[RAN95e-RAN4-R18Prep-04] - Version 0.0.7
RAN

3GPP TSG RAN Meeting #95-e RP-220022

Electronic Meeting, March 17 - 23, 2022

(Pre-RAN#95e email discussion February 7-11, 2022)

Agenda item: X.X.X

Source: RAN4 Vice-Chair (Samsung)

Title: Moderator's summary for discussion [RAN95e-RAN4-R18Prep-04] Demod Enhancements

Document for: Information

1 Introduction

This document provides as summary on demod enhancement topic [RAN95e-RAN4-R18Prep-04] during Pre-RAN#95e Rel-18 RAN4 email discussion

Following the guidance in RP-220003, the discussion is to focus on the potential RAN4-led demod enhancement topics, and the potential scope/areas for each potential WI or SI:

- **Initial Round**: Moderators are expected to use RP-212682 to come up with an initial template
- **Intermediate Round:** Aim for initial convergence on the areas/objectives for the potential projects
- **Final Round:** Aim for each potential project: final convergence on the areas/objectives, and an initial version of the overall justification

2 Initial round

Based on RP-212682, moderator provides following candidate working areas/objectives for initial round discussion:

- Advanced receiver to cancel inter-user interference for MU-MIMO (Stable enough)

*Following potential objectives need more discussion

- SoftIC
- Enhanced DL receivers for multi-DCI multi-TRP
- Inter-cell CSI-RS/SSB interference mitigation (IM)

- E-MMSE-IRC under uneven interference
- BS advanced receiver (MMSE-IRC)
- ATP
- Extend MMSE-IRC receiver for inter-cell and intra-cell MU-MIMO to CA case

Companies are encouraged to provide technical justifications including commercial interest, priority and supporting on objectives considering reasonable scope and limited RAN4 capability and suggestions on the detailed objectives on above candidate areas in initial round.

2.1 Proposals and comments collection

2.1.1 General

In general, 8 candidate areas/objectives as list above were collected till now for Rel-18 performance evoluation topic. In Rel-17, 3 objectives were included under performance enhancement WI in initial phase and later on one addtional objective added for CRS-IM under LTE CRS and NR co-existence scenario. Given the limited TU capability in Rel-18, moderator sugguests to control the work scope with less than or equal to 3 objectives (similar as Rel-17) in intial stage.

Based on previous discussion, a umbrella WI for performance evoluation can be introduced and study phase can be included for some of specific objectives.

Regarding timline of this WI and TU budget, moderator sugguests to start this WI after Rel-17 performance completed i.e. from RAN#97 (4th quarter of 2022) and 1-1.5 TU pending on the endorsed scope in the end.

Regarding WG leadership, it's still unclear whether some potential objectives have cross WG impact e.g. NWA signaling (RAN2) and some of candidate objectives are purely belong to performance part with RAN4 scope only. Moderator sugguests to take RAN4 leading WG, and FFS on the potentail impact on RAN2 and or RAN1 which can be added in later phase after the discussion status is clear in RAN4 WG.

Please provide your comments on the general aspects on potential Rel-18 RAN4 demodulation enhancement topic:

- WI vs SI: WI (study phase can be included for some of objectives if needed)
- Timeline: Start from RAN#97
- WG leadership: RAN4, [potential secondary WG: RAN2 and/or RAN1]

Feedback Form 1: General part

1 – Nokia

Nokia agrees with the proposed WF (WI with potential study phase objectives, start from RAN#97, RAN4-led).

2 – MediaTek Inc.

- We are fine to have some study phase in the WI, if needed.
- Regarding the timeline, it is up to which objectives to be considered. If 6Rx or 8Rx (which is Demod-heavy) is to be considered in this WI, some RF-related discussions can start earlier. Another issue we need to be careful is about the cross-WG impact, e.g., new RRC or DCI. This should belong to core part, which have a different deadline compared to performance requirements.
- Fine to make the WI led by RAN4. RAN1 and RAN2 can be added as secondary WG(s), if needed.

3 – China Mobile Com. Corporation

CMCC agrees with the proposed WF.

4 – Intel Corporation SAS

We support the general aspects listed above. Involvement of other WGs can be discussed based on the scope of Rel-18 WI.

5 – Ericsson France S.A.S

We're fine with these principles, although as pointed out some objectives will need a study phase; this should be on a case by case basis and the other group involvement also needs to be sorted out on a case by case basis.

When deciding what to include, it is important to consider that there is also potential significant amounts of demodulation work embedded in other WI (e.g. UL 4 layer MIMO, MIMO with >4 layers, FR2 multi RX, 8 and 6 RX, 256QAM FR2 etc.)

6 – CATT

agree with the moderator proposed WF and principles.

7 – China Telecommunications

We agree with the WF, with the understanding that the need of study phase and other WG impact will be discussed case by case.

8 – Apple GmbH

We agree with the WF. Study phase can be identified for some objectives as required. The impact to other WG can only be identified during the requirements phase in our understanding.

9 – Samsung Electronics Co.

We agree with the WF. For other WG impact, this can be further dicussed in RAN4 WG.

10 – TELECOM ITALIA S.p.A. We have concerns with the workload and need for this kind of activity, which seems to propose another round of enhancements. Stated performance improvements are clearly a key requirement, we are not sure on the commercial uptake of these enhancements and therefore we have doubt on the need to work on further this area in Rel 18. We also agree with the statement from several companies: when deciding what to include, it is important to consider that there is also potential significant amounts of demodulation work embedded in other WIs
11 – ZTE Wistron Telecom AB We are fine with Moderator's recommendation: WI with a study phase for some objective, starting from RANP#97 and RAN4-led.
12 – Huawei Tech.(UK) Co.. Ltd We agree with that some objectives need a study phase to achieve a clearer scope. For the impact on other working groups, such as new NWA can be discussed cases by case.

2.1.2 Objective #1: Advanced receiver to cancel inter-user interference for MU-MIMO

Proposal for discussion

This area is stable enough with following detailed justification and objectives:

Justification: Further improve the performance under MU-MIMO scenario with advanced receiver to cancel inter-user interference.

Objective:

- Evaluate and specify advanced receiver to cancel inter-user interference for MU-MIMO [RAN4]
    - Phase I: Study the performance gain, reference receiver assumption, testability, required signalling overhead, as well as impact on other WGs
    - Phase II (if any pending on the outcome of phase I discussion):
        - Specify PDSCH demodulation requirements under MU-MIMO scenario with advanced receiver

Comments and discussion

Please provide comments and justification on above detailed objective.

Feedback Form 2: Objective #1: Advanced receiver to cancel inter-user interference for MU-MIMO

1 – Nokia

Of high importance to Nokia. Propose to include in WI.

Effective UE side MU MIMO interference rejection reduces NW constraints in scheduling, precoder selection, etc. which improves overall performance.

No new NWA signalling is required in our opinion, a UE can measure all DM-RS ports not allocated to the UE and estimate interference from there.

2 – MediaTek Inc.

We prefer to add network assistance information. At least whether the assistance information is needed should be one of the issue to be discussed in RAN4. And it is up to the final RAN4 conclusion. If seems very strange to exclude it in the beginning.

Some more detail regarding the scope may also need to be clarify in order to make RAN4 discussion more efficient. For example, the assumptions of DMRS scrambling sequence, CDM group, rank, PRB occupation, PRB bundling, slot/non-slot scheduling of the interference UE.

3 – China Mobile Com. Corporation

We support to include this objective into WI

In MU-MIMO scenario, the inter-user interference is common especially when network has limited channel information and large number of UEs. The advanced receiver can help a lot for interference cancellation.

4 – Intel Corporation SAS

We support this topic with high priority. Similar topic was discussed in the LTE as a part of Rel-14 MuST WI and R-ML receiver was considered to significantly improve the MU-MIMO performance. In general, above detailed objective is fine for us. Probably, to have clearer scope on reference receiver assumptions, it is better to capture the candidates. We think that E-LMMSE-IRC and R-ML receivers should be included for further discussion.

5 – QUALCOMM JAPAN LLC.

We support this topic, some gains can be expected from such receiver.

6 – Ericsson France S.A.S

This is the most relevant proposed UE demodulation enhancement and we are fine with the objectives

7 – CATT

We think this is a useful feature and should be included in the scope.

8 – China Telecommunications

We support to include this topic in WI. In general the objective looks good, and we share the following views if more details need to be added:

- Candidate reference receiver: ok to restrict to E-LMMSE-IRC and R-ML receivers, as suggested by Intel.
- Scenario: we can focus on slot-based transmission
- Testability: suggest to replace “Testability” with “MU-MIMO interference modeling”. The later one is used in Rel-17 WID, and it can cover other details mentioned by MediaTek.

9 – Apple GmbH

We support this objective.

The expected network signalling would highly depend on the receiver assumption. There would be no benefit to evaluate receivers that assume certain information for the co-scheduled UE, but is not feasible when it comes to requirements phase/ NWA discussion. We prefer to limit reference receivers to those that are practical and feasible from both UE implementation and signalling overhead perspective. E-MMSE-IRC is a suitable candidate for reference receiver taking into account signalling overhead and UE complexity. With R-ML both the UE complexity and required signalling is higher, so we are not in favor of including it in the objective.

10 – Samsung Electronics Co.

We support this objective and candidate receiver can be further discussed in RAN4 WG.

11 – Huawei Tech.(UK) Co.. Ltd

We support this objective. The advanced receivers are expected to achieve better performance compared to the existing receivers in the scenarios with inter-user interference. We support to limit the candidate reference receiver to E-MMSE-IRC and R-ML to have clearer scope, but the reference receiver for final performance requirements definition can further discuss based on the Phase I study.

12 – ZTE Wistron Telecom AB

The outcome of study does not lead to any restriction on the network scheduler on pairing co-channel UEs, and this should be captured in the WID, otherwise the objective looks fine, where a study phase is absolutely required.

13 – Deutsche Telekom AG

We consider cancellation of inter-user interference for MU-MIMO as the most important UL demodulation enhancement work. We support this objective.

14 – BT plc

We support the objectives of this work

2.1.3 Objective #2: Soft-IC receiver under SU-MIMO interference

Proposal for discussion

Based on the previous discussion, study phase shall be introduced to identify the performance gain, impact on UE complexicity, detalis on referecne receiver assumption and potential impact on processing delay before normative work on introducing performance requirements for Soft-IC receiver.

The proposed justification andobjectives as following:

Justification: Futher improve performance under SU-MIMO sceanrio with Soft-IC receiver to cancel inter-stream interference.

Objective:

- Evaluate and if identified specify Soft-IC receiver to cancel inter-stream interference for SU-MIMO [RAN4]
    - Phase I:
        - Study the performance gain, UE complexity impact, reference receiver assumption and potential impact on processing delay
        - Focus on slot-based transmission and aligned SCS among cells
    - Phase II (if any pending on the outcome of phase I discussion):
        - Specify PDSCH demodulation with Soft-IC receiver under SU-MIMO scenario

Comments and discussion

Please provide comments and justification on above detailed objectives.

Feedback Form 3: Objective #2: Soft-IC receiver under SU-MIMO interference

1 – Nokia

Propose to include in WI.

Effective against inter-stream inference caused by SINR imbalance between layers of the same codeword due to use of single MCS. Increases the number of layers used in SU-MIMO transmission, at potentially lower complexity as (R-)ML.

2 – MediaTek Inc.

We have strong concern to add this objective into the WI.

- This Soft-IC demands extremely high UE complexity and provides only visible gain on selective scenarios, e.g., unequal effective SNR among layers.
- NR HARQ processing delay requirement is more stringent than LTE. It is not feasible to further adding more iterations between MIMO demapper and LDPC decoder
- In LTE, we have 2 CW with separate CRC. If one CW is decoded successfully, the LLRs can be used to help on the decoding of another CW. However, in NR, we do not have 2 CW for <5layers
- Whether and how UE can repot the correct CQI levels to realize the gain of soft-IC is unclear to us.

3 – China Mobile Com. Corporation

We support to include this objective into WI

However, for the second bullet of Phase I, we wonder the motivation to investigate the SCS among cells since the objective is focus on the interference among layers.

4 – Intel Corporation SAS

We support this topic with medium priority. We think that tradeoff between UE complexity and performance benefits should be achieved to prove the feasibility of Soft IC receiver.

As for above detailed objective, we think that it is better to specify the baseline advanced receiver over which we are going to analyze the performance benefits of Soft IC receiver and consider R-ML as such baseline advanced receiver.

5 – QUALCOMM JAPAN LLC.

We also have concerns on this work as the expected gains are small and the receiver complexity is high. Due to use of LDPC and single codeword in NR, the gains will be very limited so the tradeoff gain vs. complexity is not attractive.

6 – Ericsson France S.A.S

The benefits of this soft IC receiver compared to the existing R-ML based SU-MIMO requirements may not be great, so there should be a Study before any specification. In other WI, there are proposals for e.g. MIMO with >4 layers. We should take care on the overall workload and from a workload perspective, it may be better not to include this.

7 – China Telecommunications

We agree with Nokia's point that soft-IC is effective against inter-stream inference caused by SINR imbalance between layers of the same codeword with single MCS. In NR, only 1 CW is designed for no more than 4 layers, and 4Rx/layer UE is a typical implementation for several global TDD bands.

Some feedback on the comments from companies:

- Complexity and HARQ processing delay: it is related to the exact implementation, and different means can be used to control the complexity, e.g., limit the number of iterations for each LDPC decoding.
- CQI accuracy: CQI reporting requirements are not defined for LTE R-ML and NR R-ML, and it can seen as up to UE implementation. But we are also open to discuss the necessity of CQI reporting requirements for Soft-IC.

8 – Apple GmbH

We have some concerns on the complexity vs achievable gains. We are okay to include this with study phase. We think a few things need to be clarified in the objective for study phase:

- Baseline receiver for comparison- R-ML is the advanced receiver in Rel-15

- Baseline assumption of Soft-IC receiver

9 – Samsung Electronics Co.

We echo companies' comments on the complexicity, at least study phase need to introduced to evaluate the gain vs complexicity.

10 – Huawei Tech.(UK) Co.. Ltd

We support to add this objective into the WI with high priority.

The obvious performance gain of Soft-IC can be obtained with comparable complexity to the baseline R-ML receiver. To be specific, a further simplified R-ML detector with much lower complexity can be used in the second iteration, since reliable prior information has already been obtained from the LDPC decoder in the first iteration. The number of inner iterations within the LDPC decoder per outer iteration (the iteration between the detector and the decoder) can also be limited, ensuring not to increase the total number of LDPC iterations in the receiver. Using the above-mentioned simplified operations, the additional HARQ processing delay and the additional UE complexity introduced by performing iterations in Soft-IC can both be **WELL** controlled. As pointed out by MTK, in NR, we do not have 2 CW for <5 layers, which means that the CW-IC for LTE cannot been used for NR (1CW for 4 layers) anymore. This is also the main motivation of investigating soft-IC for NR, since NR with inter-stream interference is a different scenario from LTE. If inter-stream interference can be handled with acceptable complexity and processing delay, it is worth to study Soft-IC to increase the total throughput of network.

Regarding how UE can report the correct CQI levels, we think this is irrelevant to the gain of the Soft-IC, it is up to UE implementation. In the real network, BS will mainly rely on OLLA for scheduling. Note that the soft-IC is robust and almost has no negative performance gain compared to RML in various scenarios.

If companies still have concerns, a study phase to evaluate the performance gain, process delay and UE complexity of soft IC over R-ML should be conducted at least.

We share similar views with CMCC on the second bullet of Phase I. The Soft-IC is applied to SU-MIMO and there is no need to consider the SCS among cells.

11 – ZTE Wistron Telecom AB

We are fine to start with a study on the achievable benefits from the method of intra-codeword interference cancellation for SU-MIMO under practical assumptions and considering there is no help from a CRC-confirmed interference compared with that in LTE for the cancelation.

2.1.4 Objective #3: Enhanced DL receivers for multi-DCI multi-TRP

Proposal for discussion

Moderator observed companies questioned the applicable sceanrio and the commencial demand on this specific enhancement based on previous discussion.

The detailed objectives and justification as following:

Justification: Improve performance under multi-DCI multi-TRP transmission Scenario with enhanced DL

receiver

Objective:

- Evaluate and if identified specify PDSCH requirements with enhanced DL receivers for multi-DCI multi-TRP
    - Phase I:
        - Study performance benefits of IC receiver for multi-DCI multi TRP scenario
        - Target scenario: full or partial overlapping PDSCH allocations
    - Phase II (if any depending on the outcome of phase 1 discussion):
        - Define PDSCH requirements

Comments and discussion

Please provide comments and justification on above detailed objectives.

Feedback Form 4: Objective #3: Enhanced DL receivers for multi-DCI multi-TRP

1 – Nokia Do not include in WI. Unlikely that a separate demodulator implementation will be included in devices to serve such a low commercial demand. Having requirements that simply capture performance of using the "baseline receiver" implementation in this scenario seems not useful from a conformance testing pov.
2 – MediaTek Inc. We do not see the urgency of introducing objective in Rel-18. We would like to get more clarification about this objectives, like 1) how likely UE will be scheduled simultaneous by 2 TRPs in the real network, 2) how network can decide the MCS level for fully and partially overlapped case, 3) how UE's CQI report can help to realize the potential gain?
3 – China Mobile Com. Corporation We prefer exclude this objective from the R18 WI Comparing with Objective #1 and #2, the commercial demand is not strong, and deployment scenario is quite limited so far.
4 – Intel Corporation SAS We support this topic with medium priority. To reduce the number of objectives, this objective can be combined with Objective #2 and Multi-DCI Multi-TRP scenario can be considered as one of scenarios for Soft IC analysis.

5 – QUALCOMM JAPAN LLC.

We do no see the need for such work in Rel.18. It is not clear what is the commercial use case.

6 – Ericsson France S.A.S

Considering the workload situation, we think this does not need to be included for Rel-18. We think the gain of IC receiver is expected in the scenario where the PDSCH from two TRPs are overlapped in frequency and time domain. In Rel-16 eMIMO WI, RAN4 discussed whether to define PDSCH demodulation requirements with this scenario, but RAN4 agreed to define the case with non-overlapping configuration. In Rel-17 FeMIMO, RAN4 is now discussing whether to define PDSCH requirements for inter-cell multi-TRP cases, but it is not clear RAN4 is going to define the requirements where two PDSCHs are overlapped. We think it is too early to consider the 'enhanced' receiver for multi-DCI multi-TRP scenario because RAN4 has not defined 'minimum' requirements yet.

7 – China Telecommunications

Ok to de-prioritize this objective.

8 – Apple GmbH

We dont support this objective unless there is a commercial interest and wide usage of this use case.

9 – Samsung Electronics Co.

Considering work load, we sugguest to deproritzie this objective given lack of strong evidence from commercial interest.

It's our understanding once we specify advanced receiver for SU-MIMO i.e. R-ML and soft-IC receiver; by default these advanced receiver can also applied to M-TRP sceanrio from UE implemenation aspect even no dedicated UE requirements for transmission scheme.

10 – Huawei Tech.(UK) Co.. Ltd

Based on our evaluation, similar good performance can be achieved by using Soft-IC to handle the inter-stream interference for both one CW and two CW. CW-IC can only achieve better performance with one CW error, but no such limitation for Soft-IC. Also like Samsung indicated, if UE support Soft-IC, it will naturally support the Soft-IC for both one and two CWs. So it is fine for us to study the scenarios for both single-DCI for one CW and multi-DCI for two CW for Soft-IC receiver. The objective#2 can be updated as following:

Objective:

Evaluate and if identified specify Soft-IC receiver to cancel inter-stream interference for SU-MIMO <u>within one CW and two CWs</u> [RAN4]

Phase I:

Study the performance gain, UE complexity impact, reference receiver assumption and potential impact on processing delay

F~~ocus on slot-based transmission and aligned SCS among cells~~

Phase II (if any pending on the outcome of phase I discussion):

Specify PDSCH demodulation with Soft-IC receiver under SU-MIMO scenario

11 – ZTE Wistron Telecom AB

In our views, some works in Objective #1 may be reused for this objective #3, or vice-versa, and there are more information available in Objective #3. Therefore, if Objective #1 is included, then Objective #3 should be include.

2.1.5 Objective #4: Inter-cell CSI-RS/SSB interference mitigation (IM)

Proposal for discussion

Based on previous discussion, some companies questioned the performance gain for this case and also whether this can be handled by NW scheduling to avoid the confliction between inter-cell CSI-RS/SSB.Moderator suggests at least study phase needed if this objective introduced in Rel-18.

The proposed justification and objective as following :

Justification: Cancel or mitigate the inter-cell CSI-RS/SSB interference due to the colliding SSB/CSI-RS configuration between the serving and neighboring cells.

Objective:

- Evaluate and if identified specify PDSCH requirements for Inter-cell SSB/TRS interference mitigation
  - Phase I:
    - Evaluate the PDSCH performance gain with CSI-RS(TRS)/SSB-IM compared to that without corresponding neighbouring CRS-RS(TRS) and SSB interference cancellation or mitigation under colliding CSI-RS(TRS)/SSB configuration between the serving and neighbouring cells
    - Target scenario: SSB and TRS in neighboring cells are configured in the same time and frequency location respectively
  - Phase II (if any pending on the outcome of phase I discussion):
    - Specify PDSCH demodulation requirements for Inter-cell SSB/TRS interference mitigation

Comments and discussion

Please provide comments and justification on above detailed objectives.

Feedback Form 5: Objective #4: Inter-cell CSI-RS/SSB interference mitigation (IM)

1 – Nokia

Do not include in WI.

Situation can be handled in scheduling/cell planning. Trying to do IM on this avoidable collision is technically extremely challenging, so performance gains are debatable and algorithm complexity increase of

devices and signalling is expected to be prohibitive.

2 – MediaTek Inc.

We do not see the urgency of introducing objective in Rel-18.

For the non-colliding TRS case, the periodicity of TRS is lower than LTE CRS. If TRS only comes in 1 slot per every 40 slots, then throughput gain is expected to be lower than 2.5%, which seems not very attractive.

For the colliding TRS case, there could be some improvement on the timing/frequency estimation accuracy. However, for cell-edge UEs suffering high interference, the MCS level is usually low and is very robust to timing/frequency error. The improvement in synchronization does not bring sufficient gain to the final throughput in cell edge.

3 – China Mobile Com. Corporation

We support to include this objective in WI. While the priority is lower comparing with Objective #1 and #2.

Although the sepc supports non-colliding CSR-RS/SSB, in real network, it is hard to schedule such configuration between cells. Configuring the CSI-RS/SSB in the same frequency and time location is the typical case. The scenario is valid and wide deployed.

In R17 demod-enh WI, some companies concern about the interference between collided CSI-RS/SSB, therefore, we also would like to further study the gain of SSB/CSI-RS IM.

4 – Intel Corporation SAS

We don't support this topic.

Based on our analysis from R4-2109198, we observed very limited performance benefits of accuracy of TRS-based parameters estimation on PDSCH performance in scenarios with interference free TRS (ideal IC) and interference limited TRS. Therefore, we don't expect testable performance benefits of TRS-IM processing for typical inter-cell interference scenarios.

As for SSB-IM, based on our analysis from R4-2200512, operating SNR region for PBCH decoding is much lower in comparison to PDSCH SNR operating region for typical scenarios with inter-cell interference. Therefore, we don't expect testable performance benefits of SSB-IM processing for typical inter-cell interference scenarios.

5 – QUALCOMM JAPAN LLC.

We do not see the need for this work in NR. NR was specifically designed to have minimal number of persistent signals so no significant gains are expected.

IC in LTE was targeting some specific scenarios that do not exist yet in NR or it was not shown yet that there are issues in such scenarios.

6 – Ericsson France S.A.S

For the SSB, RRM requirements are designed for suitably low SNR (e.g., -6dB). For the colliding TRS, we have not seen issues with the time and frequency estimation. In any case, the demodulation requirements have not until now considered time/frequency estimation on TRS. It is anyhow not clear how to capture the impact of inter-cell SSB/TRS colliding because SSB/TRS from neighboring cell(s) do not directly interfere PDSCH from the serving cell. Also in our understanding it is up to UE implementation which signal is used for time/frequency tracking. With this assumption, the impact of inter-cell SSB/TRS colliding depends on the UE implementation. Within the overall workload of the Rel-18 package, we do not think this needs to be prioritized.

7 – China Telecommunications

Some feedback on the comments from companies:

- On scenario: Even if the SSB and/or TRS are not colliding among cells, data can be transmitted from the neighboring cells, so inter-cell interference still exists on SSB/TRS REs.
- On complexity: If the complexity of IC is a concern, we can consider IM-type receiver, the complexity can be similar to MMSE-IRC or LLR weighting.
- On performance gain: we understand the SSB can be correctly decoded under low SNR, but the time/frequency tracking inaccuracy would impact the PDSCH demodulation performance.

8 – Apple GmbH

We don't support this objective.

We don't think there would be a huge benefit from this. We evaluated impact of overlapping TRS in ICI in Rel-17 demod enhancements and we didn't see and performance delta between overlapping and non-overlapping TRS.

9 – Samsung Electronics Co.

We echo other companies' view, it's unclear for the motivation and benefits of this objective. From UE demodulation aspect, the performance robust enough with low MCS level for Time/frequency tacking error. And UE will rely on TRS and or DMRS for fine time/frequency tracking, we didn't see big performance impact based on previous evaluation and discussion in RAN4.

We sugguest to deprioritize this objective.

10 – Huawei Tech.(UK) Co.. Ltd

We support to add this objective into the WI with high priority.

Firstly we want to clarify that we observed this issue in the current commercial network with colliding TRS/SSB configuration, sever performance degradation is observed under light network load and higher modulation order condition.

Secondarily as shown in our paper RP-213434, obvious performance gains for PDSCH can be obtained if we handle the interference on TRS/SSB with light load and higher modulation order scheduled. Also as evaluated by Intel R4-2109198 for TRS-IC, about 0.4dB performance gain can be achieved with MCS13 but under TDLA30-10 propagation condition. Higher performance gain can be expected with higher modulation order, such as 64QAM and 256QAM, and TDLC propagation condition. For SSB-IM, although PBCH can be decoded successfully under lower SNR, but the residual time and frequency offset impact to PDSCH performance is not considered in R4-2200512 as per our understanding.

Thirdly, different from CRS-IC investigated for LTE, TRS/SSB is less frequent than CRS. For example, TRS is usually transmitted every 20ms. Therefore, it is of much more significance to exploit advanced receiver to achieve better time-frequency tracking performance using such limit amounts of TRS/SSB. If large time and frequency offsets occur due to the contaminated TRS/SSB, the demodulation performance will decrease consequently. Although NR has minimal number of persistent signals, i.e., TRS/SSB may not collide with signals from other cells, TRS/SSB also likely collides with data symbols.

Regarding how to capture the impact of inter-cell SSB/TRS colliding, we can jointly perform PBCH decoding and PDSCH demodulation that is similar as the UE behavior in the real network. To elaborate further, the time frequency offsets introduced by SSB and TRS can be forwarded to PDSCH demodulation. In this way, we do not need to model the impact of inter-cell SSB/TRS during evaluation.

For the reference receiver, we share the similar view with CTC that TSR/SSB-IM instead of the TRS/SSB-IC can be used to mitigate the interference from neighboring TRS/SSB and data.

11 – ZTE Wistron Telecom AB

We understand the potential issue if SSBs are colliding. However, one of the essential improvements of NR over LTE is the flexible locations of SSB, and we would like to understand why an off-the-shelf solution which can avoid the issue cannot be used, while we need to turn to another complex solution?

2.1.6 Objective #5: E-MMSE-IRC under uneven interference

Based on previous discussion, at least study phase is required to identify the realistic scenario, receiver assumption and potential impact to other WGs i.e. assistant signalling related to RAN1 and RAN2 if this objective included in Rel-18. With the comments in previous email discussion, the realistic commercial demand for the scenario also need to be further clarified.

Justification: Improved the performance under uneven inter-cell interference with E-MMSE-IRC receiver

Objective:

- Evaluated and if identified specify E-MMSE-IRC receiver for uneven inter-cell interference
  - Phase I:
    - Identify the typical scenario with time-selective interference
    - Study the performance, receiver assumption, required assistant signalling and potential impact to other WGs
  - Phase II (if any pending on the outcome of phase I discussion):
    - Specify PDSCH demodulation requirements with E-MMSE-IRC receiver under uneven inter-cell interference scenario
    - Specify CQI reporting requirements if needed
  - **Comments and discussion**

Please provide comments and justification on above detailed objectives.

Feedback Form 6: Objective #5: E-MMSE-IRC under uneven interference

1 – Nokia

Do not include in WI.

Effective mitigation of uneven interference using E-MMSE-IRC (or other techniques) requires highly dynamic information about co-scheduled UEs and resources. It is practically impossible to deliver such information by the NW, as it locks the scheduler into taking all decisions tens (or hundreds) of ms ahead of time. This will degrade overall NW performance significantly.

More adhoc application of E-MMSE-IRC do not yield sufficient performance increase to justify complexity and RAN4 time.

2 – MediaTek Inc.

Not interested.

The UE may not know precisely about the resource allocation (in time and in frequency) of the co-scheduled UE. We do not prefer to further increase UE's demodulation burden on these blind detection to understand the profile of the co-scheduled UE. To us, it is not an efficient way to add UE implementation complexity. The worst case could even be that UE spent all its complexity and power to do the blind detection, but in most of the case the interference is still slot-based.

3 – China Mobile Com. Corporation

We prefer to exclude this objective from the R18 WI

So far, the non-slot based transmission is not widely used in network. The scenario of non-aligned SCS between NR cells is also not likely to happen. Therefore, we don't see the typical scenario and strong demand for this objective.

4 – Intel Corporation SAS

We support this topic with medium priority.

Baseline UE MMSE-IRC receivers are based on DMRS-based interference estimation and rely on a constant interference structure on a full slot duration. Time-selective interference can become a bottleneck for DL performance for URLLC scenarios with sub-slot transmissions due to mismatched interference estimate. Also, another scenario, whether DMRS-based interference estimation will not work, is Serving cell uses DMRS APs 1000/1001 with 1 CDM group and interference cell uses DMRS APs 1002/1003.

Enhanced MMSE-IRC receivers with data-based interference estimation or other enhancements can be considered to improve the performance under such scenarios.

As for Phase I objective, probably we can discuss not only the scenarios with time-selective interference and have more discussion of typical NR scenarios where baseline MMSE-IRC receiver does not work. As for Phase II, we think that we can focus on definition of PDSCH requirements.

5 – QUALCOMM JAPAN LLC.

The need for this enhancement is not clear. In our understanding mini slots are not used in commercial deployments so the use case is not clear. Also, such scenarios can already happen in async FDD deployments.

6 – Ericsson France S.A.S The benefits of this feature would arise if there would be large amounts of non-aligned slot lengths between neighbor cells for a significant proportion of the time. We do not believe that the amount of non-aligned slots and overall gain justifies the work that would need to be invested in this complex topic in this timeframe.
7 – China Telecommunications Ok to de-prioritize this objective. The main reason is that currently non-slot based transmission has not been deployed, and it is difficult to identify the typical scenarios without knowing the real deployment scenario.
8 – Apple GmbH We dont support this objective at this time. We need to understand how common this scenario is before spending time and effort to improve performance for it.
9 – vivo Communication Technology We support this objective with high priority.
10 – Samsung Electronics Co. There are many details need to be clarified and studied for this objective including reference receiver, realistic sceanrio, required signalling and other WGs' impact. On the other hand, we didn's strong evidence from commercial interest. We would like to deprirotize this objective.
11 – Huawei Tech.(UK) Co.. Ltd We suggest to drop this objective. Firstly, non-slot based transmission is a corner case so far. Secondly, significant network assistant signaling required via DCI is not affordable if we want to properly handle the interference, because the scheduling of mini slots may be dynamic and there are countless cases to thoroughly consider. Thirdly, if we want to reduce the cost of NWA, the structure of the interference cannot be perfectly obtained, which means that the E-IRC receiver may not achieve performance gain and may be even worse than the receiver without using IRC or the IRC receiver without differentiating mini slots from normal slots.
12 – ZTE Wistron Telecom AB Low priority, lack of real commercial demands.

2.1.7 Objective #6: BS advanced receiver (MMSE-IRC)

Proposal for discussion

Moderator observed the objective is clear enough meanwhile further discussion needed for the necessity of introducing the requirements in Rel-18.

The detailed objectives and justification as following:

Justification: Improve uplink performance with MMSE-IRC receiver for suppressing inter-cell interference

Objective:

- Specify MMSE-IRC receiver for suppressing inter-cell interference (FR1 only)
  - Define PUSCH demodulation requirements
  - Reference receiver: MMSE-IRC with DMRS based interference covariance estimation
    - Note: use the DMRS for target UE's PUSCH.
  - Reuse LTE interference profiles as starting point
  - Focus on slot-based transmission and aligned SCS among cells

Comments and discussion

Please provide comments and justification on above detailed objectives.

Feedback Form 7: Objective #6: BS advanced receiver (MMSE-IRC)

1 – Nokia

Propose to include in WI, but without mention of MMSE-IRC.

BS receiver/demodulator performance has improved significantly since requirements in Rel-15 were introduced. Especially in interference scenarios. Such gains can now be highlighted by new advanced receiver requirements to enable more aggressive network planning and assumptions in algorithm implementation.

However, the implementation of the advanced receiver should not be influenced by RAN4. As such the mention of MMSE-IRC should be removed. It is possible to only mention "advanced receivers for suppressing inter-cell interference". In case delivered requirements are not aligned, a reference receiver can be introduced (e.g., MMSE-IRC with DM-RS based interference covariance estimation from target UE PUSCH).

2 – China Mobile Com. Corporation

Comparing with UE side enhancement, the priority of BS side enhancement is lower in our point of view. If TU allowed, we are fine to have further study.

3 – Intel Corporation SAS

We support this topic with high priority.

Existing BS requirements are defined for noise limited conditions and do not allow verification of BS interference rejection capabilities under practical conditions. Interference-limited conditions are quite typical for 5G deployments and support of MMSE-IRC processing is important to guarantee good performance in the field. Such requirements are considered in LTE. Therefore, we think it is rather important to verify MMSE-IRC capability for NR BSs.

4 – Ericsson France S.A.S

Since MMSE-IRC is already widely deployed for BS, we do not see a need to spend 3GPP time on creating requirements and this should have low priority. If the topic is included, care should be taken about the overall demod workload, and we would prefer to be clear that the objective is MMSE-IRC.

5 – China Telecommunications Support this objective. BS MMSE-IRC requirement was defined for LTE. For NR, with larger CBW compared to LTE, RAN4 requirements are needed to guarantee the good implementation and performance of MMSE-IRC. In addition, it is difficult to discuss further BS receiver enhancement if IRC requirement is absent. Regarding whether to mention the receiver type as commented by Nokia and Ericsson, maybe we can remove "MMSE-IRC" in the main bullet, and keep it in the bullet on "Reference receiver". Without a reference receiver, it would be difficult to provide and align simulation results.
6 – Samsung Electronics Co. We are ok to include this objective, with reference receiver as MMSE-IRC to ensure the objective clear enough.
7 – ZTE Wistron Telecom AB MMSE-IRC receiver is de facto even from the 4G era, and it is not worthy of burning RAN4 TUs if the intention is just for a 3GPP benchmark.
8 – Huawei Tech.(UK) Co.. Ltd Suggest to drop this objective. We would better focus on other enhancements that have higher industry interest considering the heavy workload and limited TU in RAN4.

2.1.8 Objective #7: ATP

In Rel-17, RAN4 already concluded the feasibility of defining absolute physical layer throughput requirements with link adaption (R4-2114569) under RAN5 Rel-16 SI FS_UE_5GNR_App_Data_Perf.

Based on previous discussion, It's also FFS whether a separate WI or this objective can be included in the umbrella performance evolution WI.

Justification: Introduce link adaption absolute physical layer throughput requirements

Objective:

- Specify absolute physical layer throughput requirements with link adaption
    - Note: Rel-17 RAN4 study outcome is a starting point for this objective

Comments and discussion

Please provide comments and justification on above detailed objectives.

Feedback Form 8: Objective #7: ATP

1 – Nokia

Propose to include in WI.

The Rel-17 study has concluded that ATP requirements are feasible to be defined in RAN4 (assuming the LA is limited to inner loop only) and such requirements show practically relevant performance figures.

RAN5 specifications are already prepared for ATP requirements and RAN5 is only waiting for RAN4 to deliver the requirements. As such the objective should be led by RAN4; RAN5 has already finished their main part earlier.

2 – MediaTek Inc.

Support.

There is some good Rel-17 study conclusions which can be used as a starting point for this work. We think it is about time for RAN4 to introduce some requirements based on the new framework.

3 – China Mobile Com. Corporation

We support this objective.

The SI in RAN5 is not completely finished. We prefer to discuss the objective after RAN5 ending the SI.

4 – Intel Corporation SAS

We don't support this topic as a part of Rel-18 Demodulation Enhancement WI.

Taking into account that ATP studies were done in the scope of a RAN5-led SI, we think that it is more natural to have RAN5-led WI and an explicit request to define the corresponding requirements in RAN4 specifications.

5 – QUALCOMM JAPAN LLC.

We support this work as a continuation of the RAN5 led SI. At the time this was discussed, there were multiple comments that a RAN5 led item is not appropriate so a RAN4 led item is better. Given the good alignment obtained in the SI phase, definition of the RAN4 requirements should be straightforward.

6 – Ericsson France S.A.S

We are OK for a WI to be RAN4 lead and OK in for ATP to be included... but if it is included then we need to take care of the overall workload for UE demod, considering both the proposals here and the things coming from other WIs.

7 – AT&T GNS Belgium SPRL

We support the justification and objective. In the original RAN5 request, there was a request to have performance expectations under link adaptation scenarios identified by RAN4.

8 – China Telecommunications

We support this objective.

RAN4 already finished the study half-year ago, it is very straightforward to start the work phase.

In addition, we think the workload is limited, with the good alignment of simulation results in the study phase. Perhaps what we need to do is just to pick the SNR testing points.

9 – Apple GmbH We support this objective. The Rel-17 study concluded that it was feasible and our understanding the work phase to define the Phy layer TP requirements with LA should be relatively straight forward.
10 – Samsung Electronics Co. Same view as other companies, this is the continuation work of Rel-17 study. We are ok with this objecticve if strong commercial interest collected.
11 – Huawei Tech.(UK) Co.. Ltd The evaluation conducted by RAN4 is based on the RAN5 SI as secondary working group, RAN4 has evaluated a large SNR range to cover all possible scenarios, the remaining work is just to select the minimum number of cases for requirements definition to meet RAN5 ATP testing. Now RAN5 doesn't complete the SI yet, and RAN5 will also create follow-up WI to define the related test cases, we think that RAN4 can do the related work as secondary working group of RAN5 follow-up WI as did for RAN5 SI. Or RAN4 can define the corresponding requirements by TEI as per RAN5's explicit request as suggested by Intel. Also we think that it is early to discuss the objective in RAN4 Rel-18 WI for the performance definition before RAN5 SI completion as CMCC indicated.

2.1.9 Objective #8: Extend MMSE-IRC receiver for inter-cell and intra-cell MU-MIMO to CA case

Proposal for discussion

The objective itself is clear enough meanwhile the justification and the necessity of introducing such requirements need further discussion.

The proposed justification and objectives as following:

Justification: Extend MMSE-IRC receiver for inter-cell and inra-cell MU-MIMO to CA case

Objective:

- Specify MMSE-IRC receiver for suppressing inter-cell interference and intra-cell inter-user interference in CA scenario
    - Extend the Rel-17 single carrier PDSCH demoulation and CQI requiremrents to CA scenarios
    - Reference receiver: MMSE-IRC with DMRS based interference covariance estimation
    - Focus on slot-based transmission and aligned SCS among cells

Comments and discussion

Please provide comments and justification on above detailed objectives.

Feedback Form 9: Objective #8: Extend MMSE-IRC receiver for inter-cell and intra-cell MU-MIMO to CA case

1 – Nokia

Do not include in WI.

Straightforward feature with predictable performance that requires significant specification work and time. Not a good use of limited RAN4 resources.

2 – MediaTek Inc.

Neutral.

We share similar view as Nokia that this is a straightforward extension of the Rel-17 requirement, but we are fine to work on it if operators have strong interest.

3 – China Mobile Com. Corporation

We prefer not to include this objective due to foreseeable large workload and limited TU. The CA function has been verified, there is no need to bundling every enhanced receiver with CA.

4 – Intel Corporation SAS

We don't support this topic as dedicated objective of Rel-18 Demodulation Enhancement WI, because, based on our understanding, we have more important topics which can be included in the Rel-18 scope.

Also, we don't see the big benefits from introduction of dedicated CA requirements for scenarios with inter-cell and inter-user interference. Correct MMSE-IRC processing will be verified by requirements introduced in Rel-17. Based on R4-1912832, it was agreed that MMSE-IRC receiver is baseline receiver for Normal CA requirements. Therefore, we don't expect the issue with interference limited conditions in CA scenarios.

In case this topic is supported by many companies, probably we can consider it in Rel-17, because we don't expect big workload and we just need to prepare results for multiple SCS/CBW combinations. All testing methodologies can be reused from Normal CA requirements.

5 – QUALCOMM JAPAN LLC.

This should be already supported by most UEs so it is of very low priority.

6 – China Telecommunications

Ok to de-prioritize this one given the workload issue.

7 – Apple GmbH

We dont support this. We cannot be defining all requirements for CA case .

8 – Samsung Electronics Co.

The UE feature for Rel-17 MMSE-IRC receiver is still on discussion in RAN4 (mostlikly no differenriation between single carrier and CA cases from UE capability aspect). Typically RAN4 demodulation requirements focused on verficiation of proper UE baseband processing; we didn't see the difference among single CC and CA cases.

We prefer to deprioritize this objective.

9 – Huawei Tech.(UK) Co.. Ltd

Suggest to drop this objective.

The performance requirements for CA feature have been defined in Rel-16. Performance requirements for MMSE-IRC will be defined in Rel-17, it is not much meaningful to define demodulation requirements by combing different features from baseband point of view.

2.1.10 Others

Please provide proposals and comments on other working areas if any.

Feedback Form 10: Others

1 – MediaTek Inc.

Regarding 6Rx and 8Rx which are discussed in another Email thread, we see them as demod-heavy works with impact in the RF session. We wonder if they can be moved to this WI or they will be arranged into a standalone WI if companies have concern to include RF impact in this Demod WI.

2 – Intel Corporation SAS

CRS-IC for scenario with overlapping spectrum of NR and LTE One topic, which we want to add as a high priority topic, is CRS-IC requirements for scenario with overlapping spectrum of NR and LTE. This receiver was excluded from Rel-17 discussion. Therefore, we suggest covering it in Rel-18.

Based on our analysis, CRS-IC receiver provides a significant performance improvement in comparison to LLR weighting receiver. Also, in the previous RAN4 meeting, many CRS-related parameters are included in the NWA signalling as optional fields with certain conditions, under which information about these parameters is provided. Therefore, we can reuse the structure of this NWA signalling and just discuss which information is required to activate CRS-IC processing. Another open issue is impact on processing time, which can be discussed in RAN4 or can be checked with RAN 1 via LS.

3 – China Telecommunications

We also support to include CRS-IC in Rel-18.

Both LLR weighting and CRS-IC are evaluated in Rel-17. LLR weighting was agreed as the baseline reference receiver in Rel-17 normative work, considering the trade-off among the performance gain, UE complexity and the required network parameters.

Based on our link-level simulation results in RP-213093, 1.4 dB ~ 2.3 dB performance gain can achieved by CRS-IC compared to LLR weighting in DSS scenario, using the parameters agreed in Rel-17.

2.2 Summary of initial round

16 companies provided comments in initial round discussion including Nokia, MediaTek, Intel, Ericsson, CATT, Apple, Samsung, ZTE, vivo, Huawei, AT&T, BT, CMCC, China Telecom, Deutsche Telekom, Telecom Italia.

General

Almost all the companies support the proposal from moderator to have a WI with RAN4 led for performance evolution related objectives.

And all the companies agreed study phase can be introduced for some of objectives if needed.

For other WG impact, companies suggested this can be further discussed case by case. Apple also mentioned the impact to other WG only can be identified after primary study phase in RAN4 discussion.

Regarding timeline, almost all the companies agree the work shall be started after Rel-17 performance completed. MTK mentioned if some objective i.e. 8Rx included in this WI then RF related discussion shall started earlier. MTK also pointed out the completion timeline for other WG impact is different compared performance part completion timeline.

MTK and Telecom Italia also mentioned there are some other RAN4 led proposals not covered in this thread also have demodulation work impact.

Objective #1: Advanced receiver to cancel inter-user interference for MU-MIMO

14 companies including 4 operators support this objective with hig priority and almost all the companies fine with current proposed objectives with some sugguestions as list below:

- Regarding reference recevier assumption:
    - Intel, China Telecom and Huawei sugguest to list candidate receiver including R-ML and E-MMSE-IRC, further discuss and decide in the study phase.
    - Apple: Recommend E-MMSE-IRC and not favour of including R-ML.
- Target scenario: China Telecom recomend to focus on Slot-based on tranmission
- Others:
    - ZTE mentioned the outcome study does not lead to any resterction on the network scheduler on pairing co-channel UEs. It's moderator's understanding this objective focused on UE receiver requirements and no any impact or restriction on network implementation.
    - Some companies mentioned NWA siganling impact, moderator observed this already reflected in the proposed objectives as "required signaling overhead".
    - China Telecom also mentioned some other detailed update, moderator sugguests to keep those details to RAN4 group discussion.

Objective #2: Soft-IC receiver under SU-MIMO interference

Nokia, CMCC, Intel, China Telecom, Huawei support this objective with Soft-IC against inter-stream interference caused by SINR imbalance between layers of same CW with single MCS.

Intel, Apple, Samsung, Ericsson, ZTE ok to include this objective with study phase to evaluate the performance gain vs complexity.

MTK and Qualcomm have concern on this objective with impact on UE complexity and the achievable gain is questionable.

Other comments:

- China Mobile and Huawei suggested to remove “SCS among cells” from detailed objectives since this not relevant to SU-MIMO scenario.
- Apple also suggest to clarify the baseline receiver for performance gain evaluation shall R-ML receiver which specified in existing RAN4 requirements.

Objective #3: Enhanced DL receivers for multi-DCI multi-TRP

Nokia, MTK, CMCC, QC, E///, China Telecom, Apple, Samsung suggest to deprioritize /drop this objective from WI given this is a specific optimization which lack of strong evidence from commercial interest and demand.

Intel and Huawei recommend this can be merged with objective 2.

Objective #4: Inter-cell CSI-RS/SSB interference mitigation (IM)

Nokia, MTK, Intel, Qualcomm, Ericsson, Apple, Samsung and ZTE suggest to deprioritize /drop this objective from WI given the benefits and justification for the needs of this objective unclear and NW scheduling avoid confliction still can be available option.

Huawei support this objective.

China Mobile support this objective with low priority compared to objective #1 and #3.

Objective #5: E-MMSE-IRC under uneven interference

Nokia, MTK, CMCC, Qualcomm, Ericsson, China Telecom, Apple, Samsung, ZTE, and Huawei suggest to deprioritize /drop this objective from WI given no strong evidence from commercial interest, and the realistic scenario, feasible solution and cross WG impact also need to be addressed firstly.

vivo supports this objective with high priority.

Intel supports this objective with medium priority.

Objective #6: BS advanced receiver (MMSE-IRC)

Nokia, Intel, China Telecom, Samsung support to include this objective into WI.

CMCC is ok but with low priority compared to UE side enhancement.

Ercisson, ZTE and Huawei comment this already widely deployed for BS, no worth to use RAN4 TU to define RAN4 requirements.

Objective #7: ATP

All the companies support this objective/work shall be included in Rel-18 given it’s a continuation work based on the outcome from Rel-17 study.

CMCC, Huawei prefer to postpone the discussion for this objective till RAN5 SI concluded

For how to handle this objective, different views collected:

- Option 1: Including in RAN4 led performance evaluation WI
- Option 2: RAN5 led WI with RAN4 objective (Intel, Huawei)

Objective #8: Extend MMSE-IRC receiver for inter-cell and intra-cell MU-MIMO to CA case

Nokia, China Mobile, Intel, Qualcom, China Telecom, Apple, Samsung and Huawei proposed to drop/deprioritize this objective.

MTK neutral.

Others

MTK mentioned the ongoing discussion on 6Rx and 8Rx have heavy demod impact with impact in the RF session and suggested to move to demod evolution WI or have standalone WI.

@MTK, moderators understand other RAN4 proposals and other approved Rel-18 WIs from RAN1, RAN2 also have potential demodulation and CSI impact as business as usual. Respect the guidance and arrangement from RAN chair in RP-220003, this email thread focused on performance driven topics. 6Rx/8Rx proposals have both RF and demod impact and already covered by thread [RAN95e-RAN4-R18Prep-01], please continue discuss how to handle 6Rx/8Rx proposals under that thread.

Intel and China Telecom suggest to consider the objective: CRS-IC receiver for scenario with overlapping spectrum of NR and LTE.

3 Intermediate round

Moderators sugguests to focus on further refinement on the detailed objectives and potential down-scope the objectives from 1st round.

3.1 Proposals and comments collection

3.1.1 General

Propsoals

Proposal 1: the general aspects on potential Rel-18 RAN4 demodulation enhancement topic:

- WI vs SI: WI (study phase can be included for some of objectives if needed)
- WG leadership: RAN4, [potential secondary WG: RAN2 and/or RAN1]

It's moderator's understanding, when we decide the objectives and scope for this performance driven umbrella WI, we need to take care of overall RAN4 capability considering the overall demodulation work from other RAN4 led proposals and other WGs approved WIs.

Based on the comments collected from initial round, moderators suggest to drop following objectives.

Proposal 2: It's proposed to drop following tentative work areas/objectives in Rel-18

- Objective #3: Enhanced DL receivers for multi-DCI multi-TRP
- Objective #4: Inter-cell CSI-RS/SSB interference mitigation (IM)
- Objective #5: E-MMSE-IRC under uneven interference
- Objective #6: BS advanced receiver (MMSE-IRC)

- Objective #8: Extend MMSE-IRC receiver for inter-cell and intra-cell MU-MIMO to CA case

Comments and discussion

Please provide comments on above proposals.

Feedback Form 11: Comments on proposal 1 and proposl 2 of general part

1 – ZTE Wistron Telecom AB We are fine with Proposal 1. For Proposal 2, our comments on Objective #3 in the initial round was overlooked. There is some commonality between Objective #1 and #3, both may have a possibility of checked CRC for the interference cancellation, thus we may look into the possibility to merge these two objectives in some way, e.g., something like "Advanced receiver to cancel inter-codeword interference including MU-MIMO and multi-DCI multi-TRP".
2 – Qualcomm Incorporated We are ok with Moderator's proposals. Regarding ZTE comment, we are not sure how objective 2 and objective 3 can be combined. Objective 2 is about inter-stream interference within a CW while Objective 3 is about inter-codeword interference. They may need different handling from UE complexity and implementation perspective. Also, multi-DCI scenario is not much deployed. So, we prefer not to increase RAN4 workload by adding Objective # 3 to Objective #2.
3 – Qualcomm Incorporated Sorry for the multiple comments. Please ignore our comment on objective 2 vs 3. But we prefer not to combine objective 1 with objective 3. They are different scenarios and may need different UE handling. Also, multi-DCI scenario is not much deployed.
4 – China Telecommunications We are ok with Proposal 1. For Proposal 2, it is not our preference. But given the feedback in round 1, we respect the moderator recommendation.

5 – Apple GmbH

We agree with Moderator's proposals.

We don't think we should combine objective 3 with objective 1.

6 – Intel Corporation SAS

Proposal #1 is fine for us.

As for Proposal #2, we would like to continue discussion on BS advanced receiver (MMSE-IRC). Based on initial round comments, the main concern for this objective is that MMSE-IRC receiver is already widely used and we can save RAN4 effort. Same time, we don't have any requirements to verify this implementation. Therefore, it will be very beneficial to verify that NR BSs are able to make inter-cell interference rejection. Also, as China Telecom mentioned, in NR we have the larger CBW and it is important to verify the support of MMSE-IRC processing for NR CBWs.

7 – China Mobile Com. Corporation

Proposal 1 is fine for us.

For Proposal 2, we prefer to include Objective #4. However, to move forward, we are fine with moderator's proposal.

We share the same view with QC and Apple, don't combine Objective#3 with Objective #1.

8 – TELECOM ITALIA S.p.A.

ok with proposal 2. however, the proposal is now to have four objectives (see Sections 3.1.2-3.1.4). I believe this is still too much workload for RAN4 and some further objectives should be dropped. We suggest to focus on objectives with stronger operators' support (i.e. objective 1 and objective 7)

9 – Huawei Tech.(UK) Co.. Ltd

We support Moderator's Proposal 1.

We are fine with Moderator's Proposal 2.

We share similar view with QC on not merging Objective #3 to #1. The Multi-DCI multi-TRP target for scheduling for one UE, while MU-MIMO is scheduled for paired UEs by BS. Although there are two CRCs both in MU-MIMO and Multi-DCI, the CRC of the interfering UE cannot provide any benefits to the demodulation of the target UE. However, the CRCs in Multi-DCI can benefit from each other, since they belongs to the same UE. From our understanding, it is more reasonable to merge the Objective #3 to Objective #2, since Soft-IC can handle inter-layer interference both within 1 CW and 2 CWs.

10 – Nokia

Agree with proposal 1.

Concerning proposal 2:

Similar to Intel we would like to continue keeping BS advanced receivers on the table.

In particular we would like to see BS advanced receiver to take the place of new objective #9.

In the first round the objective #6 had 4 supporting companies, while objective #9 had 2. Also on the technical side we see more weight on O#6 (please see our comments to O#6 and O#9).

Mirroring the comments from others, we don't agree with merging O#3 into O#1.

Finally (for informative purposes), we see the relative priorities for the remaining objectives as:

1st MU-MIMO adv receiver

2nd ATP

3rd BS adv receiver

4th soft IC

Ultimately we re-iterate the moderators initial comment that not more than 3 objectives should be included in the WI.

11 – Orange

We agree with proposal 1. For proposal 2, we think objective 6 ”BS advanced receiver” should be tackled. Indeed advanced receivers at the BS is an essential lever for improving the UL (coverage, capacity, latency) and the UE energy consumption.

12 – MediaTek Inc.

Proposal 1 is fine to us.

On Proposal 2, we have same view on no merging #1 and #3, as mentioned by several companies. We also share similar view as Nokia, Intel and Orange to also include BS enhancement (#6). Some balanced enhancements between UE and network seems more reasonable.

13 – Ericsson France S.A.S

We agree that these should be dropped as proposed.

We should bear in mind that currently the following items are under discussion elsewhere that have significant demod work: UL 4TX MIMO, 8RX including >4 MIMO layers, 6RX including >4 MIMO layers, FR2 UL 256QAM, FR2 4 layer MIMO, FR2 HST including multi-panel and 500km/h, FR1 HST, ATG, CRS-IM and redcap… plus things coming from the RAN1-3 led WI. It is important to consider the total workload for demod and considering the other items, the proposed scope is generally OK (although we should also consider if soft IC is feasible from a workload perspective depending on decisions for the other issues).

14 – Samsung Electronics Co.

We are ok with proposal 1 and 2 from moderator. For merging objective 3 to #1, as we commented in initial round, no strong commercial interest foreseen for objective #3; study phase already included in objectives, given the workload, we prefer to drop objective #3.

3.1.2 Objective #1: Advanced receiver to cancel inter-user interference for MU-MIMO

The modified Objective as following:

- Evaluate and specify advanced receiver to cancel inter-user interference for MU-MIMO
    - Phase I: Study the performance gain, reference receiver assumption, testability, required signalling overhead, as well as impact on other WGs
        - <u>FFS on reference receiver assumption with below candidate receiver</u>

- □ E-MMSE-IRC
- □ R-ML

- ■ Target scenario: Focus on slot based transmission

- ○ Phase II (if any pending on the conclusion for phase I):
  - ■ Specify PDSCH demodulation requirements under MU-MIMO scenario with advanced receiver

Comments and discussion

Please provide comments on above detailed objectives.

Feedback Form 12: Objective #1: Advanced receiver to cancel inter-user interference for MU-MIMO

1 – ZTE Wistron Telecom AB As commented in the general part, there is a possibility of merging Objective #1 and #3. And we would like to add one note ”The study assumes that the network scheduler has full flexibility to pair co-channel UEs.”
2 – Qualcomm Incorporated We are ok with the proposal in principle. However, we are not sure what R-ML receiver entails and would like to exclude any blind detection of modulation from the scope of this objective.
3 – China Telecommunications In general, it looks good. Minor wording suggestion: May replace “FFS on” with “Further discuss”. We share moderator’s understanding that this objective focuses on UE receiver requirements and no any impact or restriction on network implementation.
4 – Apple GmbH We support the objective in general. As we commented in the 1st round, we prefer evaluate receivers in study phase that are practical and feasible from both UE implementation and signalling overhead perspective. We can include R-ML in study phase if the required signalling overhead is acceptable to all companies. As commented by Qualcomm, we would like to exclude any scope of blind detection of modulation order of the co-scheduled users for R-ML.
5 – Intel Corporation SAS Objective is fine for us. We can leave the decision on reference receiver up to RAN4 and include both in the WID description.
6 – China Mobile Com. Corporation We are fine with the modified objective

7 – Huawei Tech.(UK) Co.. Ltd We are fine with the objective in general. We support to investigate both E-MMSE-IRC and R-ML in the study phase and further discuss the performance requirements based on the outcome from Phase I.
8 – Nokia Fine with the modified proposal.
9 – Orange We would prefer that network assistance mechanisms allowing each paired UE to know the transmission format (resource allocation, coding, modulation etc...) to the other paired UEs is considered in RAN1. This would allow any kind of receiver architecture to be tackled in RAN4 and would be future proof.
10 – MediaTek Inc. The modified proposal is generally fine to us. We also share the view to exclude any scope of blind detection of the co-scheduled users for R-ML.
11 – Ericsson France S.A.S We are OK with these objectives. For the reference receiver, we are OK to consider both in phase 1, but then a decision should be made to focus on one reference receiver for the standardization phase considering performance and UE complexity.
12 – vivo Communication Technology We are fine with the modified objectives.
13 – Samsung Electronics Co. We are fine with the modified objectives.

3.1.3 Objective #2: Soft-IC receiver under SU-IMO interference

The modified objectives as following:

- Evaluate and if identified specify Soft-IC receiver to cancel inter-stream interference for SU-MIMO [RAN4]
    - Phase I:
        - Study the performance gain compared to R-ML receiver, UE complexity impact, reference receiver assumption and potential impact on processing delay before specify the requirements
        - Focus on slot-based transmission ~~and aligned SCS among cells~~
    - Phase II (if any pending on the conclusion for phase I):
        - Specify PDSCH demodulation with Soft-IC receiver under SU-MIMO scenario

Comments and discussion

Please provide comments on above detailed objectives.

Feedback Form 13: Objective #2: Soft-IC receiver under SU-IMO interference

1 – ZTE Wistron Telecom AB

The objective on the study phase I looks fine except the wording ”inter-stream interference”. The wording ”inter-layer interference” might be more specific?

And for phase II, we understand that at this stage we don’t know whether there is a Phase II or not, since it is subject to the study outcome in terms of the trade-off between performance gain and complexity increase. How to make a decision once Phase I is completed, or in other words, whether or not the trade-off is ”good” enough to validate Phase II? Some criterion could be clarified.

2 – Qualcomm Incorporated

Based on our internal simulation results, we see very minimal gains (0.2-0.5dB) from Soft-IC receiver at the expense of huge UE complexity. So, we are not in favor of this objective. However, if this objective gets agreed, we would like to add to the objective that SINR imbalance between different streams need to be reasonable (For example <= 3dB).

3 – Qualcomm Incorporated

We would also like to add that soft-IC receiver will impact the UE processing timeline which are already tight in NR compared to LTE.

4 – China Telecommunications

Ok with the objective with additional update suggested by ZTE: change “inter-stream interference” to “inter-layer interference”

Regarding the tradeoff, in our understanding, it is difficult to quantify the criteria.

Regarding the SINR imbalance between different streams/layers, it is our understanding that is depends on the channel correlation, so not sure how to (additionally or explicitly?) model the 3dB suggested by QC.

Regarding the UE processing timeline, it is already captured in the objective.

5 – Apple GmbH

Okay with objective and proposal to change “inter-stream interference” to “inter-layer interference”

We recommend to update : ”potential impact on processing delay” to ”potential impact on UE processing timelines”

We would like to also include the baseline assumption of soft-IC receiver if possible as its not very obvious.

Do we need to limit it to up to 4 layers as part of the study under this WI? Since there are parallel discussion going on for > 4layers with 8RX, we would like to make it clear that the scope here is for up to 4 layers.

6 – Apple GmbH

Also, how do we evaluate UE complexity since there is no method or criteria for this currently.

On the reference receiver, we assume it will be discussed during the study phase. But including a baseline assumption might be helpful.

7 – Intel Corporation SAS

Objective is fine for us.

8 – China Mobile Com. Corporation

Generally fine with the modified objective.

At this stage, we also see the difficulty of defining the criteria to evaluate the trade off between UE complexity and performance gain.

9 – Huawei Tech.(UK) Co.. Ltd

We are OK with the suggestion provided by ZTE, i.e., replace the "inter-stream interference" by "inter-layer interference". As suggested by Apple, limit it up to 4 layers would be better to have a clearer scope.

Regarding the clarification on whether or not the trade-off is "good" enough to validate Phase II, we propose to discuss it based on the study outcome of Phase I. We agree with CTC that the additional UE complexity, processing delay and performance gain over baseline R-ML need to be quantized firstly, and then we make the decision whether or not to trigger Phase II. This is also related to one of the most attractive strengths of Soft-IC, that it can achieve a very flexible trade-off between UE complexity/process delay and performance gain. As per our comments in the initial round, by exploiting a low-complexity detector in the 2nd outer iteration and by adjusting the number of LDPC inner iterations, obvious performance gain can also be obtained with UE complexity/process delay not being an issue.

As evaluated by QC, there is indeed some performance gain of Soft-IC compared to R-ML. Regarding the 0.2-0.5dB performance gain evaluated by QC, we suppose that this result is obtained with relatively low MCS. Higher performance gain can be expected with higher modulation order, such as 64QAM and 256QAM under medium/high channel correlation. We can further align some cases during the study phase.

The SINR imbalance between different layers is one of the motivations of Soft-IC. From our understanding, the SINR imbalance all depends on the real channel conditions. We cannot figure out how to restrict the range of SINR imbalance among layers. Restricting this value range is not the case in real network. The imbalance value of at most 3dB dose not have clear physical meaning. However, we are fine to study the SINR imbalance for certain channel conditions to investigate the relationship between Soft-IC performance gain and SINR imbalance value.

Regarding how to evaluate UE complexity, we think that we would investigate the additional complexity introduced by Soft-IC compared to baseline R-ML. From our now understanding, the main additional complexity comes from the detector used in the 2nd iteration. Some other complexity caused by additional one interleaver/de-interleaver and one scrambler/de-scrambler is negligible. From our now understanding, since we have a second iteration between the detector and LDPC decoder, the complexity of the detector used in the first time can also be reduced. For example, the number of total survival paths can be further

cut down even in the first iteration compared to original R-ML. In this way, the complexity of the two-time detection of Soft-IC can be comparable to the one-time detection of R-ML.

We can discuss the specific reference receiver during the study phase based on the investigation and alignment.

10 – Nokia

Fine with the text of the objectives, though as ZTE proposed, ”layer” might be preferable to ”stream”.

We don’t see a reason for limiting the inter layer SINR imbalance, as one of the main advantages of soft-IC is the possibility to increase overall TPUT by deliberately increasing the inter-layer imbalance (which the advanced UE can now handle).

Ultimately we see softIC as ”the lowest priority among the high priority” topics.

11 – Orange

We are confident that soft-IC would allow significant gain in the DL for SU-MIMO transmission with 4 spatial layers. The complexity/performance trade-off depends strongly on the receiver implementation choices. As a result, complexity issue should not be an argument against Soft-IC without further investigation.

12 – MediaTek Inc.

As mentioned in 1st round, we have concern on the UE complexity, its performance gain in the real field.

The UE processing time budget was defined in RAN1. We are not 100% sure if the impact to on processing delay is a decision that RAN4 can make.

13 – Ericsson France S.A.S

We are OK with the objectives but considering the rest of the demod workload (also from other threads / WI), this should be deprioritized if needed.

14 – vivo Communication Technology

We are also worried about the trade off between UE complexity and gain, this objective should be low priority.

15 – Samsung Electronics Co.

We are ok to include this objective with study phase.

3.1.4 Objective #7: ATP

Moderator observed the objective iteself stabe enough meanwhile further discuss needed for how to handle this objective with below options:

- Option 1: Include this objective into RAN4 performance evolution WI
- Option 2: Include this into RAN5-led WI with RAN4 responsible objective

Moderator understands this objective shall be RAN4 responsibility no matter whether it's included in RAN4 led or RAN5 led WI; and RAN4 effort can't be avoided even under RAN5 led WI. Also moderator would like to emphasize the normal work procedure: typically, RAN4 specify performance requirements first and then RAN5 introduce corresponding test cases in later phase.

Comments and discussion

Please provide comments on the objective and above candidate options on handing this objective.

Feedback Form 14: Objective #7: ATP

1 – Qualcomm Incorporated We agree with moderator's understanding and support Option 1 since typically, RAN4 defines the performance requirements and RAN5 defines the test cases based on that.
2 – AT&T GNS Belgium SPRL We also agree with the moderator's understanding and support Option 1.
3 – China Telecommunications We support option 1.
4 – Apple GmbH We support Option 1. We have the same understanding as Moderator on the normal work procedure and that RAN4 will need to do the work either way.
5 – Intel Corporation SAS Based on our comment from initial round, we support Option 2. We think that Option 2 is more aligned with typical 3GPP procedure for conversion of SI to WI. Note that Option 2 may give an impression that we aim to endorse a RAN5-led WI in this thread and we think that proponents need to bring the WI first and it needs to be discussed separately.
6 – China Mobile Com. Corporation We agree with moderator's understanding that the work shall be RAN4 responsibility. Option 1 is fine for us.
7 – Huawei Tech.(UK) Co.. Ltd We support Option 2. As per our comments in the initial round, the work left for RAN4 on this Objective is just to select the minimum number of cases for requirements definition to meet RAN5 ATP testing. It is a waste to set such little work as a standalone WI in RAN4 Rel-18, since we have many other urgent demodulation performance enhancement work to do. We think it is more reasonable to perform as a secondary working group after RAN5 finish the SI and start a follow-up WI.

8 – Nokia We agree with the moderator observation that the main responsibility and work of this objective will land on RAN4. Hence, we prefer for RAN4 to take the lead (option 1). We could accept RAN5-led, assuming the work starts in the same time frame as Rel-18 RAN4, which seems unlikely, since RAN5 has not yet been included in this discussion.
9 – Ericsson France S.A.S We are OK with a RAN4 lead WI
10 – MediaTek Inc. We support Option 1. We see this work as a new test case framework to be defined by RAN4, which does not really need to depend on RAN5 work.
11 – Samsung Electronics Co. We are ok for either options.

3.1.5 New objective #9: CRS-IC receiver for NR PDSCH in scenarios with overlapping spectrum for LTE and NR

This is a new proposal from initial round discussion. Moderator suggests to collect comments and feedback for this new proposal in intermediate round.

The justification and objective as following:

Justification: Further improve performance under LTE and NR co-existence scenario with CRS interference

Objectives:

- Specify Neighboring cell CRS-IC receiver for NR PDSCH in scenarios with overlapping spectrum for LTE and NR
    - Cover the two scenarios
        - Scenario 1: Serving and interference cells are both operating in DSS (NR+LTE) mode
        - Scenario 2: Serving cell is operating in NR mode and interference cell is operating in LTE mode
    - Focus on synchronous network scenario.
    - Discuss and introduce network assistance signaling if needed

Comments and discussion

Please provide comments and justification on above detailed objectives.

Feedback Form 15: New objective #9: CRS-IC receiver for NR PDSCH in scenarios with overlapping spectrum for LTE and

1 – Qualcomm Incorporated

This has already been debated a lot in Rel-17 SI. All companies agreed that it has potential performance gains but UE complexity impact is large and it may also have impact on UE processing timelines. Based on LTE experience, CRS-IC will have lower gains in practical scenario than observed in the SI. Therefore, we strongly prefer to drop this objective.

2 – China Telecommunications

CRS-IC is one of LTE-Advanced features that has implemented by many LTE commercial UEs. We agree LLR weighting has its advantage in terms of the overall trade-off. But the performance-wise, we see the 1.4 dB ~ 2.3 dB additional performance gain by CRS-IC compared to LLR weighting in DSS scenario.

3 – Apple GmbH

This topic has been discussed and debated extensively a bit in Rel-17. Based on the discussions and scope of work in Rel-17 for CRS-IM receiver, all the burden is eventually on the UE as no network assistance is mandatory at this stage , except for inter-RAT MO configuration. Given the additional complexity for the UE for CRS-IC we are not supportive of this.

Also, we wonder if both scenario 1 and scenario 2 will still be prevalent when Rel-18 capable UEs and networks are deployed. We hope scenario 2 at least can be resolved with network planning.

4 – Intel Corporation SAS

Taking into account that a lot of analysis and work for CRS-IM topic is done in Rel-17, we expect rather limited RAN4 efforts for this time. Same time, introducing of these enhancements will lead to significant system performance improvement. Therefore, we have strong support of this item.

As for objective, probably, we also can clarify that this is only for 15 kHz SCS scenario, because CRS-IC processing for 30 kHz SCS was agreed as unfeasible in the previous RAN4 meeting.

5 – China Mobile Com. Corporation

We have already done the extensive discussion about CRS-IC in R17 WI. Considering of UE complexity, potential NWA signaling overhead, and average gain <1.5dB compared with LLR weighting, we prefer de-prioritize this Objective.

6 – Huawei Tech.(UK) Co.. Ltd

We are not in favor of this objective.

Exhausted evaluations and discussions were conducted in Rel-17. The CRS-IM is selected as the baseline receiver due to its attractive complexity and performance finally. The CRS-IC has a higher complexity and limited performance gain compared to CRS-IM. The performance gain achieved by using CRS-IM is enough to acquire better UE experience, we do not see commercial benefits at least so far to additionally support CRS-IC on top of CRS-IM receiver since the reward is limited but complexity is increased. We agree with Intel that RAN4 efforts are limited, however, the complexity imposed on UE is not ignorable.

Considering that LTE-NR coexistence scenario is transient, we do not observe too much benefit to do enhancements for CRS-IC in Rel-18.

7 – Nokia

After very heavy discussions in Rel-17, the compromise of CRS-IM with LLR receiver instead of IC has been reached. However, no consensus was reached if IC can even achieve performance gains over LLR.

Hence, we don't see a need to spend a significant amount of time by repeating discussions on this in Rel-18 again. Objective #9 should be excluded.

Furthermore, the current CRS-IM agreements include NWA that allows to derive the interfering CRS sequences, and thus, interference mitigation using sequence knowledge is already included/possible.

8 – Orange

We agree with China Telecommunications why LTE should be better than NR in that respect. It is important since DSS by definition suffers already from a lot of control overhead

9 – Ericsson France S.A.S

We think this should not be included in the package; it has been investigated for Rel-17 and the gains vs. complexity do not justify it.

10 – Samsung Electronics Co.

We are netrual for this objective. If this objective included, we think the study from Rel-17 can be used as starting point including NWA signaling part which still on discussion in RAN4.

11 – ZTE Corporation

Based on the discussion in thread 6, companies prefer to the discussion the support the CRS-IM on Redcap UE in thread 4 demod part, from our understanding, in addition to CRS-IC, the support the CRS-IM on Redcap UE should also been taken into account, Rel-17 CRS-IM was well investigated to handle LTE CRS interfering in addition to RAN1 led Rate Matching scheme, however the evaluation scenarios mainly focus on antenna configuration 4x2 or 4x4 which is basically targeted for normal UE;

However for Redcap UE introduced in Rel-17, its receiver number could be relaxaed to be 1Rx for Low band and 2Rx or 1Rx for FR1 high band to reduce the cost; More details could be found in R4-2201483.

3.2 Summary of intermediate round

3.2.1 General part:

All the companies ok with proposal 1.

Almost all the companies ok with proposal 2 for down-scope the tentative objectives with some specific comments:

- Objective #3: ZTE proposed to combine with objective #1. Given the feedback from companies during initial round and intermediate, majority still preferred to drop this objective with no strong evidence of commercial interest. Moderator suggests to drop this objective at current stage; and pending on further

discussion in WI phase for objective #1, if needed we can open the discussion to extend objective 1 with supporting objective #3 in later stage of WI phase.

- Objective # 6 (MMSE-IRC receiver for BS): Intel, Nokia, Orange, MTK suggests to include this objective. Moderator suggests to include this tentative objective #6 (controversial) for further discussion in final round.
- Telecom Italia suggest further down scope needed to focus on objective #1 and #7.

Agreement: Proposal 1 endorsed.

3.2.2 Objective #1: Advanced receiver to cancel inter-user interference for MU-MIMO

All the companies ok with the proposed detailed objectives with some minor suggestions as following:

- China Telecom: Suggest to replace "FFS on" with "Further discuss". Moderators believes this minor wording change probably ok for companies.
- QC/Apple would like to exclude any blind detection on modulation orders of co-scheduled UEs. Moderator can understand companies' preference; such details can be further discussed in study phase and current objective already including study phase for reference receiver assumption, required signalling overhead.
- ZTE: Suggest to add a note "The study assumes that the network scheduler has full flexibility to pair co-channel UEs." From moderator's understanding, this objective targets to specify UE requirements, there is no restriction on NW scheduling implementation. Moderator didn't see strong need to include such note in WID objectives, for moving forward, moderator suggest to minute such note in the summary as RAN4 common understanding.

3.2.3 Objective #2: Soft-IC receiver under SU-MIMO interference

The proposed objectives seem acceptable with some comments as following:

- ZTE suggested to change "inter-stream interference" to "inter-layer interference", some companies also echo such suggestion. Moderator will update the objective with above suggestion.
- Apple suggested to clarify the scope with up to 4 layers. Moderator will update the objective to clarify the scope for up to 4 layer considering until Rel-17 up to 4Rx supported and we should avoid mixed two features introducing in the same release in parallel.
- MTK, vivo, Qualcomm and Apple also mentioned tradeoff among performance gain and complexity need to be considered; moderator understands the comments meanwhile the objective already includes study phase to evaluate above factors. For the details of criteria and receiver assumption, moderator suggests to leave such details into RAN4 discussion during study phase.
- MTK, Apple and Qualcomm also mentioned this may impact UE processing timeline. Moderator thinks the potential impact on processing delay already reflected in objectives. For moving forward, moderator ok to update the wording aligned with the suggestion from Apple "potential impact on UE processing timelines". MTK also comments not sure the impact on processing delay decision that RAN4 can take. Moderator sugguests we can further discuss in study phase and if needed LS can be sent to other WGs.

- Qualcomm suggest to add to the objective that SINR imbalance between different streams need to be reasonable (for example <=3dB). China Telecom and Huawei responced this subject to channel correlation conditions and hard to give restriction and detailed valus without further study evaluation in RAN4 during study phase. Moderator thinks without enough study/evaluation, it's hard to given a detailed limitation value which clearly subject to RAN4 discussion in study phase. To address this comment, moderator suggests to include such factor to be studied in phase I.

3.2.4 Objective #7: ATP

Regarding how to handle this objective with two candidate options:10 companies prefer option 1 to include in RAN4 led WI and Intel suggests to take option 2 with RAN5-led WI given in previous release it's trigged by RAN5 led SI.

3.2.5 objective #9: CRS-IC receiver for NR PDSCH in scenarios with overlapping spectrum for LTE and NR

Qualcom, Apple, China Mobile , Huawei, Nokia and Ericsson prefer to deprioritize/drop this tentative objective given this already extensivly discussed in Rel-17 timeframe without conclusion and LLR weighting for CRS-IM already specified in Rel-17, no much benefits observed on top of that.

China Telecom, Intel and Orange sugguest to consider this in Rel-18 given CRS-IC achieve addtional gain compared to CRS-IM with LLR weighting.

ZTE sugguests to consider supporting CRS-IM for Redcap UE. Considering the performance part of Rel-17 Redcap WI still ongoing in RAN4. Moderator sugguests not mixed these two issues togehther. For supporting CRS-IM on Redcap UE, this can be further discussed either under Rel-17 Redcap WI or in March RAN pleanry.

Given majority of companies prefer to drop this objective and also considering limited RAN4 capability, moderator suggest to drop this objective.

4 Final round

Moderators suggest to focus on fine-tuning of detailed objectives and the overall justifications of this WI in final round.

4.1 Proposals and comments collection

4.1.1 General part

Proposals on downscope:

Modified proposal 2: It's proposed to drop following tentative work areas/objectives in Rel-18

- Objective #3: Enhanced DL receivers for multi-DCI multi-TRP
- Objective #4: Inter-cell CSI-RS/SSB interference mitigation (IM)

- Objective #5: E-MMSE-IRC under uneven interference
- Objective #8: Extend MMSE-IRC receiver for inter-cell and intra-cell MU-MIMO to CA case

Note: it's moderator's understanding, objective #1, #2 and #7 stable enough with fine-tuning on detailed objectives ; objective #2,#6 and #9 need to be further discussed.

Comments:

Please provide comments on above modified proposal 2.

Feedback Form 16: Modified Proposal 2 on down-scoping of tentaive objectives

1 – Nokia Agree with modified proposal 2.
2 – Ericsson France S.A.S It seems that objective #2 is listed as both stable enough and needs to be further discussed. To confirm our understanding; this means that the objectives are OK but it is not decided whether to include it. As mentioned previously we think a final decision on whether to introduce should be made after considering an overview of all demod work, including from the other threads.
3 – Qualcomm Incorporated We have similar comment as Ericsson. There are a lot of demod heavy parallel threads being discussed such as 8Rx, 4L FR2, FR2 HST and so on. Given that much RAN4 work, we should try to minimize the number of objectives in this WI. We still prefer to just include Objective #1 and Objective #7 in this WI. So, we are ok with Proposal #2 and would like to drop more objectives.
4 – China Telecommunications Fine with Modified proposal 2.
5 – Apple GmbH We are fine with modified proposal #2. We believe some further down selection is needed among other objectives. To balance out the network and UE based enhancements we think Objective 6 (Adv receiver for BS) should be included in this WI.
6 – Huawei Tech.(UK) Co.. Ltd We are fine with the proposal in general. For Proposal 2, we still prefer to further drop Objective #6 and #9. Our details comments are provided in the comments for WID justification and other Objectives.

7 – MediaTek Inc. We are fine with Proposal 2 in general. We share similar view as Ericsson and Qualcomm. It seems Rel-18 is a really Demod-heavy release. It is very important to see the whole picture before making the final decision. No mention that Demod is sharing the same TU pool with RRM. Also, a balance between network and UE enhancement is important.
8 – China Mobile Com. Corporation We are fine with the proposal in general. We share similar understanding with Ericsson and Apple that further down selection is needed among the objectives which are not in this list.
9 – Samsung Electronics Co. We support the proposal. For remaning tentative objectives #1, #2, #6,#7 and #9, we think further down-scope needed to control reasonable work.
10 – Intel Corporation SAS Modified proposal 2 is fine for us.
11 – Orange We are fine with the modified proposal 2
12 – ZTE Wistron Telecom AB We are fine with the modified proposal 2 and further down-selection.
13 – TELECOM ITALIA S.p.A. We are in general fine with the proposal, and suggest to focus on #1 and #7 only

Based on the collected feedback, moderator provides an overall justification as following:

Overall WI justification:

The UE demodulation single carrier performance requirements with MMSE/MMSE-IRC and R-ML receivers for scenario of single-cell single-user with multi-layer transmission were defined in NR Rel-15. In NR Rel-16, requirements for MMSE/MMSE-IRC receiver for scenario with single-cell single-user were extended to CA/DC cases. For NR Rel-17, the single carrier UE performance requirements for MMSE-IRC receiver with DM-RS based covariance matrix estimation for intra-cell inter-user interference under MU-MIMO scenario and inter-cell interference scenario, and CRS-IM receiver based on LLR weighting for overlapping spectrum of LTE and NR scenario are agreed to be defined.

Considering the demodulation requirement enhancement in Rel-18, for the purpose of further enhancing DL throughput and coverage performance, it is beneficial to study and specify (if feasible) requirements for more advanced UE receivers for following scenarios:

- *MU-MIMO scenario: Further improve the performance with advanced receiver to cancel inter-user*

interference.

- *SU-MIMO scenario: Further improve performance with Soft-IC receiver to cancel inter-layer interfer*ence.
- *[Overlapping spectrum for LTE and NR Scenario: Further improve performance with CRS-IC receiver to cancel neighboring cell CRS for NR PDSCH]*

In Rel-17, RAN4 concluded the feasibility of defining absolute physical layer throughput requirements with link adaption under RAN5 Rel-16 SI FS_UE_5GNR_App_Data_Perf. It's worth to specify absolute physical layer throughput requirements with link adaption in Rel-18 taking the study outcome of Rel-17 as the starting point.

[Uplink inter-cell interference scenario: Existing BS requirements are defined for noise limited conditions and do not allow verification of BS interference rejection capabilities under practical conditions. Interference-limited conditions are quite typical for 5G deployments and support of MMSE-IRC processing is important to guarantee good performance in the field.]

Comments

Please provide comments on above overall justifications.

Note: Above justification, including tentative objective #1, #2, #6, #7 and #9. Pending on further decision and refinement on the detailed objectives in the final WI, above justifications can be further adjusted i.e. removing or adding corresponding justifications on specific objectives.

Feedback Form 17: Overall WID justification

1 – Ericsson France S.A.S OK in general, but the SU-MIMO, soft IC is not in square brackets. As commented above we think that the overall demod workload should be checked first before deciding to include #2. The note implies that it can be removed if needed though, just the other open topics have [].
2 – Nokia We are fine with the proposed WID justification.
3 – Qualcomm Incorporated Same comment as Ericsson. Soft-IC should be in [].
4 – China Telecommunications ok with the justification.
5 – Apple GmbH We are fine with the proposed justification. Echoing comments from Ericsson and Qualcomm, Soft-IC could be in [], otherwise its too many objectives.

6 – Huawei Tech.(UK) Co.. Ltd

In general, we are fine with the modified Proposal 2.

We share similar views with E/// and QC that we need consider the workload overall of RAN4. That's why we must focus our limited time and energy on urgent issues. As pointed out by moderator and the majority of companies, we should drop CSR-IC receiver due to its less benefits and higher cost compared to CRS-IM.

Objective #6 focusing on BS enhancement should also been dropped due to that it lacks of commercial benefits, since MMSE-IRC is already widely deployed for BS.

We support Moderator's decision to list Soft-IC as stable enough. This is definitely of high priority since it can solve a real critical issue. Note that different from all other Objectives, Objective #2 is targeting on a totally new scenario which we never studied before in NR. The targeting scenario, i.e., 1 CW for 4 layers is one of the most demanding scenarios in NR with higher throughput. If inter-layer interference can be handled with acceptable complexity and processing delay, it is worth much to investigate Soft-IC to increase the total throughput of network.

7 – MediaTek Inc.

Same view as E///, QC, Apple that Soft-IC should be in [ ]. The current Demod workload is too big in the whole Rel-18.

8 – Huawei Tech.(UK) Co.. Ltd

It is better to add [] on ATP considering still different views on how to proceed the following work based on the intermediate round discussion.

9 – China Mobile Com. Corporation

Ok with the WID justification

10 – Samsung Electronics Co.

OK with WID justification

11 – Intel Corporation SAS

WI justification is fine for us.

12 – Orange

We regret that *Uplink intra-cell interference scenario (SU-MIMO, MU-MIMO UL)* is not considered independently from IRC of inter-cell interference

13 – ZTE Wistron Telecom AB

In general the WID justification is fine for us. However, Objective #6 is different from other objectives, and is a huge waste if just aiming for a 3GPP benchmark. We also echo other companies concern on the overall Demod workload in Rel-18.

14 – China Telecommunications To Orange, for UL, the situation is little tricky. On one hand, it is claimed that BS IRC for inter-cell interference is widely implemented, and no need to define the requirement; on the other hand, without the baseline inter-cell IRC requirements defined, it is difficult to proceed with other enhancements.

4.1.2 Objective #1: Advanced receiver to cancel inter-user interference for MU-MIMO

Proposal 3: Include objective #1 "Advanced receiver to cancel inter-user interference for MU-MIMO" into Rel-18 performance evolution WI with below detailed objectives (stable enough):

- Evaluate and specify advanced receiver to cancel inter-user interference for MU-MIMO
  - Phase I: Study the performance gain, reference receiver assumption, testability, required signalling overhead, as well as impact on other WGs
    - ~~FFS on~~ Further discuss reference receiver assumption with below candidates
      - E-MMSE-IRC
      - R-ML
    - Target scenario: Focus on slot based transmission
  - Phase II (if any pending on the conclusion for phase I):
    - Specify PDSCH demodulation requirements under MU-MIMO scenario with advanced receiver

Note: The study on this objective assumes that the network scheduler has full flexibility to pair co-channel UEs. (This note no need to be included into WID objective)

Feedback Form 18: Objective #1: Advanced receiver to cancel inter-user interference for MU-MIMO

1 – Nokia Proposal 3 is fine for us.
2 – Qualcomm Incorporated In general, it looks ok. We would like to clarify that if requirements are agreed to be defined in Phase II, it should only be defined for one receiver assumption from all candidates considered in Phase I.
3 – China Telecommunications OK with Proposal 3. To Qaulcomm, in our understanding, the receiver used in Phase II is pending on phase I outcome, and can be discussed later.

4 – Apple GmbH Proposal is fine with us.
5 – Huawei Tech.(UK) Co.. Ltd Support this modified Proposal. We are open to discuss what kind of receivers to use for the final performance requirements definition according to the outcome of Phase I.
6 – MediaTek Inc. The objective is fine in general. In addition, we would like to make it clear that in the phase II new signaling is not precluded. RAN1/RAN2 involvement is only triggered by RAN4 conclusion (or LS).
7 – China Mobile Com. Corporation OK with the proposal
8 – Samsung Electronics Co. OK with the proposal.
9 – Intel Corporation SAS Objective is fine for us.
10 – ZTE Wistron Telecom AB Ok with the Moderator's proposal.
11 – Orange OK with the proposal, we think that new signalling mechanisms to help the UEs to better deal with the MU-MIMO interference is an important part of the study phase.
12 – China Telecommunications We are ok with MTK's suggestion that: RAN1/RAN2 involvement is only triggered by RAN4 LS if needed.

4.1.3 Objective #2: Soft-IC receiver under SU-MIMO interference

Proposal 4: Detailed objectives for Objective #3: Soft-IC receiver under SU-MIMO interference

- Evaluate and if identified specify Soft-IC receiver to cancel inter-layer interference for SU-MIMO [RAN4]
    - Phase I:
        - Study the performance gain compared to R-ML receiver under reasonable SINR imbalance between difference layers , UE complexity impact, reference receiver assumption, and potential impact on processing timelines

- Focus on slot-based and up to 4 layers transmission

- Phase II (if any pending on the conclusion for phase I):
  - Specify PDSCH demodulation with Soft-IC receiver under SU-MIMO scenario

Feedback Form 19: Objective #2: Soft-IC receiver under SU-MIMO interference

1 – Nokia

We would prefer to remove ”under reasonable SINR imbalance between difference layers” as the previous discussion has already highlighted different understandings as to what is ”reasonable”.

However, we can agree to this addition, if it helps to reach an overall stable objective.

2 – Qualcomm Incorporated

It looks ok. We would like to mention that if this objective is agreed, it may also need RAN1 TUs to study the impact on UE processing timeline.

3 – China Telecommunications

As replied in the intermediate round, in our understanding, the SINR difference depends on the channel correlation. Also, it depends on how we derive the SNR per layer, e.g., the singular values of the channel matrix, or post-processing SINR based on MMSE or soft-IC.

So, our preference is to just mention that typical channel correlations will be considered. But we can be fine with the current version.

For the processing timeline, I remember that we have similar description for R17 CRS-IM, and no involvement of RAN1 in R17 discussion. So, let us first discuss soft-IC within RAN4.

4 – Apple GmbH

We are fine with the proposal.

It would need RAN1 input to evaluate processing timeline. Do we need to add RAN1 as secondary WG in advance or could such work be done with an LS to RAN1?

RAN4 didn’t evaluate processing timeline in R17 for CRS-IC in our understanding.

5 – Apple GmbH

This would be one of the objectives to down-prioritize if necessary to limit the WI scope.

6 – Huawei Tech.(UK) Co.. Ltd

For the first bullet in Phase I, we are not sure what kind of SINR imbalance between different layers is “reasonable”. We share similar view with CTC that the SINR difference depends on real channel correlation. From our understanding, all kinds of realistic/typical channel conditions are reasonable. However, we are fine to investigate the SINR imbalance value for better understanding of the relationship between the performance gain and the channel correlations while studying Soft-IC.

As per our comments for the general part in this round, we think this Objective is of the highest priority among all other Objectives. Note that different from all other Objectives, this Objective targets a very critical scenario, i.e. the scenario with inter-layer interference in NR, which has not yet been studied. Regardless of its additional complexity and maybe impact on the UE processing timeline, it is of much worth to include this Objective. Not to mention its obvious performance gain, adjustable and comparable complexity cost as we pointed out in the previous rounds.

For the processing timeline, we share the similar view with CTC, the related discussion happened for CRS-IM in Rel-17 and not involve RAN1 as secondary working group. We haven't conducted the evaluation on the processing timeline for Soft-IC, it is too early to involve RAN1, we can further discuss this based on the following evaluations outcome.

7 – MediaTek Inc.

Firstly, we suggest to de-prioritize this objective due to workload control.

If this objective is to be introduced, we need RAN1's involvement to help assess the required UE processing timeline extension. In Rel-17 CRS-IM, the LLR weighting is taken as the reference receiver. Therefore RAN1 work is not needed. But the situation is largely different for soft-IC receivers. The work would be incomplete if we only consider the performance but ignore the impact to the processing timeline.

8 – China Mobile Com. Corporation

The proposal is fine for us.

Regarding the processing timelines, we share similar view with CTC. RAN4 did the similar qualitative analysis in R17 CRS-IM. We can start the discussion for R18 Soft-IC in the same way.

9 – Samsung Electronics Co.

Ok with the detailed objectives. For potentail impact on signaling , similar as Rel-17 performance WI; pending on study outcome in phase II, we can update the WID in later stage during WI phase if needed to include other WG impact or via LS.

10 – Intel Corporation SAS

In general, objective is fine for us. The following sentence is rather confusing "reasonable SINR imbalance", exact meaning of "reasonable" word is not clear, and it is not clear how to use this sentence in further discussion. Based on our understanding, we will have the detailed discussion on scenarios which will be analyzed and during this discussion the practical scenarios will be selected. Therefore, we suggest to remove this sentence from WID. WID should contain clear technical description.

11 – Orange

We do think that Soft-IC for SU-MIMO is an important lever to improve NR performance in the DL (particularly for 4 spatial layers SU-MIMO). The network should be aware of the UE soft-IC capability to provide a sufficient delay budget for generating the HARQ acknowledgement (RAN1/RAN2 involvement)

12 – ZTE Wistron Telecom AB

The objective looks fine for us. The texts on SINR imbalance may need to be polished. One advice could be:

Study the performance gain compared to R-ML receiver **considering imbalanced SINR among layers** ~~under reasonable SINR imbalance between difference layers~~ , UE complexity impact, reference receiver assumption, and potential impact on processing timelines

13 – China Telecommunications

For processing time, in Rel-17 CRS-IM, RAN4 discussed the processing time for both LLR weighting and CRS-IC.

As companies commented in the first two rounds, the complexity and processing time depend on the receiver implementation to be discussed in RAN4.

For RAN1/2, if companies have strong view, we can be fine to add the similar note as for objective 1: RAN1/RAN2 involvement can be triggered by RAN4 LS if needed.

4.1.4 Objective #6: BS adanced receiver (MMSE-IRC)

Proposal 5: Detailed objectives for objective #6 "BS advanced receiver" as following (controversial):

- Specify advanced receiver for suppressing inter-cell interference (FR1 only)
  - Define PUSCH demodulation requirements
  - Reference receiver: MMSE-IRC with DMRS based interference covariance estimation
    - Note: use the DMRS for target UE's PUSCH.
  - Reuse LTE interference profiles as starting point
  - Focus on slot-based transmission and aligned SCS among cells

Comments:

Please provide comments and justification on above detailed objectives

Feedback Form 20: Objective #6: BS adanced receiver (MMSE-IRC)

1 – Ericsson France S.A.S

We propose one further bullet:

- Assume synchronization and equal slot length between cells.

(This corresponds to removing #5 on the UE side)

2 – Nokia

Could it be further clarified, which DM-RS the note is referring to when stating ”target”? Is it the served UE or the interfering UE(s)?

In the LTE interference model for enhanced performance requirements type A, it is required that ”each interferer shall transmit 16QAM randomly modulated data over the entire PUSCH region and the same resource blocks as the tested signal”.

Hence, we assume that the note refers to the served UE’s DM-RS.

3 – China Telecommunications

We support this objective.

Views on E/// comments:

For sync and async, does it mean the time synchronization of the network? If so, we can discuss in WG level, similar to LTE BS IRC and NR UE IRC.

For equal slot length between cells, the proposed objective already says slot-band transmission, it means 14-symbol slot in all cells. So, may not need to additionally add the “equal slot length”.

Views on Nokia comment:

It looks to us ”target UE” equals to “served UE”, but is fine to change it to “served UE” in case it is clearer.

4 – Apple GmbH

We support this objective under demod enh to balance out network and UE enhancements.

5 – MediaTek Inc.

We support this objective to balance the enhancement to network and UE.

6 – Huawei Tech.(UK) Co.. Ltd

We suggest to drop this objective.

We would better focus on other enhancements that have higher industry interest considering the heavy workload and limited TU in RAN4. Considering MMSE-IRC is already widely supported for BS, we need justification on the industry value to do this paper work.

7 – China Mobile Com. Corporation

Due to limited TU, we prefer de-prioritize this Objective.

As mentioned by HW, MMSE-IRC has already widely deployed for BS, the commerial benefits is less comparied to other ongoing objectives

8 – Samsung Electronics Co.

We are netrual if RAN4 workload is strong concern, this one can deprioritize.

The proposed objective is fine for us.

9 – Ericsson France S.A.S To China Telecom: Regarding synchronization, yes we mean network synchronization. For slot length yes you have a point that it is covered. Our intention is to clarify that the scope of any WI under discussion does not include the uneven interference scenario, for which we would have the same arguments as the UE (corner scenario). It would be good to be clear in any WID. By the way, as commented earlier we prefer that this objective is deprioritized / dropped anyhow, since MMSE-IRC is already widely deployed, there is a large amount of demod work and there are better things to spend the TUs on.
10 – Intel Corporation SAS We support this objective. As for interference profiles, probably, it is also beneficial to mention that analysis and using of NR interference profiles is not precluded.
11 – Orange We regret that only inter-cell interference is tackled while for intra-cell interference better alternatives than linear receiver (LMMSE-IRC) exist
12 – ZTE Wistron Telecom AB Our view on this objective is not changed, at least it should be deprioritized if considering overall Demod workload in Rel-18.

4.1.5 Objective #7: ATP

Given above majority supporting on option 1, moderator suggests to take option 1. And the expected work on this objective is limited given RAN4 already do evaluation and study in Rel-17.

Proposal 6: Include objective #7 "ATP" into Rel-18 performance evolution WI with below detailed objectives:

- Specify absolute physical layer throughput requirements with link adaption
    - Note: Rel-17 RAN4 study outcome is a starting point for this objective

Feedback Form 21: Objective #7: ATP

1 – Nokia Agree with proposal.
2 – AT&T GNS Belgium SPRL Agree with Proposal 6.

3 – Qualcomm Incorporated Agree with Proposal 6.
4 – China Telecommunications Agree with Proposal 6.
5 – Apple GmbH We agree with the proposal.
6 – MediaTek Inc. Agree with Proposal 6.
7 – Huawei Tech.(UK) Co.. Ltd We still prefer Option 2 as per our comments in the initial and intermediate round discussion. Also we observed 4 companies are fine with Option 2 in the intermediate round discussion. It is feasible that RAN4 act as secondary working group for RAN5 SI, we think that it is very reasonable that RAN4 still continue as secondary working group for RAN5 follow-up WI. Before RAN5 SI is completed, it is too early to conclude the necessity of defining performance requirements in RAN4.
8 – China Mobile Com. Corporation Agree with the proposal
9 – Samsung Electronics Co. Agree with the proposal with option 1 to follow majority's preference.
10 – Intel Corporation SAS We keep the original view that there is no sufficient justification for this work and there is no relevant RAN5 WI. The objective has lower priority from our point of view and further discussion on WI down-scoping is required. If the objectives is added to the package we prefer to keep it in [] and have further discussion on prioritization.
11 – ZTE Wistron Telecom AB Ok with the proposal.

4.1.6 Objective #9: CRS-IC receiver for NR PDSCH in scenarios with overlapping spectrum for LTE and NR

Proposal 7: It's proposed to deporitize objective #9 " CRS-IC receiver for NR PDSCH in scenarios with overlapping spectrum for LTE and NR" in Rel-18.

If needed, the modified detailed objectives given below for reference:

- Evaluate and if identified specify neighboring cell CRS-IC receiver for NR PDSCH in scenarios with overlapping spectrum for LTE and NR
    - Phase I: Study the performance gain over LLR weighting receiver, impact on UE complexity, required signalling overhead, and potential impact on processing timelines
        - Cover the two scenarios
            - Scenario 1: Serving and interference cells are both operating in DSS (NR+LTE) mode
            - Scenario 2: Serving cell is operating in NR mode and interference cell is operating in LTE mode
        - Focused on synchronous network and 15kHz SCS
    - Phase II (if any pending on the conclusion for phase I):
        - Specify PDSCH demodulation requirements with neighboring cell CRS-IC receiver for NR PDSCH in scenarios with overlapping spectrum for LTE and NR

Feedback Form 22: Objective #9: CRS-IC receiver

1 – Ericsson France S.A.S As previously we do not support introduction of this objective (i.e., support proposal 7 above)
2 – Nokia Agree with proposal.
3 – Qualcomm Incorporated Agree with Proposal 7.
4 – Apple GmbH We agree with the proposal.
5 – Huawei Tech.(UK) Co.. Ltd We support Moderator's notes in the Overall WI justification to drop this Objective instead of deprioritize it and remove it from the draft WID in general part. As per our comments, the gain of CRS-IC is limited compared to CRS-IM. Although some NWA has been decided to be introduced for CRS-IM, we are not sure whether additional new NWA has to be introduced for CRS-IC, it is expected more hot discussions on the network signaling to help UE to reduce the complexity considering UE vendors' strong concerns on the UE complexity impact. Moreover, the significant UE complexity with regard to the limited gain makes CRS-IC lacking of any commercial benefits, not to mention LTE-NR coexistence scenario is transient, and this scenario is getting more and more corner. In a summary, it is a waste if we focus meaningless enhancements instead of focusing other urgent issues.
6 – China Mobile Com. Corporation Support the proposal

7 – Samsung Electronics Co. Support the proposal to drop this tentative objectibe given heavy work load in RAN4.
8 – Intel Corporation SAS We prefer to keep this topic for now. We already spend a lot of time for this topic in Rel-17 and due to limited time units and prioritization procedure it was excluded from Rel-17 scope. Therefore, to complete all efforts done in the Rel-17, we think discussion on definition of CRS-IC can be considered in Rel-18 with limited RAN4 effort. The only controversial topic, for which we could not reach the consensus due to limited time, is impact on processing time. Same time, most of the agreements of NWA signaling and test setup can be reused from Rel-17 discussion. Based on our analysis, CRS-IC allows to achieve reasonable performance (> 2 dB) benefits over MMSE-IRC receiver for wider set of scenarios (up to 50% interference cell loading) in comparison to LLR weighting (for which reasonable performance benefits can be observed for scenarios with low interference loading only, up to 20%). Therefore, taking into account significant system performance improvement and limited RAN4 efforts, we think it is very beneficial to consider this topic.
9 – Orange It is bit weird to be in this situation since LTE was implementing CRS-IC, the LTE-NR coexistence scenario may not be transient for some countries, frequency bands etc...
10 – ZTE Wistron Telecom AB We fully understand the demands for this feature, however we can live with the majority view.

4.2 Summary of final round

Down scope on tentative objectives

All the companies ok with modified proposal 2. Several companies also mentioned further down scope among remaining tentative objectives #1, #2, #6, #7 and #9 considering the Rel-18 demod workload especially the potential impact from RAN1/2 approved WIs and potential other RAN4 led proposals.

Agreement: Modified proposal 2 endorsed.

Overall WID justification

Companies overall ok with the proposed justification with specific comments:

- Suggest to keep the justification for objective #2, #6, #7 and #9 with [ ]. Moderator will follow such suggestion to keep them with [ ].

4.2.1 Objective #1: Advanced receiver to cancel inter-user interference for MU-MIMO

All the companies general ok with the proposed detailed objectives with some minor suggestions as following:

- MTK suggested to make it clear that in the phase II new signalling is not precluded. RAN1/RAN2 involvement is only triggered by RAN4 conclusion (or LS). In the objective for phase I, we already mentioned "required signalling overhead, as well as impact on other WGs" need to be stuied; based on the study outcome from phase I, RAN2 impact can be added if needed. In Rel-17 performance enhanced WI, for CRS-IM objective we add RAN2 impact into WID in later stage based on the study conclusion in RAN4. We can follow the same procedure as Rel-17 did. I hope above explanation can address MTK concern.
- Qualcomm suggests to clarify RAN4 shall specify performance requirements based on single reference receiver assumption. It's moderator's understanding this shall be common understanding, we can add one note in phase II objective "Note: Performance requirements shall be specified based on single reference receiver assumption."

4.2.2 Objective #2: Soft-IC receiver under SU-MIMO interference

For detailed objectives, companies general ok with some comments as following:

- Potential impact to RAN1 on PDSCH processing timeline: Apple, MTK and Qualcomm mentioned this potential involved RAN1. Considering we already have study phase, we can add RAN1 impact once we have clear conclusion during study phase. Moderator suggests to modify objective as " Study□□□, as well as impact on other WGs", and add a note in study phase "Note: RAN1 involvement can be triggered via RAN4 LS if needed"
- Regarding the sentence proposed by Qualcomm "reasonable SINR imbalance between difference layers", Intel, Huawei commented "reasonable" unclear. ZTE suggested to refine the sentence "**considering imbalanced SINR among layers** ~~under reasonable SINR imbalance between difference layers~~. Moderator suggest to make the refinement on the wording as "considering practical SINR imbalance among layers" to moving forward.

China Telcomm, CMCC, Orange, Huawei, ZTE, Samsung and Intel (7 companies including 3 operators) support to include this objective with study phase to address the concern for complexicity vs gain.

Apple, MTK, Qualcom (3 companies) sugguest to deprirotize this objective.

Moderator sugguests to include this objective into WI with study phase based on the majority supporting.

4.2.3 Objective #6: BS advanced receiver

Companies general OK with the proposed objectives with following sugguestion:

- Ericsson suggests to add such bullet "Assume synchronization and equal slot length between cells." into objective. China Telecom clarified in current objective, already restrict to slot-based scenario; for sync and async can be further discussed in RAN4 group during WI phase if agreed. Moderator think above reply already addressed Ericsson comments, no need to include this bullet.
- Nokia suggest to "target UE" changed to "served UE". Seems this suggestion agreeable, moderator will update the objective with above suggestion.

- Intel also mentioned it's better to clarify that analysis and using of NR interference profiles is not precluded. Moderator thinks such details can be left to RAN4 group discussion; current WID objective not preclude such activity in RAN4.

Nokia, China Telecom, Apple, MTK, Intel (5 companies) support to include this objective into WI.

Ericsson, Huawei, China Mobile and ZTE (4 companies) would like to deprioritize this objective due to RAN4 workload.

Samsung is neutral and also ok to deprioritize this objective if RAN4 workload is big concern.

Moderator suggests to include this objective into WI if RAN4 workload manageable.

4.2.4 Objective #7: ATP

The situation quite similar as intermediate round.

Nokia, AT&T, Qualcomm, China Telecom, Apple, MTK, CMCC, Samsung, ZTE (9 companies including 3 operators) agree with the proposal from moderator to include this objective into RAN4-led WI.

Huawei and Intel (2 companies) prefer option 2 to include into RAN5 led-WI.

Moderator sugguests to respect the majority view with option 1 to inclue this objective into RAN4 WI.

4.2.5 objective #9: CRS-IC receiver for NR PDSCH in scenarios with overlapping spectrum for LTE and NR

Ericsson, Nokia, Qualcomm, Apple, Huawei, China Mobile, Samsung (7 companies) prefer to deprioritize/drop this objective.

ZTE can accept to drop this repecting the majority view.

Intel prefer to keep this topic for now.

Moderator suggests to deprioritize/ drop this objective.

5 Conclusion

5.1 General part

Proposal 1 (agreeable): the general aspects on potential Rel-18 RAN4 demodulation enhancement topic:

- WI vs SI: WI (study phase can be included for some of objectives if needed)
- WG leadership: RAN4, [potential secondary WG: RAN2 and/or RAN1]

Modified proposal 2 (agreeable): It's proposed to drop following tentative work areas/objectives in Rel-18

- Objective #3: Enhanced DL receivers for multi-DCI multi-TRP
- Objective #4: Inter-cell CSI-RS/SSB interference mitigation (IM)
- Objective #5: E-MMSE-IRC under uneven interference
- Objective #8: Extend MMSE-IRC receiver for inter-cell and intra-cell MU-MIMO to CA case

Updated justification:

————-Start of justification————————

The UE demodulation single carrier performance requirements with MMSE/MMSE-IRC and R-ML receivers for scenario of single-cell single-user with multi-layer transmission were defined in NR Rel-15. In NR Rel-16, requirements for MMSE/MMSE-IRC receiver for scenario with single-cell single-user were extended to CA/DC cases. For NR Rel-17, the single carrier requirements for MMSE-IRC receiver with DM-RS based covariance matrix estimation for intra-cell inter-user interference under MU-MIMO scenario and inter-cell interference scenario, and CRS-IM receiver based on LLR weighting for overlapping spectrum of LTE and NR scenario are agreed to be defined.

Considering the demodulation requirement enhancement in Rel-18, for the purpose of further enhancing DL throughput and coverage performance, it is beneficial to study and specify (if feasible) requirements for more advanced UE receivers for following scenarios:

- *MU-MIMO scenario: Further improve the performance with advanced receiver to cancel inter-user interference.*
- *[SU-MIMO scenario: Further improve performance with Soft-IC receiver to cancel inter-layer interference.]*
- *[Overlapping spectrum for LTE and NR Scenario: Further improve performance with CRS-IC receiver to cancel neighboring cell CRS for NR PDSCH]*

[In Rel-17, RAN4 concluded the feasibility of defining absolute physical layer throughput requirements with link adaption under RAN5 Rel-16 SI FS_UE_5GNR_App_Data_Perf. It's worth to specify absolute physical layer throughput requirements with link adaption in Rel-18 taking the study outcome of Rel-17 as the starting point.]

[Uplink inter-cell interference scenario: Existing BS requirements are defined for noise limited conditions and do not allow verification of BS interference rejection capabilities under practical conditions. Interference-limited conditions are quite typical for 5G deployments and support of MMSE-IRC processing is important to guarantee good performance in the field.]

————————End of Justification part————————————-

5.2 Objective #1: Advanced receiver to cancel inter-user interference for MU-MIMO

Detailed Objective:

- Evaluate and specify advanced receiver to cancel inter-user interference for MU-MIMO
  - Phase I: Study the performance gain, reference receiver assumption, testability, required signalling overhead, as well as impact on other WGs
    - Further discuss reference receiver assumption with below candidates
      - E-MMSE-IRC
      - R-ML
    - Target scenario: Focus on slot based transmission
  - Phase II (if any pending on the conclusion for phase I):
    - Specify PDSCH demodulation requirements under MU-MIMO scenario with advanced receiver
      - Note: Performance requirements shall be specified under single reference receiver assumption

Note: The study on this objective assumes that the network scheduler has full flexibility to pair co-channel UEs. (this note no need to be included into WID objective)

Status: Stable enough, this objective can be included into WI

5.3 Objective #2: Soft-IC receiver under SU-MIMO interference

Detailed objective:

- Evaluate and if identified specify Soft-IC receiver to cancel inter-layer interference for SU-MIMO
  - Phase I:
    - Study the performance gain compared to R-ML receiver considering pratical SINR imbalance among layers~~under reasonable SINR imbalance between difference layers~~, UE complexity impact, reference receiver assumption, potential impact on processing timelines, as well as impact on other WGs
      - Note: RAN1 involvement can be triggered via RAN4 LS if needed
      - Focus on slot-based and up to 4 layers transmission

- Phase II (if any pending on the conclusion for phase I):
    - Specify PDSCH demodulation with Soft-IC receiver under SU-MIMO scenario

Status: Objective clear enough, FFS whether need to be included into Rel-18 WI with majority supports

Moderator suggests to include this objective into Rel-18 WI with study phase.

5.4 Objective #6: BS advanced receiver

Detailed objectives:

- Specify advanced receiver for suppressing inter-cell interference (FR1 only)
    - Define PUSCH demodulation requirements
    - Reference receiver: MMSE-IRC with DMRS based interference covariance estimation
        - Note: use the DMRS for served ~~target~~ UE's PUSCH.
    - Reuse LTE interference profiles as starting point
    - Focus on slot-based transmission and aligned SCS among cells

Status: Objective clear enough, controversial whether need to be included into Rel-18 WI

Moderator suggests to include this objective into Rel-18 WI if RAN4 workload manageable

5.5 Objective #7: ATP

Detailed Objectives:

- Specify absolute physical layer throughput requirements with link adaption
    - Note: Rel-17 RAN4 study outcome is a starting point for this objective

Status: Objective stable enough, FFS for how handle this objective with two options

- Option 1: Included this objective into RAN4 performance evolution WI (majority's preference)
- Option 2: Included into RAN5-led WI with RAN4 responsible objective

Moderator suggests to follow the majority, include this objective into Rel-18 RAN4 WI

5.6 Objective #9: CRS-IC receiver for NR PDSCH in scenarios with overlapping spectrum for LTE and NR

Tentative objectives

- Evaluate and if identified specify neighboring cell CRS-IC receiver for NR PDSCH in scenarios with overlapping spectrum for LTE and NR
    - Phase I: Study the performance gain over LLR weighting receiver, impact on UE complexity, required signalling overhead, and potential impact on processing timelines
        - Cover the two scenarios
            - Scenario 1: Serving and interference cells are both operating in DSS (NR+LTE) mode
            - Scenario 2: Serving cell is operating in NR mode and interference cell is operating in LTE mode
        - Focused on synchronous network and 15kHz SCS
    - Phase II (if any pending on the conclusion for phase I):
        - Specify PDSCH demodulation requirements with neighbouring cell CRS-IC receiver for NR PDSCH in scenarios with overlapping spectrum for LTE and NR

Status: Controversial, majority supports to drop/deprioritize this objective.

Moderator suggests to deprioritize this objective