**3GPP TSG RAN WG1 #109-e R1-220XXXX**

**e-Meeting, May 9th – 20th, 2022**

**Agenda Item: 9.3.3**

**Source: Moderator (LG Electronics)**

**Title:** **Summary #1 of [109-e-R18-Duplex-04] Email discussion on dynamic/flexible TDD**

**Document for:** **Discussion and Decision**

# Introduction

The following email thread for AI 9.3.3 Potential enhancements on dynamic/flexible TDD is announced by chair:

[109-e-R18-Duplex-04] Email discussion on dynamic/flexible TDD by May 20 – Hyunsoo (LGE)

* Check points: May 12, May 18, May 20

In this documentation, proposals based on the technical documentation submitted in RAN1#109-e and the email discussion on dynamic/flexible TDD are summarized.

# Deployment Scenarios for Potential Enhancement on Dynamic/flexible TDD

## Deployment scenarios

### *Submitted proposal*

|  |  |
| --- | --- |
| **ZTE [2]** | ***Proposal 1****: RAN1 studies the following two kinds of dynamic/flexible TDD in Rel-18 Duplex.*   * ***Understanding#1 (1st priority)****: Two cells are configured with different semi-static slot format configurations.* * ***Understanding#2 (2nd priority)****: At least one cell is configured with L1 slot format indication, i.e., SFI.*   ***Proposal 3****: During the interference cancellation/management study, the impact to the legacy macro base stations should be minimized.* |
| **vivo [7]** | ***Proposal 1:*** *For Rel-18 enhancements on dynamic/flexible TDD, Hetnet scenario can be studied.* |
| **xiaomi [9]** | ***Proposal 1:*** *Further evaluation on the two-layer layout scenario should be prioritized in Rel-18, where the macro layer operates with semi-static TDD and the small cell layer operates with dynamic TDD.* |
| **Samsung [10]** | ***Observation 2:*** *TDD urban micro deployments experience high CLI and less variation of the offered UL/DL traffic ratio*  ***Observation 3:*** *TDD indoor hotspot and factory deployments offer most potential for improved configuration flexibility to use dynamic TDD operation* |
| **Apple [17]** | ***Proposal:*** *The scope of R18 study on dynamic TDD shall be limited to cell-center aggressor UE with reduced transmit power.* |
| **Nokia, Nokia Shanghai Bell [20]** | ***Observation 1:*** *Dynamic TDD operation for FR1 deployments is primarily applicable for low power gNBs, while being problematic for high power macro gNBs without causing adjacent channel coexistence problems, i.e. macro gNB use static and fully aligned/synchronized TDD radio frame configurations.*  ***Proposal 1:*** *In line with Rel-16 TDD coexistence findings (3GPP TR 38.828), it is proposed that the FR1 macro gNBs use a static DL-heavy TDD radio frame configuration, while low power gNBs are allowed to use dynamic TDD, where the ratio of DL and UL resources is dynamically adjusted.* |
| **Qualcomm Incorporated [30]** | ***Observation 1:*** *For FR1, deployments scenario with large Tx Power BS suffers from inter-gNB interference.*  *• In general, inter-UE CLI is not an issue except for macro-to-indoor deployment.*  ***Observation 2:*** *For FR2, Dynamic TDD is possible under careful assumption of layout and power parameterization to avoid inter-gNB interference.*  ***Observation 6:*** *Link budget analysis shows that SB-based dynamic TDD is feasible for macro-cell deployment.*  ***Observation 7:*** *Qualcomm OTA test network validated the feasibility of dynamic TDD in macro-cell deployment using subband half-duplex.*  ***Proposal 1:*** *The focus of Rel-18 study on potential enhancement for dynamic TDD should be limited to co-channel intra-operator deployment.*  ***Proposal 2:*** *Support subband half-duplex as solution to enable dynamic TDD at least for FR1* |

### *Summary*

Companies considers Hetnet scenario as a deployment scenarios for study of potential enhancement of dynamic/flexible TDD [2][9][10][20].

* Macro layer operates with semi-static TDD and the small cell layer operates with dynamic TDD [9]
* The FR1 macro gNBs use a static DL-heavy TDD radio frame configuration, while low power gNBs are allowed to use dynamic TDD, where the ratio of DL and UL resources is dynamically adjusted [20]
* TDD indoor hotspot and factory deployments offer most potential for improved configuration flexibility to use dynamic TDD operation [10]

Also, it is proposed to consider cell-center aggressor UE with reduced transmit power [17]. And the other proposal is to support subband half-duplex as solution to enable dynamic TDD at least for FR1 [30]

### *1st Round Discussion*

Initial FL Proposal #1-1

Co-channel HetNet scenario is considered as a deployment scenarios for study of potential enhancement of dynamic/flexible TDD.

* Macro layer operates with semi-static TDD and the small cell layer operates with dynamic TDD

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

|  |  |
| --- | --- |
| **Companies** | **Views** |
|  |  |
|  |  |
|  |  |

# Cross Link Interference Handling

## Interference Scenarios for potential enhancement on dynamic/flexible TDD

### *Submitted proposal*

|  |  |
| --- | --- |
| **Huawei, HiSilicon [1]** | ***Observation 2:*** *For flexible TDD scenario, the downlink cross link interference from the interfering cell consists of various downlink signals and are precoded differently according to the signal type, user etc.*  ***Observation 3:*** *Various types of downlink interference signal with various precoding will result in various downlink cross link interference and should be considered separately at the victim uplink receiver.* |
| **ZTE [2]** | ***Proposal 2****: The following interferences are to be considered for dynamic/flexible TDD study.*   * *gNB-gNB co-channel intra-subband interference;* * *UE-UE co-channel intra-subband interference;* * *gNB-gNB adjacent-channel interference;* * *UE-UE adjacent-channel interference;* * *gNB-UE co-channel intra-subband interference (Legacy);* * *UE-gNB co-chanel intra-subband interference (Legacy).* |
| **vivo [7]** | ***Observation 1:*** *For dynamic TDD, co-channel CLI at gNB and UE side is the main challenge.*  ***Proposal 2:*** *Considering the CLI issues exist in both dynamic TDD and SubBand Full Duplex (SBFD) operation, the unified solution for mitigate the CLI should be strived for both SBFD and dynamic TDD.* |
| **OPPO [12]** | ***Proposal 2:*** *It should be clarified whether the dynamic/flexible TDD (from UE/gNB perspective) and subband non-overlapping full duplex (from gNB-only perspective) should be assumed to operate together.*  *• If yes, interference mitigation to handle inter-gNB/inter-UE CLI from adjacent full-duplex sub-band need to be studied.*  *• If yes, it should be further determined whether Rel-18 study of dynamic/flexible TDD should assume full-duplex being transparent to gNB-side enhancement (if any) for dynamic/flexible TDD.* |
| **CEWiT [28]** | ***Observation 1:*** *Networks with SBFD enabled gNBs are subject to intra-cell UE-to-UE CLI, in addition to the CLI present in flexible TDD system.* |
| **Qualcomm Incorporated [30]** | ***Observation 3:*** *Rel-18 study on potential enhancement of dynamic TDD suggests utilizing the outcome of Rel-15 and Rel-16 studies outcome avoid repetition of same discussion, e.g., inter-operator Dynamic TDD coexistence study.* |

### *Summary*

It is considered that most of interference scenario is shared for both the subband non-overlapping full duplex and dynamic/flexible TDD. Hence, clarification which interference scenario(s) is/are considered for studying potential enhancement of dynamic/flexible TDD is required.

In [2], it is proposed that the following interferences are to be considered for dynamic/flexible TDD study.

* gNB-gNB co-channel intra-subband interference
* UE-UE co-channel intra-subband interference
* gNB-gNB adjacent-channel interference
* UE-UE adjacent-channel interference
* gNB-UE co-channel intra-subband interference (Legacy)
* UE-gNB co-chanel intra-subband interference (Legacy)

In [7], it is mentioned that for dynamic TDD, co-channel CLI at gNB and UE side is the main challenge. Also, in [30], it is proposed to avoid repetition of same discussion, e.g., inter-operator Dynamic TDD coexistence study.

### *1st Round Discussion*

Initial FL Proposal #2-1

Following interference scenarios can be considered for study of dynamic/flexible TDD study:

* gNB-to-gNB co-channel intra-subband interference
* UE-to-UE co-channel intra-subband interference
* FFS: gNB-to-gNB adjacent-channel interference
* FFS: UE- to-UE adjacent-channel interference

**Companies are invited to provide views on the above proposal. Also, companies are encouraged to provide views which interference scenarios should be considered for dynamic/flexible TDD in agenda item 9.3.3.**

|  |  |
| --- | --- |
| **Companies** | **Views** |
|  |  |
|  |  |
|  |  |

## CLI handling for dynamic/flexible TDD

### *Submitted proposal*

|  |  |
| --- | --- |
| **ZTE [2]** | ***Proposal 4****: RAN1 discusses how to coordinate on interference cancellation/management for subband full duplex (AI 9.3.2) and dynamic/flexible TDD (*AI 9.3.3*) to avoid duplicated discussion.* |
| **Spreadtrum Communications [5]** | ***Observation 3:*** *Interferences in dynamic/flexible TDD scenarios is a subset of that in SBFD scenarios, a unified CLI mechanism for dynamic/flexible TDD and SBFD can be studied.* |
| **vivo [7]** | ***Proposal 2:*** *Considering the CLI issues exist in both dynamic TDD and SubBand Full Duplex (SBFD) operation, the unified solution for mitigate the CLI should be strived for both SBFD and dynamic TDD.* |
| **Samsung [10]** | ***Observation 5:*** *SBFD is a potential CLI mitigation solution for urban macro and micro TDD deployments* |
| **Ericsson [16]** | ***Observation 1:*** *Dynamic/flexible TDD is a special case of subband full duplex (SBFD) where the UL subband size (0% or 100%) is different within and between operators.*  ***Proposal 1:*** *To study in a targeted way whether or not enhancements of dynamic/flexible TDD are beneficial, define a phased study approach based on a deployment with two SBFD operators with different UL subband sizes. Each phase introduces increasing sources of difference first between and then within each operator's network. In the final phase, full dynamic TDD is studied, which is equivalent to dynamic adjustment of the UL subband size between 0% and 100% of the carrier bandwidth.* |
| **Lenovo [23]** | ***Proposal 4:*** *The CLI handling for dynamic/flexible TDD can be reused as much as possible for CLI handling for full duplex. On the other hand, specific schemes are needed to handle the more complex CLI in full duplex.* |
| **CEWiT [28]** | ***Proposal 1:*** *Consider solutions proposed for CLI management in flexible TDD as the starting point for CLI management in SBFD enabled networks.* |

### *Summary*

CLI handling method are discussed in two agenda items (*AI 9.3.2* and *AI 9.3.3*). Based on this understanding, it is proposed to discuss how to coordinate on interference cancellation/management for the subband non-overlapping full duplex and dynamic/flexible TDD to avoid duplicated discussion [2].

Also, it is proposed that the unified solution for mitigate the CLI should be strived for both the subband non-overlapping full duplex and dynamic TDD because interferences in dynamic/flexible TDD scenarios is a subset of that in the subband non-overlapping full duplex [5][7]. And it is proposed that the CLI handling for dynamic/flexible TDD can be reused as much as possible for CLI handling for the subband non-overlapping full duplex [23]. In addition, it is proposed to consider solutions proposed for CLI management in flexible TDD as the starting point for CLI management in the subband non-overlapping full duplex enabled networks [28].

In summary, it can be considered that CLI handling method discussed for dynamic/flexible TDD can be a starting point of discussion of CLI handling for the subband non-overlapping full duplex.

### *1st Round Discussion*

Initial FL Question #3-1

How to coordinate on discussion of CLI handling for in the subband non-overlapping full duplex in AI 9.3.2 and for dynamic/flexible TDD AI 9.3.3?

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

|  |  |
| --- | --- |
| **Companies** | **Views** |
|  |  |
|  |  |
|  |  |

## Inter-cell gNB-to-gNB CLI

### *Submitted proposal*

|  |  |
| --- | --- |
| **Huawei, HiSilicon [1]** | ***Observation 1:*** *IRC receiver is essential to suppress the cross link interference while minimizing the impact on the downlink performance of the Macro cells.*  ***Proposal 1:*** *Potential enhancements on the interference covariance matrix estimation for the IRC receiver should be studied in Rel-18 dynamic/flexible TDD enhancement.*  ***Proposal 2:*** *Study the feasibility and performance of advanced IRC receivers based on muting resources for interference covariance matrix estimation considering different interference characteristics.*  ***Proposal 3:*** *Study the feasibility and performance of Tx beamforming based on gNB-to-gNB interference channel estimation.* |
| **ZTE [2]** | ***Proposal 5****: Take the Rel-16 UE-UE CLI and RIM as a starting point for Rel-18 enhancements on dynamic/flexible TDD.*  ***Proposal 6****: Rel-16 RIM Framework-1 can be considered as baseline for gNB-gNB interference management for Rel-18 dynamic/flexible TDD.*  ***Proposal 7****: The existing DL RS (e.g., SSB, CSI-RS) can be reused as measurement RS for gNB-gNB CLI for Rel-18 dynamic/flexible TDD.*   * *FFS: determination of receiving timing of the victim.*   ***Proposal 8****: UL rate matching/cancellation mechanism can be defined for more accurate gNB-gNB measurement.* |
| **Spreadtrum Communications [5]** | ***Observation 1:*** *Enhancements on dynamic/flexible TDD can focus on inter-gNB CLI mitigation with high priority and further signaling design, to better support this existing feature to be implemented.*  ***Proposal1:*** *Focus on the following aspects of dynamic/flexible TDD enhancement*   * *CLI analysis* * *CLI handling (gNB/UE)*   ***Proposal2:*** *gNB-to-gNB CLI management should be firstly studied and UE-to-UE CLI measurement/reporting can also be enhanced.* |
| **CATT [6]** | ***Proposal 2:*** *TRP-to-TRP CLI handling is prioritized for Rel-18 duplex enhancement.*  ***Proposal 3:*** *Prioritize TRP-to-TRP CLI handling scheme which are applicable to both subband non-overlapping full duplex and dynamic/flexible TDD.*  ***Proposal 4:*** *Deprioritize advanced receiver based interference cancellation solution in CLI handling study.*  ***Proposal 5:*** *Consider power based interference measurement at gNB side in Rel-18.* |
| **xiaomi [9]** | ***Proposal 2:*** *The Rel-18 study on dynamic/flexible TDD should focus on the following aspects:*   * *Inter-gNB CLI* * *Further enhancement on the inter-UE CLI*   ***Proposal 4:*** *Network listening based interference measurement can be further studied.*  ***Proposal 5:*** *The candidate solutions for CLI handling studied in Rel-14 duplex can be the baseline for further investigation in Rel-18.* |
| **Samsung [10]** | ***Observation 1:*** *gNB-to-gNB interference dominates co- and adjacent channel CLI in TDD urban macro deployments*  ***Observation 4:*** *TDD base stations can measure DL signals received from neighbor cells of the same or different operator using implementation techniques*  ***Observation 7:*** *The existing R16 RIM-RS type 1 or 2 are not suitable for purpose of intra-operator gNB-to-gNB (DL-to-UL) CLI measurements in NR mid-band small deployments*  ***Proposal 1:*** *RAN1 to study and evaluate the benefits of a new DL reference signal design to support intra-operator gNB-to-gNB (DL-to-UL) CLI measurements*  ***Proposal 2:*** *RAN1 to study and evaluate the benefits of providing desired/prohibited beam indications using Xn-AP to support intra-operator gNB-to-gNB (DL-to-UL) CLI mitigation* |
| **SHARP Corporation [13]** | ***Proposal 1:*** *RAN1 further study how to handle TRP-to-TRP/UE-to-UE intra-cell intra-subband CLI under dynamic/flexible TDD.*  ***Proposal 2:*** *RAN1 further study how to handle gNB-to-gNB/UE-to-UE inter-cell intra-subband CLI under dynamic/flexible TDD.* |
| **CMCC [18]** | ***Proposal 2:*** *For inter-gNB CLI handling, the following aspects can be further studied:*   * *How to handle the timing misalignment between the received UL transmission of target UE and the CLI interference from aggressor gNB? e.g., set via information n-TimingAdvanceOffset.* * *To enable advanced beamforming algorithms to suppress the gNB-gNB CLI, how to measure the effective channel () between aggressor gNB and victim gNB?*   + *Potential resources muting schemes in UL transmission or more accurate gNB-gNB CLI measurement.* * *Inter-gNB coordination in time-domain, frequency-domain, spatial-domain, and power domain.*   + *Backhaul signalling enhancement to support inter-vendor cooperation.* |
| **Nokia, Nokia Shanghai Bell [20]** | ***Proposal 3:*** *For studying inter-cell CLI for traditional TDD, we suggest focusing on gNB-to-gNB CLI mitigation. This is motivated by the higher gNB transmit powers and antenna gains as compared to that of UEs.*  ***Observation 5:*** *The UL performance of the small cells with dynamic TDD is severely impacted by the strong gNB-to-gNB CLI from the macro layer with DL-heavy TDD configuration. At least 20 dB UL SINR improvement is needed to achieve decent UL performance in slots with gNB-to-gNB CLI.*  ***Observation 6:*** *The victim gNB is heavily impacted by the strongest CLI aggressor cell (normally the closest macro gNB), while the other aggressor cells provides much weaker CLI contributions. Enhancements to mitigate the CLI from the strongest aggressor cell are therefore sufficient to achieve good performance benefits.*  ***Proposal 4:*** *Enhanced gNB receivers should be considered as a possible solution for CLI mitigation, potentially assisted through information exchange of the CLI aggressor characteristics over the Xn interface (or the F1 interface in case of gNB-split architectures). Detailed solution is FFS.*  ***Proposal 5:*** *The potential benefits of boosting the UE Tx power in slots that are subject to high CLI should be further investigated as a potential method to boost UL received SINR at the victim cell. Detailed solution is FFS.*  ***Proposal 6:*** *The potential benefits of reducing the Tx power of the aggressor cell to reduce the CLI impact on the victim cell should be further studied, including potential coordination mechanisms between aggressor and victim cells (e.g. via the Xn or F1 interface) to orchestrate this. Detailed solution is FFS.* |
| **Lenovo [23]** | ***Proposal 3:*** *Consider using dedicated resources for inter-gNB CLI measurement as one potential area for inter-gNB CLI mitigation in dynamic/flexible TDD.* |
| **LG Electronics [24]** | **BS-to-BS CLI handling methods**  ***Proposal 2:*** *BS-to-BS CLI handling in Rel-14 NR SI and evaluation results of UE-to-UE CLI handling in Rel-16 should be a starting point of discussion for CLI handling.*  ***Proposal 3:*** *If necessary, discuss how to enable measurement for BS-to-BS CLI handing.* |
| **MediaTek Inc. [27]** | ***Observation 1:*** *Advanced receivers at the gNB can help to address the inter-gNB CLI but they require the exchange of interference parameters between gNBs.*  ***Observation 2:*** *Proactive mitigation schemes at the gNB can help to avoid the inter-gNB CLI but they require the exchange of coordination information between gNBs.*  ***Observation 3:*** *Proactive mitigation schemes may be more feasible for same operator scenario due to the need for coordination between gNBs.*  ***Observation 4:*** *Power control at the gNB may have a negative impact on DL performance.*  ***Observation 5:*** *Analog beam coordination between gNBs can be the most practical approach for inter-gNB CLI handling.*  ***Observation 6:*** *Measurement of inter-gNB CLI in NR duplex operation can be based on existing RSs, such as CSI-RS.*  ***Proposal 1:*** *Advanced receiver-based interference mitigation schemes could be considered in RAN1 to address the inter-gNB CLI.*  ***Proposal 2:*** *Proactive-based interference mitigation schemes such as DL power control and analog beamforming could be considered in RAN1 for same operator inter-gNB CLI handling.* |
| **Intel Corporation [29]** | ***Observation 1***  *• For inter-operator dynamic TDD operation, gNB-to-gNB CLI may be more pronounced due to asynchronous network.*  ***Observation 2***  *• Additional UE-to-UE and gNB-to-gNB CLI can be observed in case of NOFD with TDD operation.*  ***Proposal 1***  *• RAN1 to further study the potential benefit and specification impact for gNB-to-gNB CLI mitigation.* |
| **Qualcomm Incorporated [30]** | ***Observation 4:*** *SBHD can enable dynamic TDD and mitigate the impact of inter-gNB CLI.*  ***Observation 8:*** *In FR2, Dynamic TDD with misaligned slots format is possible where CLI could be mitigated with proper beam-pair selection and lower Tx power.*  ***Observation 12:*** *In Rel-16 RIM framework, this no support for beam-based interference detection and mitigation which may be needed for reducing inter-gNB CLI in dynamic/flexible TDD.*  ***Observation 13:*** *Rel-16 RIM-RS is used for conveying information about presence of ducting phenomenon and sufficiency of the applied interference mitigation. It was not intended for enabling inter-gNB CLI channel measurement.*  ***Proposal 6:*** *Support of inter-gNB coordination schemes for inter-gNB CLI mitigation in dynamic/flexible TDD to identify compatible inter-gNB beam pairs, which is enabled by inter-gNB CLI measurement and reporting per candidate DL/UL beam pair.*  ***Proposal 7:*** *Support of inter-gNB CLI channel measurement and reporting to neighbouring gNBs for enabling Tx/Rx beamforming or nulling.* |
| **NEC [11]** | ***Proposal 2:***  *■ For gNB-to-gNB CLI measurement,*  *- The measurement matric should be defined first, such as CLI sensitivity level.*  *- Study the resource configuration and RS sequence properties for IM resources to optimally handle TRP-TRP interference measurement.*  ***Proposal 3:***  *■ Following points need to be studied further for gNB-gNB interference mitigation using inter-gNB signaling*  *- CLI RS configuration needs to be implicitly or explicitly shared between gNBs for interference measurement*  *- Information exchange should allow victim gNB to identify the aggressor gNBs/TRPs identity from CLI RS measurement*  *- Assistance information sharing between gNBs to mitigate the interference observed by the victim gNB*  ***Proposal 4:***  *■ Unified design for CLI RS for gNB-to-gNB and UE-to-UE measurement should be considered to reduce the RS overhead.*  ***Proposal 5:***  *■ Sensing based scheme can be studied to avoid the CLI.*  ***Proposal 6:***  *■ Mechanisms to progressively mitigate interference based on measurement or report of measurement results should be studied.* |
| **NTT DOCOMO, INC. [19]** | ***Proposal 2:*** *Study on how much PSD difference is expected at gNB for FR1 and FR2, and if the difference is critical for the duplex operation, CLI handling at gNB is considered.* |

### *Summary*

In Rel-14 SI, gNB-to-gNB CLI handling scheme were studied. Followings are list of gNB-to-gNB CLI handling method studied in Rel-14 SI.

* List of Rel-14 NR SI:
  + - Advanced receiver (IC/IS), hybrid dynamic/static UL/DL resource assignment, scheduling coordination, beam coordination, link adaptation, power control, sensing, cell/TRP clustering, co-channel multiple connectivity, dynamic TDD type definition, load/link-based resource/scheduling adaptation

In Rel-16 CLI handling and RIM WI, gNB-to-gNB CLI handling was not specified and it was left up to network implementation. In Rel-18 Duplex Evolution SI, it is proposed to study gNB-to-gNB CLI handling, and the study with higher priority than enhancement of UE-to-UE CLI handling. Also, companies propose that gNB-to-gNB CLI handling in Rel-14 SI should be a starting point/baseline of discussion [1][2][6][9][24].

Several kinds of gNB-to-gNB CLI handling method such as gNB-to-gNB CLI measurement, Tx beamforming, Power control, Timing Alignment, Backhaul signaling enhancement, Advanced receiver, RIM are proposed as below:

* gNB-to-gNB CLI measurement
  + - The existing DL RS (e.g., SSB, CSI-RS) can be reused as measurement RS for gNB-to-gNB CLI [2]
    - UL rate matching/cancellation mechanism for more accurate gNB-to-gNB measurement [2]
    - Network listening based interference measurement [9]
    - New DL reference signal design to support intra-operator gNB-to-gNB CLI measurement [10]
    - Measure the effective channel between aggressor gNB and victim gNB [18]
    - Dedicated resources for inter-gNB CLI measurement [23]
    - How to enable measure for gNB-to-gNB CLI handling [24]
    - The measurement matric should be defined, such as CLI sensitivity level [11]
    - Resource configuration and RS sequence properties for IM resources to optimally handle TRP-TRP interference measurement [11]
    - Unified design for CLI RS for gNB-to-gNB and UE-to-UE measurement [11]
    - Sensing based scheme to avoid the CLI [11]
* Tx beamforming
  + - Feasibility and performance of Tx beamforming based on gNB-to-gNB interference channel estimation [1]
    - desired/prohibited beam indication using Xn-AP to support intra-operator gNB-to-gNB CLI mitigation [10]
    - advanced beamforming algorithm to suppress the gNB-to-gNB CLI [10]
    - Analog beamforming [27]
    - inter-gNB beam pairs [30]
* Power control
  + - Boosting the UE Tx power in slot that are subject to high CLI [20]
    - Reducing the Tx power of the aggressor cell to reduce the CLI impact on the victim cell [20]
    - DL power control [27]
    - low Tx power [30]
* Timing alignment
  + - Timing misalignment between the received UL transmsision of target UE and CLI interference from aggressor gNB [18]
* Backhaul signaling enhancement
  + - Inter-gNB coordination in time-domain, frequency domain, spatial-domain and power domain [18]
    - Potentially assisted through information exchange of the CLI aggressor characteristics over the Xn interface [20]
    - Inter-gNB CLI measurement and reporting to neighbouring gNBs [30]
    - CLI RS configuration implicitly or explicitly shared between gNBs for interference measurement [11]
* Advanced Receiver
  + - Advanced IRC receivers and muting resource for interference covariance matrix estimation [1]
    - Enhanced gNB receiver should be considered as a possible solution for CLI mitigation [20]
    - Advanced receiver-based interference mitigation scheme [27]
    - Deprioritize advanced receiver based interference cancellation solution [6]
* RIM
  + - Rel-16 RIM Framework-1 as baseline for gNB-to-gNB interference management [2]
    - R16 RIM-RS type 1 or 2 are not suitable for purpose of intra-operator gNB-to-gNB CLI measurement [10]

In order to avoid repeated discussion, it needs to make clear which issues can be discussed in Rel-18 Duplex Evolution SI, and it needs to be identified which methods addressed in Rel-14 SI can be re-open for discussion in Rel-18.

In addition, in order to avoid duplicate discussion of gNB-to-gNB CLI handling in both AI 9.3.2 and AI 9.3.3, it need to be identified which schemes should be studied for potential enhancement on dynamic/flexible TDD.

### *1st Round Discussion*

Initial FL Proposal #4-1

For study of potential enhancement on dynamic/flexible TDD, enhancement of gNB-to-gNB CLI handling is considered.

* At least gNB-to-gNB CLI measurement and Tx beamforming are studied.
* FFS: Power control, Advanced Receiver, RIM based solution

**Companies are invited to provide views on the above proposal. Also, companies are encouraged to provide views which schemes should be studied for dynamic/flexible TDD in agenda item 9.3.3.**

|  |  |
| --- | --- |
| **Companies** | **Views** |
|  |  |
|  |  |
|  |  |

## Inter-cell UE-to-UE CLI

### *Submitted proposal*

|  |  |
| --- | --- |
| **Huawei, HiSilicon [1]** | ***Observation 4:*** *The overhead of**UE-to-UE CLI measurement can be reduced by aperiodic measurement, and layer 1 based UE-UE CLI report could improve the accuracy of measurement.*  ***Proposal 4:*** *Study the feasibility and performance of UE-to-UE CLI measurement based on muting resources, aperiodic UE-to-UE CLI measurement and layer 1 based UE-UE CLI report.* |
| **ZTE [2]** | ***Proposal 5****: Take the Rel-16 UE-UE CLI and RIM as a starting point for Rel-18 enhancements on dynamic/flexible TDD.*  ***Proposal 9****: Timing alignment solution on measurement RS transmission for UE-UE CLI should be considered in Rel-18.* |
| **TCL Communication Ltd. [4]** | ***Proposal 2:*** *A specific cell area of a neighbor cell, where the UE existence may create negligible or insignificant CLI in a given cell can be consider as a beneficial cell area.*  ***Proposal 3:*** *Study CLI management in dynamic TDD based on the neigbour cells UEs existance in the beneficial cell areas.* |
| **Spreadtrum Communications [5]** | ***Proposal1:*** *Focus on the following aspects of dynamic/flexible TDD enhancement*   * *CLI analysis* * *CLI handling (gNB/UE)* |
| **CATT [6]** | ***Proposal 1:*** *UE-to-UE CLI handling enhancement is deprioritized for dynamic/flexible TDD in R18.* |
| **vivo [7]** | ***Proposal 3:*** *To mitigate the impact of CLI, UL power control and CLI measurement enhancement can be considered for further study.* |
| **xiaomi [9]** | ***Proposal 3:*** *Dynamic UE CLI measurement can be further studied to acquire instantaneous interference level.* |
| **Samsung [10]** | ***Observation 6:*** *The existing R16 CLI features can be re-used for intra-cell and inter-cell CLI measurements and associated UE-based measurement reporting* |
| **NEC [11]** | ***Proposal 4:***  *■ Unified design for CLI RS for gNB-to-gNB and UE-to-UE measurement should be considered to reduce the RS overhead.* |
| **OPPO [12]** | ***Observation 1:*** *R16 inter-UE CLI handling remains applicable.* |
| **Panasonic [15]** | ***Proposal 2:*** *For CLI measurement and reporting, further discuss the following enhancements:*  *• L1 report, instead of or on top of L3 report, to aid scheduling decision*  *• How to include spatial domain information to facilitate efficient UE pairing to avoid UE-UE interference* |
| **CMCC [18]** | ***Proposal 1:*** *For inter-UE CLI handling, the following enhancements can be considered:*   * *Support L1 CLI measurement and report to better reflect the interference variation, and aperiodic LI CLI measurement and report can also be considered to reduce the overhead.* * *Enhance the backhaul signaling to exchange necessary information, e.g., CLI SRS configuration, to support inter-vendor inter-gNB cooperation.* |
| **NTT DOCOMO, INC. [19]** | ***Observation 1:*** *RSSI measurement is a baseline of CLI measurement for subband non-overlapping full duplex, since the frequency bandwidth of aggressor signals and that of victim signals are not fully overlapped.*  ***Proposal 1:*** *For the enhancement of UE-UE CLI for subband non-overlapping full duplex, following aspects needs to be studied.*   * *Introduction of spatial domain information for CLI measurement* * *Introduction of multiple frequency resource configurations for CLI measurement* |
| **Nokia, Nokia Shanghai Bell [20]** | ***Observation 2:*** *Solutions for Rel-16 co-channel CLI focused on UE-to-UE CLI problems, where new UE-to-UE CLI measurements (and corresponding reporting) were standarized. Solutions to mitigate gNB-to-gNB CLI were not standardized in Rel-16.*  ***Observation 3:*** *For having a completely standardized solution for UE SRS-RSRP measurements, gNBs should be able to exchange their cells/UEs SRS configurations over the Xn/F1 interface. This is missing from current NR specifications.* |
| **Lenovo [23]** | ***Proposal 1:*** *Any potential area for further enhancements of CLI mitigation shall take the Rel-16 enhancement as baseline, and provide noticeable performance gain.*  ***Proposal 2:*** *Consider more dynamic interference measurement and reporting as one potential area for further enhancements for inter-UE CLI mitigation in dynamic/flexible TDD.* |
| **CEWiT [28]** | ***Observation 2:*** *Factors like synchronization errors between gNBs, smaller CP length in higher numerologies, higher propagation delay between the UEs causes the misalignment to go beyond CP duration while measuring the CLI on SRS as both the UEs are not time synchronized.*  ***Proposal 2:*** *Study enhancements to improve CLI measurement accuracy.*  ***Observation 3:*** *The aggressor UE can transmit the SRS at a different numerology as compared to the numerology at which the victim UE is receiving. This discrepancy in the transmitted and received SRS numerologies will affect the accuracy of CLI RSRP measurement.*  ***Proposal 3:*** *Study methods to overcome the impact of aggressor and victim UEs operating at different numerologies on CLI measurement.*  ***Observation 4:*** *The victim UE might receive only a part of the transmitted SRS by the aggressor UE for measurement of CLI RSRP where the reference points for SRS sequence generation and filling are different at victim and aggressor UEs.*  ***Proposal 4:*** *Study the impact of partial reception of SRS with different reference points for sequence generation and filling at victim and aggressor UEs for CLI measurement on CLI measurement accuracy.*  ***Observation 5:*** *CLI varies with dynamic scheduling in flexible TDD scenario.*  ***Proposal 5:*** *Mechanism for dynamic reporting of CLI is supported.* |
| **Intel Corporation [29]** | ***Observation 2***  *• Additional UE-to-UE and gNB-to-gNB CLI can be observed in case of NOFD with TDD operation.*  ***Proposal 2***  *• RAN1 to further study L1 CLI measurement and reporting at UE for dynamic TDD operation.* |
| **Qualcomm Incorporated [30]** | ***Observation 9:*** *Rel-16 CLI reporting is based on L3 which has limited flexibility and slow adaptability*  *• This leads to increased latency in CLI reporting which is not suitable for fast adaptation to mitigate CLI*  *• L1/L2 report can be obtained by gNB-DU with lower latency, in turn it can better reflect current CLI*  *• L1 report can be sent on-demand enabling fast L1 beam adaptation*  ***Observation 10:*** *In Rel-16 CLI framework, there is no dedicated signalling or configuration of QCL-D for CLI measurement, hence not suitable for enabling CLI-aware beam management*  ***Observation 11:*** *Rel-16 CLI framework does not support subband CLI reporting, i.e., reporting CLI for one or more subbands in the measurement bandwidth. In SBFD, CLI leakage to adjacent subbands is not uniform over the measurement bandwidth and may require subband CLI reporting.*  ***Proposal 3:*** *Support L1/L2 based CLI reporting to increase flexibility and reduce reporting latency compared to Rel-16 L3 based framework.*  ***Proposal 4:*** *Support UE Rx beam (QCL-D) configuration and indication per CLI measurement resource for enabling CLI-aware beam management.*  ***Proposal 5:*** *Support subband-based CLI reporting to provide accurate CLI reporting in dynamic TDD in which CLI could be non-uniform across the DL.* |
| **InterDigital, Inc. [14]** | ***Observation 2.*** *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.*  ***Observation 4.*** *Joint beam management between victim UE and gNB taking into account beams from aggressor UE can be beneficial in dynamic beam selection for CLI mitigation.*  ***Observation 5.*** *A beam failure instance due to CLI may occur even when the signal received from gNB is not physically blocked, where the degradation in the DL radio link is mainly due to the interference from an aggressor UE.*  ***Proposal 1.*** *Consider supporting means of CLI measurement and reporting at the potential victim UE that includes distinguishing aggressor UEs.*  ***Proposal 3.*** *Consider enhancements in joint beam management between gNB, victim UE, and aggressor UE for optimal beam selection or beam avoidance at the victim UE or aggressor UE, respectively.*  ***Proposal 4.*** *Consider enhancements in beam failure detection and recovery, in case the beam failure is caused by CLI from one or more aggressor UEs.* |

### *Summary*

In Rel-16, L3 based UE-to-UE CLI-RSSI and SRS-RSRP measurement and reporting are introduced, which may have limitation of flexibility. For fast reflection of measured CLI to resource assignment, enhancement of UE-to-UE CLI handling is proposed.

* CLI measurement/reporting
  + L1 based UE-to-UE CLI measurement/report [1][15][18][29][30]
  + Aperiodic UE-to-UE CLI measurement [1]
  + Dynamic UE CLI measurement [9][28]
  + Different numerologies on CLI measurement [28]

Also, for further enhancement of UE-to-UE CLI handling, followings are proposed.

* UE power control [7]
* Spatial domain information [15][19][30]
* Joint beam management between gNB, victim UE, and aggressor UE [14]
* Reference signal and Resource [11][28][30]
  + Unified design for CLI RS for gNB-to-gNB and UE-to-UE measurement [11]
  + Partial reception of SRS [28]
  + Subband-based CLI reporting [30]

On the other hand, deprioritization of enhancement of UE-to-UE CLI handling is proposed [6]. Also, it is mentioned that existing R16 CLI feature can be re-used for intra-cell and inter-cell CLI measurement and association UE based measurement reporting [10], and R16 inter-UE CLI handling remains applicable [12].

### *1st Round Discussion*

Initial FL Proposal #5-1

For study of potential enhancement on dynamic/flexible TDD, enhancement of UE-to-UE CLI handling is considered.

* At least L1 based UE-to-UE CLI measurement and reporting is studied.

**Companies are invited to provide views on the above proposal. Also, companies are encouraged to provide views which schemes should be studied for dynamic/flexible TDD in agenda item 9.3.3.**

|  |  |
| --- | --- |
| **Companies** | **Views** |
|  |  |
|  |  |
|  |  |

## Information Exchange

### *Submitted proposal*

|  |  |
| --- | --- |
| **Samsung [10]** | ***Proposal 2:*** *RAN1 to study and evaluate the benefits of providing desired/prohibited beam indications using Xn-AP to support intra-operator gNB-to-gNB (DL-to-UL) CLI mitigation* |
| **OPPO [12]** | ***Proposal 1:*** *For inter-gNB CLI handling, especially for inter-operator gNB CLI, mechanism on interference measurement and resource configuration exchange should be studied.* |
| **CMCC [18]** | ***Proposal 1:*** *For inter-UE CLI handling, the following enhancements can be considered:*   * *Support L1 CLI measurement and report to better reflect the interference variation, and aperiodic LI CLI measurement and report can also be considered to reduce the overhead.* * *Enhance the backhaul signaling to exchange necessary information, e.g., CLI SRS configuration, to support inter-vendor inter-gNB cooperation.* |
| **Nokia, Nokia Shanghai Bell [20]** | ***Observation 4:*** *Exchange of the ”Intended TDD DL-UL Configuration” over the XnAP and F1AP was standardized in Rel-16, basically to allow a gNB to announce the TDD radio frame configuration that a cell intends to use. No additional Xn/F1 signalling is standardized to facilitate TDD radio frame coordination between cells.*  ***Proposal 2:*** *For having a completely standardized solution of UE SRS-RSRP measurements, exchange of cells/UEs SRS configuration over the Xn/F1 interface shall be standardized.* |
| **LG Electronics [24]** | **Inter-operator Interference Handling**  ***Proposal 4:*** If information exchange between inter-operators are not assumed, technical schemes to support dynamic TDD can be studied, and candidate solutions for interference handling (e.g., uplink band suppression, sensing, etc.) can be discussed. |

### *Summary*

For supporting inter-UE/gNB-to-gNB CLI handling or for having a completely standardized solution of UE SRS-RSRP measurement, exchange of information is proposed [10][18][20].

* For intra-opeator gNB-to-gNB CLI mitigation, Beam indication using Xn-AP [10]
* For inter-UE CLI handling, enhancement of backhaul signaling to exchange necessary information [18]
* For having a completely standardized solution of UE SRS-RSRP measurement, exchange of cells/UEs SRS configuration over the Xn/F1 interface [20]

Also, for inter-operator gNB CLI, mechanism on interference measurement and resource configuration exchange are proposed. [12]

### *1st Round Discussion*

Initial FL Question #6-1

Whether enhancement of information exchange is necessary or not for study of potential enhancement on dynamic/flexible TDD.

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

|  |  |
| --- | --- |
| **Companies** | **Views** |
|  |  |
|  |  |
|  |  |

# Others

## TDD configuration, Resource allocation

### *Submitted proposal*

|  |  |
| --- | --- |
| **New H3C Technologies Co., Ltd. [3]** | ***Observation 1:*** *GP shall be reserved for the purpose of HF UE even the gNB works in the FD mode.*  ***Proposal 1:*** *Extend the functionality of flexible symbol for supporting FD, and the frame structure configuration mechanism in legacy TDD can be reused.*  ***Proposal 2:*** *support the configurations of a number of dedicated symbols as FD symbols, the dedicated FD symbols should be consecutive in a period of the frame structure.* |
| **Spreadtrum Communications [5]** | ***Observation 2:*** *When the legacy gNB uses DL dominant TDD UL-DL configuration and Rel-18 duplex gNB uses UL dominant TDD UL-DL configuration, there is no impact to the legacy gNB, only impact to legacy UE should be considered.* |
| **Sony [8]** | ***Observation 1:*** *FD-TDD can be supported for legacy UEs by scheduling DL & UL transmissions for different UEs within the same Flexible OFDM symbols but in different frequency resources.*  ***Observation 2:*** *Reconfiguring slot format with heavy FL symbols for support of FD-TDD would have major impacts on legacy operations.*  ***Observation 3:*** *To enable Rel-18 UEs to fully utilize FD-TDD from the network perspective, allow UE to overwrite DL OFDM symbols to UL OFDM symbols and vice-versa.*  ***Proposal 1:*** *Allow gNB to indicate in the DL & UL grants whether semi-static/SFI indicated DL and UL OFDM symbols can be overwritten for UL and DL transmissions respectively.* |
| **NEC [11]** | ***Proposal 1:*** *Enhancement for the flexible symbols allocation can be studied, such as:*  *■ Methods to achieve different UE interpretation different slot format for flexible symbols can be studied.*  *■ LBT scheme can be applied to determine the flexible symbols used for DL or UL transmission.* |
| **Panasonic [15]** | ***Proposal 1:*** *Per-subband slot format should be considered to enable flexible resource allocation over different subbands at least from gNB perspective. Further discuss whether UE can be configured with multiple per-subband slot formats for a cell.* |
| **ITRI [21]** | ***Observation 1:*** *A slot configuration period and a number of downlink symbols, uplink symbols, and flexible symbols in each slot of the slot configuration period is determined from tdd-UL-DL-ConfigurationCommon and tdd-UL-DL-ConfigurationDedicated and is common to each configured BWP.*  ***Observation 2:*** *For a set of symbols of a slot that are indicated as downlink/uplink by tdd-UL-DL-ConfigurationCommon, or tdd-UL-DL-ConfigurationDedicated, the UE does not expect to detect a DCI format 2\_0 with an SFI-index field value indicating the set of symbols of the slot as uplink/downlink, respectively, or as flexible.*  ***Observation 3:*** *A UE has a flexible resource configured by higher layer, and*  *• if a PDCCH/PDSCH/CSI-RS configured by higher layer in the flexible resource, the UE does not receive the PDCCH/PDSCH/CSI-RS, respectively, if the UE detects a DCI format 2\_0 indicating the flexible resource as flexible resource.*  *• if a DL PRS configured by higher layer in the flexible resource, the UE receives the DL PRS, if the UE detects a DCI format 2\_0 indicating the flexible resource as flexible resource.*  *• if a SRS/UCCH/PUSCH/PRAH configured by higher layer in the flexible resource, the UE does not transmit the SRS/UCCH/PUSCH/PRAH, respectively, if the UE detects a DCI format 2\_0 indicating the flexible resource as flexible resource.*  ***Proposal 1:*** *Considering gNB’s full duplex structure, study a mechanism to achieve more than one potential transmission states at a time at the UE side could be supported.* |
| **LG Electronics [24]** | ***Proposal 1:*** *It should be prioritized to identify the issues that cannot be supported by the Rel-15 TDD configuration.* |
| **WILUS Inc. [25]** | ***Proposal 1:*** *RAN1 to study semi-static sub-band format configuration based on semi-static TDD slot format configuration.*  *‐ RAN1 to study cell-specific and/or UE-specific sub-band format configuration.*  ***Proposal 2:*** *RAN1 to study whether/how to support dynamic sub-band format indication.*  ***Proposal 3:*** *RAN1 to study the UE behavior for following cases on semi-static flexible sub-band.*  *‐ PDCCH monitoring in configured CORESET symbols.*  *‐ DCI-indicated DL reception or UL transmission.*  *‐ Higher layer configured DL reception or UL transmission.* |
| **ASUSTeK [26]** | ***Observation 1:*** *A new scenario that UE would expect either UL or DL could happen on a symbol arises for subband non-overlapping duplex.*  ***Proposal 1:*** *RAN1 further investigates whether existing symbol type, e.g. “F”, or a new symbol type is required to support subband non-overlapping duplex.*  ***Observation 2:*** *Legacy SFI assume a wideband transmission direction while subband non-overlapping duplex may require subband transmission direction(s).*  ***Proposal 2:*** *RAN1 further investigates whether subband transmission direction(s) is achieved by proper scheduling or frequency resource related information in DCI format 2\_0 is required in addition to signaled slot format.* |
| **Qualcomm Incorporated [30]** | ***Observation 5:*** *SBHD-based dynamic enables flexible adaption of slots direction based on traffic which leads to reduced latency and improved UL coverage.* |

### *Summary*

It is proposed that enhancement for the flexible symbols allocation can be studied [11]. In addition, in many contributions, methods for enhancement for supporting the subband non-overlapping full duplex are proposed. But, clarification seems to be necessary whether AI 9.3.3 is appropriate for discussion on these proposals.

### *1st Round Discussion*

**Companies are encouraged to provide views which issues regarding TDD configuration and resource allocation can be studied for potential enhancement on dynamic/flexible TDD in agenda item 9.3.3.**

|  |  |
| --- | --- |
| **Companies** | **Views** |
|  |  |
|  |  |
|  |  |

# FL Proposals for GTW session

## 1st Round Discussion

# Contact Person

Please provide the information of the contact person for the purpose of discussion facilitation

|  |  |  |
| --- | --- | --- |
| **Company** | **Name** | **Email address** |
|  |  |  |
|  |  |  |
|  |  |  |

# Reference

1. R1-2203158 Potential enhancements on dynamic/flexible TDD Huawei, HiSilicon
2. R1-2203205 Discussion of enhancements on dynamic/flexible TDD ZTE
3. R1-2203216 Discussion for potential enhancements on dynamic/flexible TDD New H3C Technologies Co., Ltd.
4. R1-2203221 Potential enhancement on dynamic/flexible TDD TCL Communication Ltd.
5. R1-2203329 Discussion on potential enhancements on dynamic/flexible TDD Spreadtrum Communications
6. R1-2203460 Discussion on potential enhancements on dynamic/flexible TDD CATT
7. R1-2203559 Potential enhancements on dynamic/flexible TDD vivo
8. R1-2203733 Enhancements to dynamic/flexible TDD for Full Duplex operation Sony
9. R1-2203816 Discussion on potential enhancements on dynamic TDD xiaomi
10. R1-2203905 Dynamic and flexible TDD for duplex evalution Samsung
11. R1-2203944 Views on enhancements of dynamic/flexible TDD NEC
12. R1-2204023 Discussion on potential enhancements on dynamic/flexible TDD OPPO
13. R1-2204056 Potential enhancements on dynamic/flexible TDD SHARP Corporation
14. R1-2204070 Discussion on enhancements of dynamic TDD operations InterDigital, Inc.
15. R1-2204076 Potential enhancements on dynamic/flexible TDD for subband full duplex Panasonic
16. R1-2204108 Flexible/dynamic TDD Ericsson
17. R1-2204246 Views on potential enhancements on dynamic/flexible TDD Apple
18. R1-2204305 Discussion on potential enhancements on flexible/dynamic TDD CMCC
19. R1-2204381 Discussion on potential enhancements on dynamic/flexible TDD NTT DOCOMO, INC.
20. R1-2204432 Dynamic TDD enhancements Nokia, Nokia Shanghai Bell
21. R1-2204442 Discussion on potential enhancements on dynamic/flexible TDD ITRI
22. R1-2204475 Discussion on potential enhancements on dynamic/flexible TDD Spreadtrum Communications
23. R1-2204503 Potential enhancements on dynamic/flexible TDD Lenovo
24. R1-2204531 Study on Potential enhancements on dynamic/flexible TDD LG Electronics
25. R1-2204551 Discussion on potential enhancements on dynamic/flexible TDD WILUS Inc.
26. R1-2204638 Enhancement on dynamic TDD ASUSTeK
27. R1-2204723 Discussion on potential enhancements on dynamic/flexible TDD MediaTek Inc.
28. R1-2204752 Discussion on enhancements on dynamic/flexible TDD CEWiT
29. R1-2204801 On potential enhancements to dynamic/flexible TDD in NR systems Intel Corporation
30. R1-2205032 On potential enhancements on dynamic-flexible TDD Qualcomm Incorporated