting together with legacy reporting, such as SR, HARQ ACK, CSI, and can be periodic. Each CLI reporting should be linked to a dedicated SRS configuration.**Proposal 18: The new reporting quantity SRS-RSRP and CLI-RSSI can be configured for CLI reporting.**Proposal 19: The CLI measurement results of all the interference gNB can be reporting in one single CLI reporting. The CLI measurement results related to one gNB has it unique result ID. For each CLI result, the SRS-RSRP related to the SRS resources should be sorted by the SRS resource ID, from smallest to largest.**Proposal 20: If L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework are supported for UE-to-UE CLI handling, the following are recommended to be specified* * *Measurement resources*
	+ *Periodic, semi-persistent, or aperiodic measurement resource (set) i.e., SRS-RSRP resource or CLI-RSSI resource*
* *Measurement reporting*
	+ *Periodic, semi-persistent or aperiodic reporting on PUCCH/PUSCH*
	+ *New report quantities: e.g L1-SRS-RSRP, L1-CLI-RSSI and/or RS indexes*
	+ *UCI bits generation*
	+ *UCI omission rule*
	+ *Priority rules for multiple CSI reporting*
	+ *CSI processing unit and CPU occupation rule*
	+ *Timeline and related UE behaviours*
* *CLI measurement accuracy requirement [RAN4]*

*Proposal 21: The PDSCH scheduling scheme should be considered in case of the overlapping with SRS for CLI. Two options are considered: No PDSCH scheduling or PDSCH RM. The scheduling scheme is determined by gNB.* |
| **Nokia** | [*Proposal 12: The candidate schemes to be prioritized are L1/L2 UE-to-UE co-channel CLI measurements and reporting, as well as time, frequency, and spatial coordination to combat the CLI.*](#_Toc166244940)[*Proposal 13: UE-to-UE co-channel CLI measurements should be performed over the UL subband as baseline*](#_Toc166244941)[*Proposal 14: Support the power ratio between CLI measured over the UL subband and over the guardband(s) as a new CLI metric.*](#_Toc166244942)[*Proposal 15: Existing CLI-RSSI measurement resource configuration can be re-used to indicate the measurement resources over the guardbands.*](#_Toc166244943)[*Proposal 16: The gNB can indicate the CLI measurement resources over the guardbands by 1) introducing a new dedicated resource type, e.g., guardBand-ResourceConfigCLI, or 2) assigning a wideband CLI-RSSI resource that the UE autonomously assigns to guardband(s) and UL subband measurement resources.*](#_Toc166244944)[*Proposal 17: Study methods to jointly measure the fundamental signal power and leakage power of a given SRS over the UL subband*](#_Toc166244945)[*Proposal 18: Support L1/L2-based co-channel UE-to-UE CLI measurement and reporting.*](#_Toc166244946) [*Proposal 19: L1 UE-to-UE CLI measurements and reporting should re-use the existing CSI framework.*](#_Toc166244947)[*Proposal 20: Re-use legacy SRS-RSRP and CLI-RSSI measurement resources configuration for L1 UE-to-UE CLI measurements.*](#_Toc166244948)[*Proposal 21: Define new CLI metrics in the CSI framework, e.g., L1-CLI-RSSI and L1-SRS-RSRP, to enable explicit reporting of the CLI conditions.*](#_Toc166244949)[*Proposal 22: Support the introduction of mini-subbands measurements for CLI-RSSI based measurements.*](#_Toc166244950)[*Proposal 23: Re-use the SRS-Request field in DCI 0\_1 to enable aperiodic SRS-RSRP triggering at the victim UE*](#_Toc166244951)[*Proposal 24: Support dynamic indication of the aperiodic CLI-RSSI measurement resources via DCI to fully overlap in time and frequency with the aggressor UE of interest.*](#_Toc166244952)[*Proposal 25: Support joint indication of PDSCH resources and aperiodic CLI measurements via DL DCI.*](#_Toc166244953)[*Proposal 26: Support including the aperiodic CLI-RSSI measurement as part of the HARQ feedback UCI.*](#_Toc166244954)[*Proposal 27: Support CLI-RSSI power difference measurements and reporting to help the UE determining the UE-to-UE CLI levels while performing measurements over the DL subband(s).*](#_Toc166244955)[*Proposal 28: For CLI measurement, UE shall assume RX beam/filter is the same as the RX beam/filter for receiving the downlink channels/RS (PDCCH/PDSCH/TRS).*](#_Toc166244956) [*Observation 13: The outcome of a collision handling impacts the performance of CLI measurements.*](#_Toc166244957)[*Proposal 29: Specify mechanisms to indicate the result of a collision handling at both victim and aggressor UEs.*](#_Toc166244958)[*Proposal 30: For inter-cell UE-to-UE CLI measurements, the exchange of the SRS configuration between gNBs is needed to properly configure the SRS-RSRP measurements. Otherwise, the SRS-based CLI measurements functionality is not fully implementable.*](#_Toc166244959)[*Observation 14: The timing information together with the CLI power level helps the gNB identifying the aggressor UE(s) even if measurements are based on CLI-RSSI.*](#_Toc166244960)[*Proposal 31: Enhance the CLI reporting by including the time information, e.g., slot index, in addition to the CLI power level.*](#_Toc166244961) |
| **NTT DOCOMO** | ***Proposal 4****: L1 based UE-to-UE CLI measurement and reporting should be supported to obtain the instantaneous interference information.****Proposal 5****: Alt.2 should be downselected with considering advantage of L1 based scheme and specification impact.****Proposal 6****: Method #1: UE measures RSSI within DL subband should be considered for CLI measurement within active DL BWP.****Proposal 7****: Separate CLI-RSSI measurement in each DL subband should be considered.****Proposal 8****: Spatial domain coordination method such as based on report of CLI measurement results with spatial domain information should be considered.* |
| **OPPO** | *For UE-to-UE co-channel CLI handling:* *Proposal 1: For inter-UE inter-subband CLI measurement, support RSSI measurement by victim UE within DL subband (Method #1 in RAN1 #116 agreement).**Proposal 2: For UE-to-UE CLI-RSSI measurement/report across DL subbands, CLI-RSSI measurement resources/reports are separated per each DL subband.**Proposal 3: If L1 CLI is supported, support Alt#3 in RAN1 #116bis agreement.** *L1 CLI report quantities of CLI-RSSI and/or SRS-RSRP can be newly-added in CSI report.*
* *Reuse existing CSI-IM resource for CLI-RSSI measurement.*
* *Define new trigger state in existing signaling information field.*

*Proposal 4: A given threshold of CSI/CLI measurement result can be provided for L1 CLI report to reduce signaling overhead and power consumption.* |
| **Samsung** | *Proposal 8: For UE-to-UE co-channel CLI handling, support L1-based UE CLI measurement and reporting.* |
| **Sony** | *Proposal 9: Support L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework for UE-to-UE CLI handling, and consider the following aspects to be specified (i.e. Alt-3):** *Measurement resources*
	+ *Periodic, semi-persistent, or aperiodic measurement resource (set) i.e., SRS-RSRP resource or CLI-RSSI resource or CLI-IMR*
* *Measurement reporting*
	+ *Periodic, semi-persistent or aperiodic reporting on PUCCH/PUSCH*
	+ *New report quantities: e.g. L1-SRS-RSRP, L1-CLI-RSSI and/or RS indexes*
	+ *UCI bits generation*
	+ *UCI omission rule*
	+ *Priority rules for multiple CSI reporting*
	+ *CSI processing unit and CPU occupation rule*
	+ *Timeline and related UE behaviours*
	+ *CSI measurement procedure integrating CLI measurement*
* *Note: The new measurements on CLI-IMR are included in the interference measurement term for the existing report quantities, i.e., CQI, L1-SINR.*

*Proposal 10: Support finer frequency granularity for CLI measurement and reporting, by dividing the BWP or the victim subband into smaller frequency blocks, where CLI measurement and reporting are performed on each frequency block.**Proposal 11: If UE is allowed to measure in the UL subband, then at least information exchange on SRS is supported.**Proposal 12: UE measurements of DL beam CLI is discussed under L1 UE measurements.* |
| **Panasonic** | *Proposal 3: When Rel.16 UE-to-UE CLI measurement is reused for CLI measurement for SBFD aware UEs, averaging/filtering of the CLI measurement should be carried out only in the same property.**Proposal 4: For L1-based UE-to-UE CLI measurement and reporting based on existing CSI framework, support Alt.2.**Proposal 5: Subband-based CLI measurement and reporting for UE-to-UE CLI handling should be supported.**Proposal 6: Beam-based UE-to-UE CLI measurement should be discussed considering the system/measurement/reporting overhead, UE complexity and necessity of limiting TCI states.* |
| **Qualcomm** | *Proposal 1: Propose the modify the spec impact of L1 based UE-to-UE CLI measurement and reporting on Alt 1 and Alt 3 as:** *UCI bits generation similar as L1 beam reporting*
* *Priority rules for CSI reports*
* *Single CPU occupation*
* *Timeline similar as L1 beam reporting.*

*Proposal 2: Propose the following down selected inter-UE and inter-gNB CLI handling schemes to be specified in R19 work item:**For Inter-UE CLI handling schemes:** *L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework – with preferred Alt 1.*
	+ *Rx beams configuration (QCL-D) configured per CLI measurement resource.*
* *Rx beams configuration (QCL-D) configured per CLI measurement resource for L3 UE-to-UE CLI measurement enhancement.*
* *L2 event triggered UE to UE CLI measurement and reporting.*

*For Inter-gNB CLI handling schemes:** *Beam nulling.*
* *Beam pairing.*
* *Coordinated scheduling in time and/or frequency.*

*Proposal 3: Propose RAN1 to specify SBFD specific inter-subband CLI measurement and reporting in R19 work item to support SBFD operation.**Proposal 4: Support to specify CLI measurement method #1 as baseline, additionally support method #2/3.** *FFS: Method #4 at least with a UE capability.*

*Proposal 5: For SBFD aware UEs, CLI measurements is performed within the active DL BWP and the following can be considered:** *Method#1: UE measures RSSI only at RSSI frequency resources within DL usable PRBs*
* *Method#2: UE measures RSRP of aggressor UE only at SRS-RSRP frequency resources within UL usable PRBs but within DL BWP*
* *Method#3: UE measures RSSI only at CLI-RSSI frequency resources within UL usable PRBs but within DL BWP*
* *Method#4: UE measures RSSI within guard band, if guard band exists only at CLI-RSSI frequency resources outside the DL and UL usable PRBs but within DL BWP.*

*Proposal 6: For CLI-RSSI measurements within DL subband, support to discuss Alt #1 and Alt #3.* *Proposal 7: For Alt#3, UE implicitly determines the non-contiguous frequency resources for CLI-RSSI measurement in the DL subband(s). The non-contiguous CLI frequency resource could implicitly be determined by the UE by excluding some frequency resources based on SBFD indication.* *Proposal 8: For Alt#3, when UE is configured to measure and report CLI-RSSI based on non-contiguous CLI-RSSI resource in SBFD symbols, the UE may report single wideband RSSI measurement or per-DL-subband CLI-RSSI measurements.**Proposal 9: Propose certain changes related to L1/L2 based UE-to-UE co-channel CLI measurement and reporting related to Proposal 3-2a (UE to UE CLI handling) of R1-2401635:** *Change 1) We suggest having L1/L2 based UE-to-UE co-channel CLI measurement and reporting under scheme of “UE-to-UE co-channel CLI measurement and reporting” instead of “coordinated scheduling”. Because for intra-cell L1/L2 based UE-to-UE co-channel CLI measurement and reporting, it does not require coordinated scheduling between gNBs for UE-to-UE co-channel CLI measurement and reporting.*
* *Change 2) In addition, we suggest separating L1/L2 based UE-to-UE co-channel CLI measurement and reporting schemes to at least two schemes: CLI either explicitly captured in SRS, CLI-RSSI and/or implicitly captured in CQI, L1-SINR with adding CLI IMR. The table captures both schemes; however, the two schemes indeed have different spec impact. For example, if CLI is implicitly captured, then there shall be no spec impact on report quantity, UCI multiplexing, CPU computation rule and timeline.*
* *Change 3) Lastly, operational details shall capture “facilitate gNB adjusting UE scheduling” in first bullet as it was captured in TR 38.858 together with short term interference measurement and low latency.*

*The suggested edits are highlighted in yellow:*

|  |  |  |  |
| --- | --- | --- | --- |
| ***UE-to-UE co-channel CLI handling schemes*** | ***Potential specification impact*** | ***Performance evaluations*** | ***Operational details*** |
| *UE-to-UE co-channel CLI measurement and reporting* | * *L1/L2 based UE-to-UE co-channel CLI measurement and reporting*
* *Measurement resources*
	+ *Implicitly scheme: Periodic, semi-persistent, or aperiodic, e.g., CLI-IMR*
	+ *Explicit scheme: Periodic, semi-persistent, or aperiodic, e.g., SRS-RSRP, CLI-RSSI*
* *Measurement reporting:*
	+ *Implicitly scheme: reuse CQI, L1-SINR as in current spec*
	+ *Explicit scheme: reporting quantity, e.g., SRS-RSRP, CLI-RSSI*
		- *Periodic, semi-persistent, aperiodic and event-triggered reporting on PUCCH/PUSCH*
		- *Subband CLI reporting*
		- *UCI multiplexing priority rule, CPU occupation rule, timeline and related UE behavior*
 | ***Section 7.4.3 of TR 38.858****Coordinated scheduling based on L3 UE-UE CLI measurement has similar DL average-UPT gain compared to coordinated scheduling based on L1 UE-UE CLI measurement for all load levels.****Section 2.2.1 of R1-2400689 [11]**** *The use of a L1/L2 measurement and reporting (Scheme 2) provides the gNB with a more accurate picture of current UE-to UE CLI, allowing the gNB to carefully select an optimal pairing of downlink and uplink Ues that minimizes the impact of UE-to-UE CLI on downlink Ues. This in turn improves downlink performance when compared to Scheme 1 – loss drops from 38% to 15.5% for low load, and from 47% to 28% for medium load, respectively.*
 | * *L1/L2 based UE-to-UE CLI measurement can be optimized for short term interference measurement and low latency and facilitate gNB adjusting UE scheduling.*
* *The above does not imply that L3 based measurement and reporting cannot be used for similar purposes.*
 |

*Proposal 10: Support following schemes in the table:** *L1/L2 based UE-to-UE co-channel CLI measurement and reporting*
* *coordinated scheduling in time and frequency domain*
* *Rx beam configuration for the L1/L2/L3 based UE-to-UE CLI measurement*
* *UE power control based scheme*

*Proposal 11: Support RAN1 specification of enhancements of co-channel CLI measurement and reporting in R19 work item:** *For L1/L2 UE-to-UE CLI measurement, periodic, semi-persistent, or aperiodic measurement resource.*
* *For L1/L2 UE-to-UE CLI reporting, periodic, semi-persistent, aperiodic reporting.*
* *Use existing CSI framework as the baseline*

*Proposal 12: RAN1 considers specifying one or both schemes for CLI measurement and report:* * *Scheme 1: Explicitly capture CLI in separate new CLI reportQuantity metrics, e.g. SRS-RSRP and CLI-RSSI*
	+ *Potential spec impact: separate CLI resources and new reportQuantity configuration*
* *Scheme 2: Implicitly capture CLI in existing CSI report e.g. via existing CQI and L1-SINR metrics*
	+ *Potential spec impact: enhance existing CSI framework by adding configuration of IMR dedicated for inter-UE CLI in a CSI-ReportConfig*

*Proposal 13: Support RAN1 to specify UE Rx beam (QCL-D) configuration and indication per CLI measurement resource (e.g. for top X DL beams or active DL beams) for enabling CLI-aware gNB beam management for CLI mitigation, as enhancement of CLI measurement and reporting.**Proposal 14: Support to specify information exchange between gNBs for UE-to-UE CLI measurement resource configuration including time/frequency resources and beam indication.* |
| **Spreadtrum** | *Proposal 7: The impact on legacy UEs in coexistence scenarios caused by enhancement of L1/L2 based UE-to-UE CLI measurement and reporting should be considered as one important aspect for UE-to-UE CLI handling study.**Proposal 8: The workload and effectiveness of L1 based UE-to-UE CLI measurement and reporting is another aspect to consider for down-selection.**Proposal 9: Do not support to specify L1/L2 based UE-to-UE CLI measurement and reporting.**Proposal 10: L2/L3 based UE-to-UE CLI reporting can be taken into account for down-selection.**Proposal 11: Check the effectiveness of spatial domain based schemes especially in mobility scenarios.**Proposal 12: Method#1, Method#2 and Method#4 can be considered to support in Rel-19.**Proposal 13: Specify inter-subband UE-to-UE CLI measurement and reporting.* |
| **Transsion Holdings** | *Proposal 1: Support Rx beam configuration for the L1/L2 based UE-to-UE CLI measurement.**Proposal 2: For L1/L2 based UE-to-UE CLI reporting, Alt 1 should be supported.* |
| **Xiaomi** | *Proposal 7: For L1 based UE-to-UE CLI measurement, at least periodic and aperiodic CLI measurement resource should be supported.**Proposal 8: For L1 based UE-to-UE CLI reporting, at least periodic and aperiodic CLI reporting should be supported.**Proposal 9: For L2 based CLI reporting, the event-triggered reporting can be further considered.**Observation 1: CSI and CQI may bring high calculation complexity with non-linear operations.**Proposal 10: For L1/L2 based UE-to-UE CLI measurement and reporting, the configuration can be realized via updating CSI-ReportConfig:** *Adding CLI measurement resources as components of CSI-ReportConfig.*
* *Adding CLI-RSRP and CLI-RSSI as components of reportQuantity.*
* *Adding event-triggered reporting as a component of reportConfigType.*

*Proposal 11: Subband CLI reporting can be considered for UE-to-UE CLI mitigation.**Proposal 12: For inter-UE inter-subband CLI measurement, the following four methods should be supported:** *Method#1: victim UE measures RSSI within DL subband*
* *Method#2: victim UE measures RSRP of aggressor UE within UL subband*
* *Method#3: victim UE measures RSSI within UL subband*
* *Method#4: UE measures RSSI within guard band, if guard band exists*

*Proposal 13: For UE-to-UE CLI-RSSI measurement/report across downlink subbands,* * *Alt#1 and Alt#2 are automatically supported by existing specifications.*

*Alt#3 can be suspended until non-contiguous CSI-RS resource allocation across DL subbands is settled.* |
| **ZTE** | *Proposal 13: For SBFD aware UEs, the following measurements should be supported.** *Method#1: UE measures RSSI within DL subband*
* *Method#2: UE measures RSRP of aggressor UE within UL subband*
* *Method#3: UE measures RSSI within UL subband*

*Observation 9: The UE is difficult to derive the reception timing accurately for UE-to-UE CLI measurement without any information exchange, especially in the typical deployment, e.g., HetNet, of Rel-19 SBFD.* *Proposal 14: Timing alignment solution on measurement RS transmission for UE-to-UE CLI should be supported in Rel-19.* * *For example, exchange timing related information for reception of measurement RS.*

*Observation 10: L1 based measurement and reporting can provide much low which can reflect the short-term interference and the change of interference better.* *Observation 11: For L1-based UE-to-UE CLI reporting,** *The interference source can be identified in Alt.1.*
* *If Alt.1 is supported, Alt.2 and Alt.3 can be achieved by gNB implementation.*

*Observation 12: If L1-based CLI reporting is supported, it requires CLI resource to be configured in the CSI-RS resource setting.* *Observation 13: If L1-based CLI reporting is supported, it requires a new configuration on the quantity to be configured in the CSI reporting configuration.* *Observation 14: If L1-based CLI reporting is supported, there is no specification impact to support periodic, semi-persistent or aperiodic CLI reporting.* *Observation 15: If L1-based CLI reporting is supported, it requires to define the UCI bit generation and the UCI bit generation for L1-RSRP can be reused.**Observation 16: If L1-based CLI reporting is supported, it requires to reuse the legacy method for multiplexing with other types of UCI, subband CLI reporting, UCI omission, priority for overlapping handling, CSI processing unit and CPU occupation rule and timeline related UE behaviour with adaptive specification change, if any.**Proposal 15: Alt.1 should be supported for L1-based UE-to-UE CLI measurement and reporting* *Observation 17: Wideband CLI measurement and reporting may fail to reflect the changes of inter-subband interference in different frequency resources.* *Proposal 16: For L1-based reporting, aperiodic reporting and reporting according to defined conditions should be supported to reduce the reporting overhead and measurement effort.* *FFS: whether/how the L1 reporting and L3 reporting for the CLI co-exist with each other.* |
| **Vivo** | *Proposal 5: Compared to L3 UE-to-UE CLI measurement, the motivation to support L1 UE-to-UE CLI measurement needs to be further clarified.**Proposal 6: If L1 based UE-to-UE CLI measurement and reporting is supported, Alt 2 is preferred.**Proposal 7: If enhancements to L3 based UE-to-UE CLI measurement and reporting are supported for UE-to-UE CLI handling, the following are recommended to be specified** *Information exchange of SRS resource configurations among gNBs*
* *Reduce the value of ReportInterval for L3 based UE-to-UE CLI measurement*
* *CLI measurement accuracy requirement [RAN4]*
* *CLI measurements results exchange among gNBs, e.g. CLI-RS index with larger CLI*

*Proposal 8: For UE-to-UE CLI measurement and/or channel measurement, enhancements to L3 based UE-to-UE CLI measurement and reporting are supported**Proposal 9: Coordination on SBFD configuration between gNBs can be supported for UE-to-UE co-channel CLI handling.**Proposal 10: Separate power control parameters in SBFD and non-SBFD symbols can be supported in NR Rel-19.**Proposal 11: For UE-to-UE inter-subband CLI measurement for SBFD, the following methods can be considered.**- Method#1: victim UE measures RSSI within DL subband.**- Method#2: victim UE measures RSRP of aggressor UE within UL subband.**Proposal 12: For UE-to-UE CLI-RSSI measurement/report across downlink subbands, the following Alt #1 or Alt #2 is sufficient.**- Alt #1: separate CLI-RSSI measurement resources/reports in each DL subband**- Alt #2: CLI-RSSI measure/report in one DL subband only* |
| **WILUS** | *Proposal 2: It should be further investigated for UE-to-UE co-channel CLI measurement and reporting at aggressor UE side for UE-to-UE co-channel CLI handling.**Proposal 3: IEs (information elements) of L1/L2 UE-to-UE co-channel CLI measurement and reporting can be included in CSI reporting configuration (i.e., CSI-ReportConfig) with new report quantities to measure and report UE-to-UE co-channel CLI.**Proposal 4: Although separate UL power control parameters based on co-channel CLI are configured/indicated, it should be further investigated how to maintain power consistency across PUSCH transmissions or PUCCH transmissions with and without co-channel CLI if DMRS bundling is configured as enabled for a UE.* |

* 1. **Summary**

Based on the companies’ input, spatial domain based schemes, coordinated scheduling in time and/or frequency based schemes, power control based schemes and UE-to-UE co-channel CLI measurements and reporting were discussed. For discussion in this meeting, moderator recommends to focus on the down-selection of CLI handling schemes taking into account the guiding principles concluded in RAN1#116 and RAN1#116bis.

* + 1. **Spatial domain based schemes**

Spatial domain based schemes are proposed for UE-to-UE co-channel CLI handling by **CEWiT, Interdigital, Lenovo, NTT DOCOMO, Qualcomm, NEC., Samsung**

**CEWiT:** Support repetition of CLI RSSI resources for UE-to-UE CLI measurement for allowing UE to measure CLI-RSSI on different receive beams.

**Interdigital:**

Support preventive aspects in spatial domain coordination by determining the most and least favourable beam pairings between the victim and aggressor UEs

Support CLI mitigation aspects in spatial domain coordination by determining beam pairing between victim UE and gNB based on directional CLI

Support methods to restrict UL beam directions for a configured UL transmission at an aggressive UE based on scheduled victim UEs, that is only for the occasions that a respective victim UE is scheduled for DL reception

Support a conditional CLI handling behaviour based on monitoring the beams at the victim UE side, where the condition can at least include a case when the victim UE detects a PDSCH reception failure, which initiates a subband-wise CLI measurement/reporting for a subband switching to avoid the CLI.

Support CLI mitigation techniques based on configuring a second candidate UL beam direction at the aggressor UE to be used in case the UL transmission based on the first UL beam direction could cause CLI to other UEs.

**Lenovo:** Support spatially differentiated CLI measurement and reporting.

Support inter-UE CLI handling by joint aggressor UEs and preferred Tx beams indication.

**NTT DOCOMO:** Spatial domain coordination method such as based on report of CLI measurement results with spatial domain information should be considered.

**Qualcomm:** propose to indicate RX QCL/TCI per CLI measurement resource, which is measured at UE. By indicating Rx QCL/TCI per CLI resource, gNB can identify the Rx beam corresponding to the reported CLI. Qualcomm thinks that UE Rx beam (QCL-D) configuration and indication per CLI measurement resource is an important enhancement to enable CLI-aware gNB beam management for CLI mitigation, which can apply to enhanced L3 and future L1/L2 if adopted for CLI measurement and reporting.

**NEC:** The configuration information for UE-to-UE L1 CLI measurement should include a list of TCI states for beam-based CLI measurements

The UE-to-UE L1 CLI report configuration/indication information should include K (K>=1) TCI states with the highest L1-SRS-RSRP, L1-SINR, or L1-CLI-RSSI.

**Samsung:**

Another limitation using the existing Rel-16 CLI reporting is that it currently cannot be associated with spatial-domain information, e.g., Tx and/or Rx beams. However, exploiting CLI reports at the gNB for purpose of beam management for the UEs can be seen as one promising interference management solution for SBFD.

**Not support/deprioritize：CATT, Nokia**, **Sony, Panasonic**

**CATT:** Spatial domain coordination to avoid/mitigate UE-to-UE CLI is not supported.

* the DL/UL throughput performance of victim/aggressor UE will be degraded
* additional UE measurement complexity and spec work will be introduced

Nokia: For CLI measurement, UE shall assume RX beam/filter is the same as the RX beam/filter for receiving the downlink channels/RS (PDCCH/PDSCH/TRS).

**Sony:** UE measurements of DL beam CLI is discussed under L1 UE measurements.

**Panasonic:** Beam-based UE-UE CLI measurement should be discussed considering the system/measurement/reporting overhead, UE complexity and necessity of limiting TCI states

There seems to be some support of spatial domain based schemes. Among all proposals, configuring the Rx beam, e.g., QCL assumptions or TCI states, for the UE-to-UE CLI measurement has the largest support. Companies not supporting this mainly concern about the additional UE complexity and specification effort. From the moderator’s understanding, for L1 based UE-to-UE measurement and reporting, this may anyway need to discussed. One possibility is to allow the UE to optionally support this and the default behavior follows Rel-16 UE behavior, i.e., the UE assumes that the Rx beam for CLI measurement follows the Rx beam for the latest received PDCCH or PDSCH.

**Proposal 4-1**

**Proposed agreement**

If spatial domain-based schemes are supported for UE-to-UE CLI handling, the following are recommended to be specified

* Rx beams configuration for UE-to-UE CLI measurement
* Note: The above is a separate optional UE capability.

**Companies are invited to provide views on the above proposal.**

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|  | **Companies** |
| Support |  |
| Not support |  |

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| **Companies** | **Views** |
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* + 1. **Coordinated scheduling in time and/or frequency based schemes**

The following agreement was made in RAN1#116bis for the specification impact of coordinated scheduling in time and/or frequency.

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| **Agreement**If coordinated scheduling in time and/or frequency is supported for gNB-to-gNB CLI handling and UE-to-UE CLI handling, the following is recommended to be specified* Information exchange of semi-static cell-specific SBFD time and frequency location configuration
 |

* + 1. **UE-to-UE co-channel CLI measurement**

The following are discussed for UE-to-UE co-channel CLI measurement

* **Issue#1: Whether support L1/L2 based UE-to-UE co-channel CLI measurement and reporting or L3 based UE-to-UE co-channel CLI measurement and reporting**

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| --- |
| **Agreement**Consider the following alternatives for down selection in RAN1#117.**Alt.1:**If L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework are supported for UE-to-UE CLI handling, the following are recommended to be specified * Measurement resources
	+ Periodic, semi-persistent, or aperiodic measurement resource (set) i.e., SRS-RSRP resource or CLI-RSSI resource
* Measurement reporting
	+ Periodic, semi-persistent or aperiodic reporting on PUCCH/PUSCH
	+ New report quantities: e.g L1-SRS-RSRP, L1-CLI-RSSI and/or RS indexes
	+ UCI bits generation
	+ UCI omission rule
	+ Priority rules for multiple CSI reporting
	+ CSI processing unit and CPU occupation rule
	+ Timeline and related UE behaviours
* CLI measurement accuracy requirement [RAN4]

**Alt.2:** If L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework are supported for UE-to-UE CLI handling, the following are recommended to be specified * Measurement resources
	+ Periodic, semi-persistent, or aperiodic measurement resource (set), i.e., CLI-IMR
* Measurement reporting
	+ CSI measurement procedure integrating CLI measurement
	+ Note: Reuse the existing periodic, semi-persistent and aperiodic reporting on PUCCH/PUSCH
	+ Note: Reuse the existing report quantities, i.e., CQI, L1-SINR, and the new measurements on CLI-IMR are included in the interference measurement term for the existing report quantities

**Alt.3:**If L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework are supported for UE-to-UE CLI handling, the following are recommended to be specified * Measurement resources
	+ Periodic, semi-persistent, or aperiodic measurement resource (set) i.e., SRS-RSRP resource or CLI-RSSI resource or CLI-IMR
* Measurement reporting
	+ Periodic, semi-persistent or aperiodic reporting on PUCCH/PUSCH
	+ New report quantities: e.g. L1-SRS-RSRP, L1-CLI-RSSI and/or RS indexes
	+ UCI bits generation
	+ UCI omission rule
	+ Priority rules for multiple CSI reporting
	+ CSI processing unit and CPU occupation rule
	+ Timeline and related UE behaviours
	+ CSI measurement procedure integrating CLI measurement
* CLI measurement accuracy requirement [RAN4]

Note: The new measurements on CLI-IMR are included in the interference measurement term for the existing report quantities, i.e., CQI, L1-SINR.**Conclusion**L1 based UE-to-UE CLI measurement and reporting based on event triggered based reporting are not considered for UE-to-UE CLI handling in Rel-19. |

Based on companies’ input, the following issues are discussed

* **L1 based UE-to-UE co-channel CLI measurement and reporting**

The main benefits to support L1 based UE-to-UE co-channel CLI measurement include short term interference measurement and lower CLI measurement latency.

For the three alternatives for L1 based UE-to-UE co-channel CLI measurement and reporting, companies have different views. Some companies think Alt.1 is enough, while other companies think Alt.1 is only used for aggressor UE identification and Alt.3 can be used for further improving performance including link adaptation. **Panasonic** thinks Alt.2 can work sufficiently and the specification impact is smaller than Alt.1.

* **Alt.1: CATT, CMCC, Interdigital, LG, New H3C, Nokia, Transsion Holdings, Xiaomi**
* **Alt.2: NTT DOCOMO, Panasonic, Vivo/Ericsson** (if L1 based UE-to-UE CLI measurement and reporting is supported)
* **Alt.3: CEWiT, CMCC, Interdigital, OPPO, Sony**

In addition, **LG and Samsung** have some concerns on the potential specification impact of Alt.1 and Alt.3. **Samsung** thinks introduction of the L1-based CLI reporting feature should not affect the **CSI processing timeline and UE CSI reporting behavior**. The motivation to consider new/additional **UCI omission/priority rules** in L1 in the normative stage is unclear when the RRC-configured CSI reporting mode can be used to configure the desired UE reporting behavior. It is also unclear if Alt.2 is feasible when considering typical CSI processing capabilities in the UE.**LG** thinks at least the following enhancements are unnecessary and should be deprioritized.

* ***UCI bits generation***
* ***UCI omission rule***
* ***CSI measurement procedure integrating CLI measurement***
* ***Timeline and related UE behaviors***

**Qualcomm** suggests leveraging existing framework of L1 beam reporting to reduce the spec impact, e.g. UCI bits generation similar as L1 beam reporting, remove UCI omission rule as for single part reporting, single CPU occupation, timeline similar as L1 beam reporting (no UE behaviors update).

**Deutsche Telekom, Huawei, Hisilicon, Ericsson, Vivo** do not support L1 based UE-to-UE co-channel CLI measurement and reporting.

**Deutsche Telekom** thinks RAN1 should stop the work on UE-UE CLI interference mitigation**.** They observed that for the likely SBFD uses cases UE-UE CLI might be not such relevant and legacy techniques such as e.g., scheduling based on ACK/NACK can be used to further reduce the impact of CLI.

**Vivo** thinks Compared to L3 UE-to-UE CLI measurement, the motivation to support L1 UE-to-UE CLI measurement needs to be further clarified.

**Huawei, HiSilicon** observed that L3 UE-to-UE CLI measurement based coordinated scheduling has similar DL average-UPT gain compared to L1 UE-to-UE CLI measurement based coordinated scheduling for all load levels.

**Ericsson** would like to reuse existing L3 measurement reporting with enhancements to measurements and reporting to cater to SBFD.

Overall, there is a good support of L1 based UE-to-UE co-channel CLI measurement and reporting.

**Proposal 4-2**

Agree the updated Alt.1 and Alt.3 (changes in red) for L1 based UE-to-UE co-channel CLI measurement and reporting

**Alt.1:**

If L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework are supported for UE-to-UE CLI handling, the following are recommended to be specified

* Measurement resources
	+ Periodic, semi-persistent, or aperiodic measurement resource (set) i.e., SRS-RSRP resource or CLI-RSSI resource
* Measurement reporting
	+ Periodic, semi-persistent or aperiodic reporting on PUCCH/PUSCH
	+ New report quantities: e.g. L1-SRS-RSRP, L1-CLI-RSSI and/or RS indexes
	+ UCI bits generation
	+ ~~UCI omission rule~~
	+ Priority rules for multiple CSI reporting
	+ ~~CSI processing unit and CPU occupation rule~~
	+ ~~Timeline and related UE behaviours~~
	+ Note: The existing UCI omission rule, CSI processing unit, CPU occupation rule and timeline for L1 beam reporting are reused for L1 UE-to-UE CLI measurement and reporting.
* CLI measurement accuracy requirement [RAN4]

**Alt.3:**

If L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework are supported for UE-to-UE CLI handling, the following are recommended to be specified

* Measurement resources
	+ Periodic, semi-persistent, or aperiodic measurement resource (set) i.e., SRS-RSRP resource or CLI-RSSI resource or CLI-IMR
* Measurement reporting
	+ Periodic, semi-persistent or aperiodic reporting on PUCCH/PUSCH
	+ New report quantities: e.g. L1-SRS-RSRP, L1-CLI-RSSI and/or RS indexes
	+ UCI bits generation
	+ ~~UCI omission rule~~
	+ Priority rules for multiple CSI reporting
	+ ~~CSI processing unit and CPU occupation rule~~
	+ ~~Timeline and related UE behaviours~~
	+ Note: The existing UCI omission rule, CSI processing unit, CPU occupation rule and timeline for L1 beam reporting are reused for L1 UE-to-UE CLI measurement and reporting.
* CLI measurement accuracy requirement [RAN4]

Note: The new measurements on CLI-IMR are included in the interference measurement term for the existing report quantities, i.e., CQI, L1-SINR.

**Companies are invited to provide views on the above proposal.**

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| **Companies** | **Views** |
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* **Whether support L2 based UE-to-UE co-channel CLI measurement and reporting or not**

In RAN1#116bis, the following proposal was discussed.

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| **Proposal 3-2b**If L2 based UE-to-UE CLI measurement and reporting based on event triggered based reporting are supported for UE-to-UE CLI handling, the following are recommended to be specified* Measurement resources
	+ Periodic or semi-persistent measurement resource, i.e., SRS or CLI-RSSI resource
* Measurement reporting
	+ Definition and configuration of triggering conditions for CLI reporting
	+ CLI reporting quantities, e.g., SRS-RSRP, CLI-RSSI, RS indexes
* Notification to the gNB about CLI measurement reporting
* MAC CE for CLI measurement report [RAN2]
* CLI measurement accuracy requirement [RAN4]
 |

In this meeting, **CEWiT, Interdigital, MediaTek, Qualcomm, Spreadtrum, Xiaomi** propose to support L2 based UE-to-UE CLI measurement and reporting.

**CEWiT:** Support L2 based event triggered UE-to-UE CLI measurement and reporting.

**Interdigital:** In addition to periodic type of CLI reporting, support L2-event based CLI reporting.

**MediaTek:** Support mechanisms to enable L2 based autonomous reporting of UE-to-UE CLI by SBFD aware UE.

**Qualcomm:** Support RAN1 specification of enhancements of co-channel CLI measurement and reporting in R19 work item:

* For L1/L2 UE-to-UE CLI measurement, periodic, semi-persistent, or aperiodic measurement resource.
* For L1/L2 UE-to-UE CLI reporting, periodic, semi-persistent, aperiodic reporting.
* Use existing CSI framework as the baseline

**Spreadtrum:** L2/L3 based UE-to-UE CLI reporting can be taken into account for down-selection.

* Do not support to specify L1/L2 based UE-to-UE CLI measurement and reporting.

**Xiaomi:** For L2 based CLI reporting, the event-triggered reporting can be further considered.

There is some support of L2 based UE-to-UE CLI measurement and reporting, mainly related to event triggered based reporting. From the moderator’s point of view, the benefit of support L2 based measurement and reporting is that the specification impact on the physical layer can be simplified. In addition, there could be benefit of by reducing the reporting overhead since the UE only report the measurement results when a certain condition is met. On the other hand, L2 based measurement and reporting can also be viewed as a further optimization of L1 based measurement and reporting. Therefore, no sperate proposal is made.

* **L3 based UE-to-UE co-channel CLI measurement and reporting**

In this meeting, **Ericsson, Panasonic, Spreadtrum, Vivo, Huawei** propose to support L3 based UE-to-UE CLI measurement and reporting.

Ericsson: Reuse existing L3 measurement reporting with enhancements to measurements and reporting to cater to SBFD.

For UE-UE CLI mitigation schemes, do not support information exchange of SRS configuration and/or UE timing information.

**Panasonic:** L3 filtering calculation should be separated for SBFD slot/symbol and slot/symbol, i.e., SBFD aware UEs keep two calculation results, one for SBFD slots/symbols and one for non-SBFD slots/symbols. In addition, CLI leakage from UL transmission on UL subband is asymmetrical in the frequency direction, i.e., the effect of CLI leakage is different for each DL subband. Therefore, separating the L3 filtering calculations for each DL subband would be beneficial.

**Spreadtrum:** L2/L3 based UE-to-UE CLI reporting can be taken into account for down-selection. CLI measurement and reporting latency can also be reduced by L3 reporting enhancement such as shorten the report interval for L3 based UE-to-UE CLI reporting with minimal changes.

**Vivo**: If enhancements to L3 based UE-to-UE CLI measurement and reporting are supported for UE-to-UE CLI handling, the following are recommended to be specified.

- Information exchange of SRS resource configurations among gNBs

- Reduce the value of ReportInterval for L3 based UE-to-UE CLI measurement

- CLI measurement accuracy requirement [RAN4]

- CLI measurements results exchange among gNBs, e.g. CLI-RS index with larger CLI

**Huawei:** Support L3 based UE-to-UE CLI measurement and reporting by reducing the candidate values of ReportInterval.

**Proposal 4-3**

If enhancements to L3 based UE-to-UE CLI measurement and reporting are supported for UE-to-UE CLI handling, the following are recommended to be specified

* Reduce the value of *ReportInterval* for L3 based UE-to-UE CLI reporting

**Companies are invited to provide views on the above proposal.**

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| **Companies** | **Views** |
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* **Issue#2: SBFD specific measurement issue**

**Issue#2-1: Measurement behavior within the active DL BWP**

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| **Agreement**For SBFD aware UEs, CLI measurements is performed within the active DL BWP and the following can be considered* Method#1: UE measures RSSI within DL subband
* Method#2: UE measures RSRP of aggressor UE within UL subband
* Method#3: UE measures RSSI within UL subband
* Method#4: UE measures RSSI within guard band, if guard band exists

Note: If DL subband, UL subband or guard band is outside the active DL BWP, the above methods does not apply.Note: Method#4 does not imply that guard band is explicitly configured. |

For Method#1, **CATT, Interdigital, NEC, NTT DOCOMO, OPPO, Qualcomm, Spreadtrum, Xiaomi, ZTE, vivo** proposed to support it.

For Method#2, **CATT, CEWiT, InterDigital Inc, NEC, ZTE, Vivo, Xiaomi, Samsung, Nokia, Qualcomm** proposed to support it.

For Method#3, **CATT, InterDigital Inc, ZTE, Xiaomi, Nokia, Qualcomm** propose to support it.

For Method#4, **CATT, InterDigital Inc, Xiaomi, Nokia** proposed to support it.

**Issue#2-2: Measurement reporting across DL subbands**

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| **Agreement**For UE-to-UE CLI-RSSI measurement/report across downlink subbands, the following methods are discussed by companies. Note that Alt #1 and Alt #2 are supported in existing specifications.- Alt #1: separate CLI-RSSI measurement resources/reports in each DL subband.- Alt #2: CLI-RSSI measure/report in one DL subband only.- Alt #3: CLI-RSSI measurement/report based on non-contiguous CLI-RSSI resource across downlink subbands. |

For Alt #1, **CATT, CEWiT, NEC, NTT DOCOMO, OPPO, Qualcomm, ZTE, vivo** proposed to support it.

For Alt #2, **NEC** propose to support it.

For Alt #3, **Interdigital, Lenovo, Qualcomm** propose to support it.

**Issue#2-3: Subband-based CLI reporting**

**Xiaomi, OPPO, InterDigital, Sony, Panasonic, Media Tek, NEC and Nokia** propose to consider subband CLI reporting.

**Xiaomi:** Subband CLI reporting can be considered for UE-to-UE CLI mitigation.

**OPPO:** To be more explicit, report quantity CLI-RSSI and SRS-RSRP can be newly-added in CSI report associated with its measurement resource, which can be reported in subband with existing report quantities because the CLI may be non-uniform across different subband.

**InterDigital:** In UE-to-UE CLI-RSSI measurement techniques within active DL BWP, support measuring and reporting delta-CLI-RSSI based on differences in measured CLI-RSSI in subband-edge or guard-bands with measured CLI-RSSI in the middle of the DL subband.

**Sony** propose to support finer frequency granularity for CLI measurement and reporting, by dividing the BWP or the victim subband into smaller frequency blocks, where CLI measurement and reporting are performed on each frequency block.

**Panasonic** also proposes to support subband-based (shown as following figure) CLI measurement and reporting for UE-to-UE CLI handling.

**MediaTek:** Support CLI measurement on finer RB Groups on the UL subband of SBFD slots

**NEC:** Consider the CSI report size enhancement for SBFD operation and different types of CLI interference. Consider the non-uniform CLI bandwidth in inter-subband CLI measurement/report.

**Nokia:** Support the introduction of mini-subbands measurements for CLI-RSSI based measurements.

It is the moderator’s understanding that this can be discussed in the details of L1 based UE-to-UE CLI measurement and reporting if supported, e.g., whether there is a need to report the subband L1-SRS-RSRP or L1-CLI-RSSI. Therefore, no separate proposal is made.

* **Issue#3: Timing alignment issue for UE-to-UE co-channel CLI and channel measurement**

**Support: Apple, ZTE, ETRI, Lenovo**

**Apple**: To assure symbol level alignment at victim UEV, aggressor UEA is indicated to hold two different TAs:

* one TA for symbols on which TRP is doing legacy TDD, another TA for symbols on which TRP is doing SBFD or dynamic TDD.



**ZTE** proposes to exchange timing related information for reception of measurement RS. In Rel-16 CLI, the time offset is derived by UE implementation. the victim UE cannot derive the time offset accurately by itself, especially in the typical deployment of Rel-19 SBFD. Much more measurements are needed in SBFD compared with Rel-16 CLI.



**ETRI:** It is necessary to investigate specification impacts for timing alignment issues for UE-to-UE CLI measurement and reporting (e.g., timing synchronization between victim UE and aggressor UE for CLI-RSRP measurement, victim UE’s two different reception timings for CLI-RS and DL).

To ensure accurate RSRP and channel measurement using CLI-RS, it is necessary to consider adjusting the aggressor UE’s transmission timing of CLI-RS and/or victim UE’s reception timing of CLI-RS.

**Lenovo:** To handle SRS reception timing misalignment in UE-to-UE CLI measurements, support signalling and information exchange for assisting the victim UE with SRS reception timing and/or indicating to the aggressor UE the SRS transmission timing.

* + 1. **others**

**MedieTek**: Support muting of the first UL symbol in the first SBFD slot after a non-SBFD (DL-only) slot.

**NEC**:

* Differentiation of the BFR caused by CLI with the beam blockage is needed.
* Eliminating the effect of the CLI on BFR for BFD and NBI should be considered.
1. **Down-selection of CLI handling schemes**

**Proposal 5-1**

For enhancements for CLI handling, the following are recommended from RAN1's perspective:

* Specify information exchange of semi-static cell-specific SBFD time and frequency location configuration (RAN3)
* Specify information exchange of measurement resource configuration, i.e., SSB and/or periodic NZP CSI-RS (RAN3)
* Specify UL resource muting for PUSCH, including (RAN1)
	+ UL resource muting pattern configuration for PUSCH, assuming comb-2 for DFT-S-OFDM and [comb-2/PT-RS/CSI-RS] for CP-OFDM
	+ PUSCH resource mapping, i.e., rate-matching around the muted REs
	+ UCI resource determination in symbols with muted REs
	+ Power allocation in symbols with muted REs
	+ Note: UL resource muting does not apply for PUSCH transmission during random access procedures.
* Specify L1 based UE-to-UE CLI measurement and reporting based on existing CSI framework, including (RAN1)
	+ Measurement resource
		- Periodic, semi-persistent, or aperiodic measurement resource (set) i.e., SRS-RSRP resource or CLI-RSSI resource
	+ Measurement reporting
		- Periodic, semi-persistent and aperiodic reporting on PUCCH/PUSCH
		- New report quantities: e.g., L1-SRS-RSRP, L1-CLI-RSSI and/or RS indexes
		- UCI bits generation
		- UCI omission rule
		- Priority rules for multiple CSI reporting
		- CSI processing unit and CPU occupation rule
		- Timeline and related UE behaviors

**Companies are invited to provide views on the direction of the above proposal**

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|  | **Companies** |
| Support |  |
| Not support |  |

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| **Companies** | **Views** |
| Moderator | This is a draft compromised proposal for the down-selection of CLI handling schemes considering the companies’ input and the workload. The first two bullets fall into the RAN3 domain while the last two bullets propose two schemes for gNB-to-gNB CLI handling and UE-to-UE CLI handling respectively that require normative work evolving RAN1. This proposal can be updated if there is further agreement in section 3 and section 4. |
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1. **Contact person**

Please provide/update the information of the contact person in the following table to facilitate the discussions.

|  |  |  |
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