3GPP TSG RAN Rel-18 workshop **RWS-210499**

Electronic Meeting, June 28 - July 2, 2021

Agenda Item: **4.1**

Source: **Apple Inc.**

Title: **Considerations on Even Further MIMO Enhancement**

Document for: **Discussion/Decision**

1 Introduction

In this contribution, we provide some discussion on even further MIMO Enhancement.

2 Discussion

2.1 Beam management enhancement

Since Rel-15/Rel-16, to improve the reliability, beam failure recovery operation has been supported for both PCell and SCell. However, the beam failure recovery mechanism only focuses on the recovery from downlink beam failure. It is possible that uplink beam fails while downlink beam can still work. With regard to joint TCI and separate TCI based beam indication, such case could be possible. For joint TCI, a common beam is applied for uplink and downlink, however the link budget for uplink is still smaller than downlink, and with regard to MPE impact, the uplink link budget can get even smaller. For separate TCI, the uplink and downlink may be based on different beams, and the failure status for both beams could be quite different.

Then when uplink beam failure happens, gNB cannot decode the beam report or acknowledgement of beam indication signaling correctly. As shown in Figure 1, gNB may not get information of the potentially new uplink beam and may not be able to decode ACK for beam indication. The whole link can still be broken.

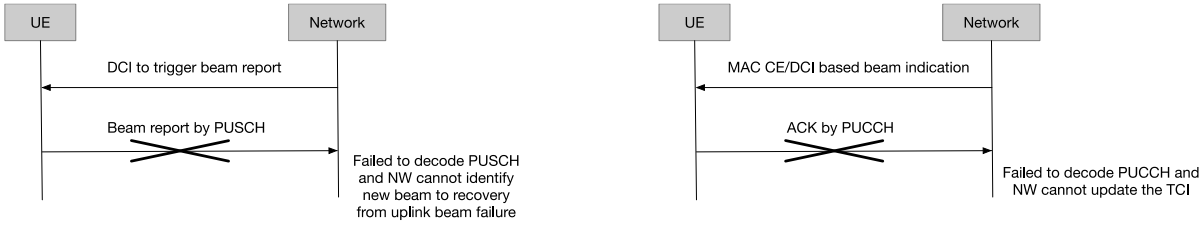

Figure 1: Potential issue to main beam pair link due to uplink beam failure

Therefore, it is necessary to enhance the beam failure recovery with regard to uplink beam status and both beam indication modes: separate TCI and joint TCI.

Proposal 1.1: Specify beam failure recovery enhancement with regard to uplink beam failure status and mechanism to recover from uplink beam failure.

In addition, Rel-15 beam management is designed based on 3 procedures: P1 is used for initial beam acquisition, P2 is used for network beam refinement, and P3 is used for UE beam refinement. From some study and simulation in Rel-17, it can be observed that UE beam change happens more frequently than network beam change. However, one problem is that gNB has no information whether/when to trigger P3, since gNB has no information about the UE beam status. Then UE has to rely on periodic SSB for P3, which increases the overall latency for UE beam refinement. Rel-17 has reduced the latency for network beam change, but it fails to provide some mechanism for fast UE beam refinement. With regard to the network overhead and latency for P3, it is better that the P3 is triggered by UE. Thus, UE can trigger some aperiodic CSI-RS with repetition=on. In addition, with regard to IFDMA based CSI-RS structure, it would be better that gNB can provide some information to UE whether intra-symbol beam sweeping can be applied. The gNB may still transmit something in the unused resource elements, but such signals should be spatially uncorrelated.

Moreover, legacy QCL rule only defines the spatial Rx assumption from UE perspective. Such QCL rule is not friendly for UE to identify the best Rx beam for signals in a QCL chain. Some signals that are QCLed with QCL-TypeD may be transmitted with different Tx beams with the same or similar coarse direction. However, the best Rx beam for that kind of signals could still be different. Then it could introduce some unnecessary problems for UE to perform joint beam refinement based on signals in a QCL chain. Then to facilitate UE beam refinement, it is better that gNB can provide some direct QCL relationship for signals that share the same Tx beam.

Proposal 1.2: Investigate and if needed specify latency reduction for UE beam refinement, e.g. UE triggered aperiodic CSI-RS for P3, intra-symbol beam sweeping based on IFDMA based CSI-RS and to introduce a new QCL type to provide spatial Tx parameters.

Further, L1/L2 centric inter-cell mobility has been introduced since Rel-17. It was agreed to study whether to introduce some event-based beam report. However, with ideal backhaul, the inter-cell mobility could be quite similar to intra-cell mobility. Thus, no matter whether the beam report is for intra-cell mobility or inter-cell mobility, more important aspect is that the potential better beam should be identified as soon as possible. Thus, the event-based beam report can be considered in both intra-cell mobility and inter-cell mobility so as to reduce the whole beam selection latency.

Proposal 1.3: Investigate and if needed specify event-based beam report to reduce beam selection latency for both intra-cell and inter-cell mobility.

In addition, the latency for initial beam acquisition for SCell activation and new beam identification is still large. To find out the best beam pair, UE may need to try N_{Tx}*N_{Rx} SSBs or N_{Tx}*N_{Rx}/K SSBs, where K indicates the number of beams to be applied for a SSB. However, UE has no QCL relationship related information for the SSBs. Thus, UE has to blindly tried the beam tracking loop for each SSB individually. If the UE can be made aware of some QCL information for SSBs, then UE can try Rx beam sweeping across SSBs. This may not be helpful for initial access procedure, but it could help to accelerate the beam acquisition procedure for intra-cell/inter-cell mobility, SCell activation and new beam identification, etc. Figure 2 illustrates an example for this NW assisted beam selection, where the beams for SSB can be divided into several groups, and UE can firstly track the SSBs in a group based on a single beam tracking loop, and then UE can perform some further beam tracking for the beams in a SSB group to identify the best beam.

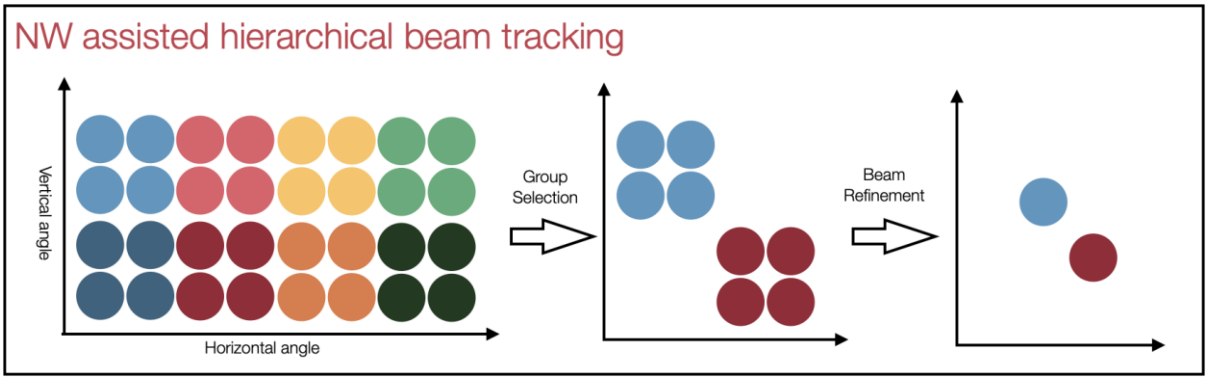

Figure 2: An example for NW assisted beam tracking

Proposal 1.4: Specify that network can provide some QCL relationship between SSBs to reduce beam selection latency for P1 for SCell activation, intra-cell/inter-cell mobility and new beam identification.

2.2 UE coordination-based beam management and CSI report

Currently, each UE should perform the beam management and CSI report related procedure individually. As more and more UEs connect to the network, such individual beam management and CSI report would increase the system overhead. In addition, individual beam management and CSI report would also cause unnecessary power consumption in UE side. For some UEs that are spatially correlated, e.g. in the similar location, most likely such UEs could share the same best transmission direction. With certain coordination, the UEs can share some beam management and CSI related procedure as shown in Figure 3.

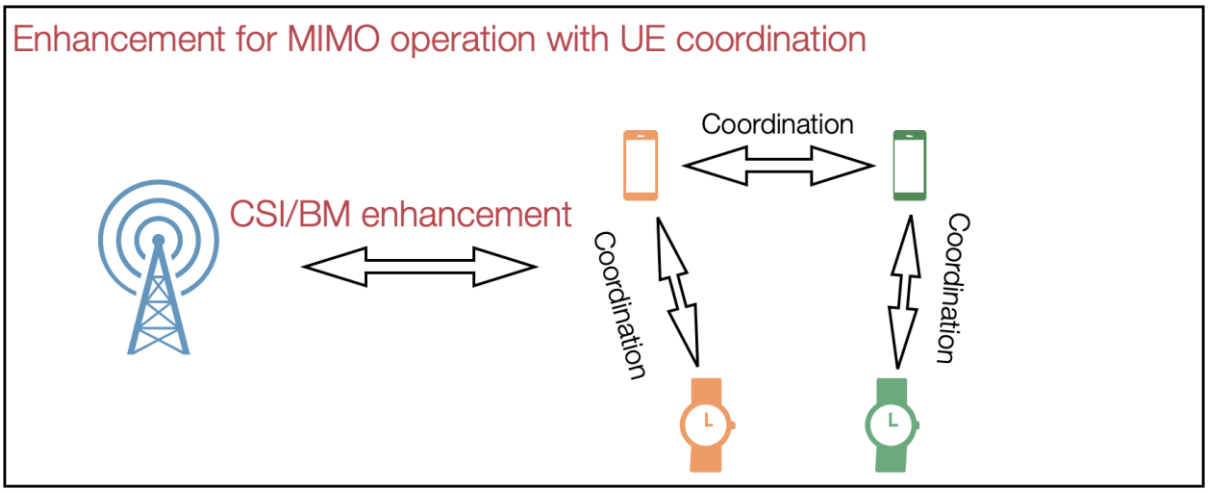

Figure 3: UE coordination-based beam management and CSI

Since the UEs may share the same or highly correlated downlink transmission direction, one single beam management and CSI report related procedure should be enough for both UEs, and one of the UEs can be used to perform such procedure. The other UEs do not need to waste power to perform any measurement related procedure. Instead, such UEs only need to communicate with the gNB for data and control signal related transmission and reception.

Proposal 2.1: With regard to overhead reduction for beam/CSI measurement/report/selection and UE power saving, or to facilitate NW Multi-user scheduling, specify UE coordination-based beam measurement/report/selection and CSI feedback.

2.3 CSI feedback enhancement

Currently UE can report the PMI/CQI for a single rank in CSI report. However sometimes as a result of MU-MIMO pairing or retransmission, gNB needs to try a different rank for the downlink transmission. The gNB may not have enough information about another rank as shown in Figure 4 and Figure 5, but UE should have already measured the CSI for different ranks in CSI measurement. Then to support different kinds of scenarios that may require a different rank for downlink transmission, it is necessary to study that UE can report PMI/CQI for more than 1 ranks in a CSI report.

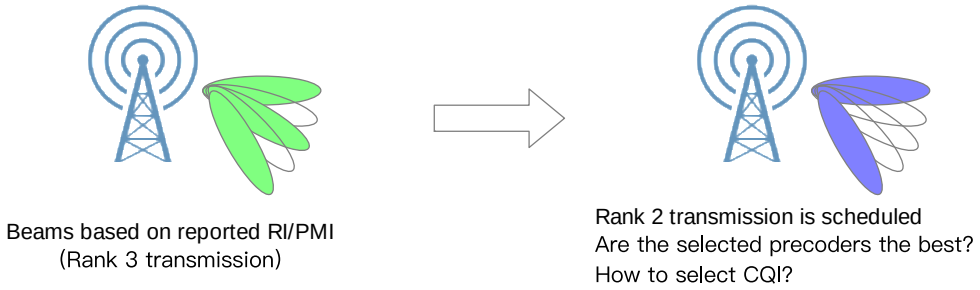

Figure 4: Smaller rank transmission

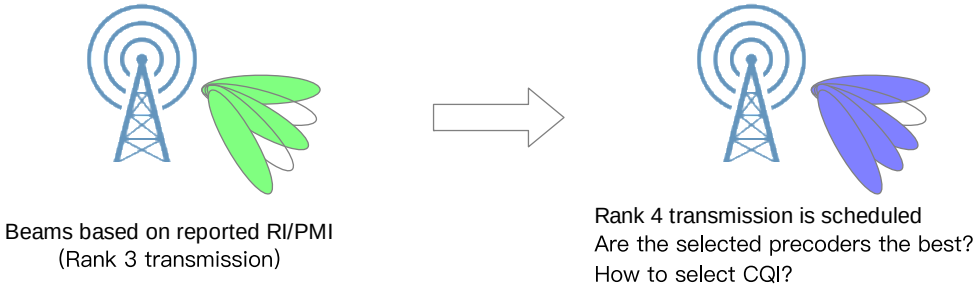

Figure 5: Higher rank transmission

Proposal 3.1: Investigate and if needed specify CSI report enhancement to report PMI/CQI for more than 1 ranks in a CSI report instance, and/or, more hypothesis for MU-MIMO scheduling.

Another issue arises from the current specification is related to the UE CSI processing complexity related capability. Currently, there are two categories of UE CSI processing complexity related capability, (1) CPU, and, (2) active CSI-RS/RS related. For CPU related UE capability, NW can still configure an amount of CSI that exceeds UE CPU related capability, in which case, UE is expected to report the staled CSI reports that exceeds the UE processing complexity capability following the CSI priorities. For active RS related capability, UE is not expected to be configured to measure more RS than the UE reported capability. However, in practice, the CSI processing timeline is complicated in UE implementation UE may schedule and carry out CSI processing differently, for example, using pipeline processing, or parallel processing, furthermore, the CSI processing timeline may also be impacted by other factors such as the UE power management, thermal management and the other processing load, etc. This is illustrated in Figure 6. We observe at least two issues due to the static reporting of UE CSI processing capability and the dynamic nature of the actual UE CSI processing management, (1) The static UE CSI reporting cannot reflect the dynamic situation of the UE CSI processing condition (2) It is too memory demanding to require UE to feedback the stale CSI when the CSI report configuration exceeds UE capability. Therefore, we have the following proposal

Proposal 3.2: Investigate and if needed specify CSI report enhancement to handle the UE dynamic CSI processing complexity related capacity and to avoid requiring UE to report stale CSI explicitly when the CSI report configuration exceeds UE capability

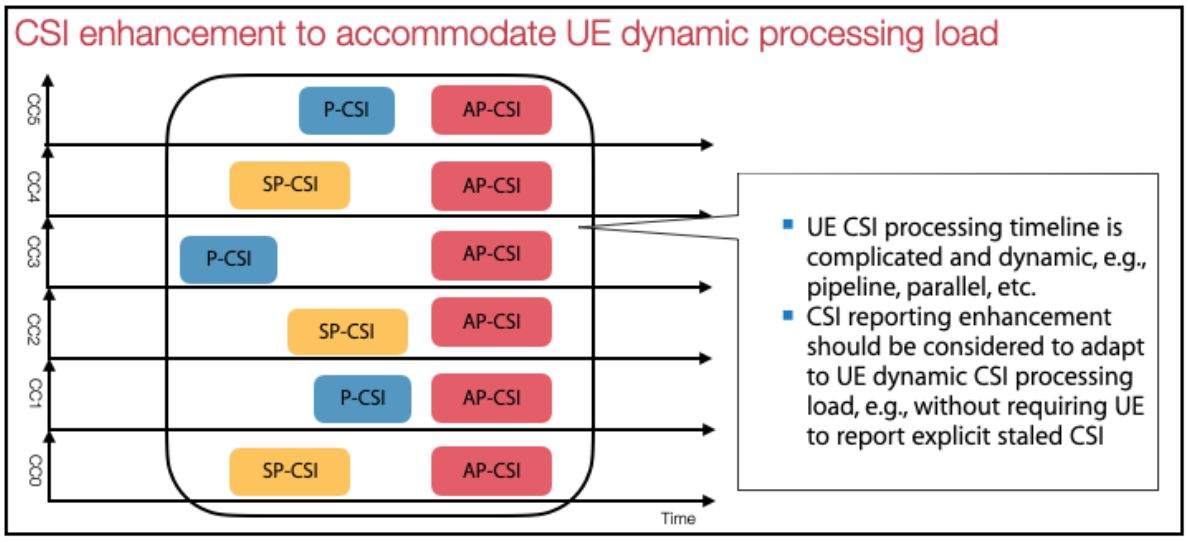

Figure 6: UE CSI processing

2.4 MU-MIMO enhancement

The general trend for cellular communication evolution is to design solutions to allow cellular system to operate at higher frequency. High frequency communication, not only, allows UE to access wider bandwidth, it also allows larger amount of antenna elements to be deployed which enables more directional communication to improve the link budget and spatial reuse. Therefore, in our view, it is reasonable to assume that MU-MIMO is one of the focus of future MIMO evolutions. Furthermore, modern UE is also starting to be capable of more and more advanced signal processing capability which is important for multi-user detection. In our view, for MU-MIMO operation, there are two major areas for improvement, one area is the CSI enhancement to better assist the gNB MU-MIMO scheduling, which is covered by Proposal 3.1. The other area is to assist UE to perform advanced MU detection. Currently, UE has only limited information about the co-scheduled UE for MU-MIMO operation. More specifically, UE is only aware of the “antenna port” configuration, i.e., CDM groups without data for rate matching purpose and some MU-MIMO scheduling restriction in 38.214. This limited information restricts the performance of MU detection and/or significantly increases the UE receiver complexity. For enhancement, we propose

Proposal 4.1: Investigate and if needed specify MU-MIMO enhancement including the scheduling information enhancement to assist advanced UE MU detection receiver.

3 Conclusion

In this contribution, we discussed aspects on even further MIMO enhancement. Based on the discussion, the following proposals are proposed

Beam Management Enhancement

Proposal 1.1: Specify beam failure recovery enhancement with regard to uplink beam failure status and mechanism to recover from uplink beam failure.

Proposal 1.2: Investigate and if needed specify latency reduction for UE beam refinement, e.g. UE triggered aperiodic CSI-RS for P3, intra-symbol beam sweeping based on IFDMA based CSI-RS and to introduce a new QCL type to provide spatial Tx parameters.

Proposal 1.3: Investigate and if needed specify event-based beam report to reduce beam selection latency for both intra-cell and inter-cell mobility.

Proposal 1.4: Specify that network can provide some QCL relationship between SSBs to reduce beam selection latency for P1 for SCell activation, intra-cell/inter-cell mobility and new beam identification.

UE coordination-based beam management and CSI report

Proposal 2.1: With regard to overhead reduction for beam/CSI measurement/report/selection and UE power saving, or to facilitate NW Multi-user scheduling, specify UE coordination-based beam measurement/report/selection and CSI feedback.

CSI feedback enhancement

Proposal 3.1: Investigate and if needed specify CSI report enhancement to report PMI/CQI for more than 1 ranks in a CSI report instance, and/or, more hypothesis for MU-MIMO scheduling.

Proposal 3.2: Investigate and if needed specify CSI report enhancement to handle the UE dynamic CSI processing complexity related capacity and to avoid requiring UE to report stale CSI explicitly when the CSI report configuration exceeds UE capability

MU-MIMO enhancement

Proposal 4.1: Investigate and if needed specify MU-MIMO enhancement including the scheduling information enhancement to assist advanced UE MU detection receiver.