

RAN-R18-WS-eMBB-Overall - Version 0.0.1

RAN

**3GPP TSG RAN Rel-18 workshop
RWS-210654**

Electronic Meeting, June 28 - July 2, 2021

Agenda Item: 4.1

Source: RAN Vice-Chair (Deutsche Telekom)

Title: Email discussion summary for [RAN-R18-WS-eMBB-Overall]

Document for: Information

This NWM thread is not meant to handle Questions/Comments/Answers already handled in the related NWM threads before the RAN Rel-18 Workshop.

Per the RAN Rel-18 Workshop Management document in RWS-210002, the NWM thread is NOT intended to debate the list of topics! It is meant to focus on Q&A to address comments/questions common to multiple contributions and interactions among different topics.

The participants shall avoid asking questions/giving comments of supportive/unsupportive nature in order to influence any prioritization/promotion of the topic, as in this phase there is no prioritization discussion.

Time line:

Questions/comments: June 28 08:00 UTC – June 30 8:00 UTC

Answers/comments: June 30 08:00 UTC – July 1st 12:00 UTC

Each company is expected to provide up to one input covering the set of topics of interest in each of the above two windows.

An email discussion summary is to be uploaded right after July 1st 12:00 UTC.

1 Evolution for DL MIMO

This section is targeted at identifying commonalities and interactions for Evolution for DL MIMO.

Feedback Form 1: Questions/Comments

1 – Apple Hungary Kft.

Beam Management

We found several companies (Samsung, Qualcomm and so on) proposed to further reduce the latency/overhead for beam selection to handle the remaining issues from Rel-17 FeMIMO. Since we have identified

several directions or groups for the enhancement in Rel-17, we would like to understand what the specific enhancements would be in companies mind. Could proponents clarify it a little bit?

Multi-TRP transmission

We have one question on the TRS-less proposal from Ericsson. Without TRS, how can UE perform AGC? Would network guarantee SSB is always transmitted in each active BWP and provide some information on power offset between PDCCH/PDSCH and SSB?

2 – Nokia Corporation

Based on the contributions and discussions so far, it seems that there is strong request from operators to focus on UL enhancements in Rel-18, including capacity driven enhancements and multi-TRP/multi-panel aspects. As by RAN chair guidance, the UL MIMO aspects should be continued under “UL enhancements” section, at least for the time being, but it would be good to clarify whether the multi-TRP/multi-panel, which are also related to UL, should be continued in the MIMO section. CSI enhancements for medium/high velocity are clearly proposed by quite many companies, and it would make sense to continue discussing those further in this section.

Multi-beam operation is certainly relevant, but it may be difficult to align on the exact enhancements that are needed in the near future, due to strong dependency with ongoing Rel-17 work. In any case, this is already a relatively mature area, and hence further enhancements are expected to be based on needs arising from practical deployments, as somewhat discussed in the GTW session. As for L1/L2-centric mobility, the RAN chair guidance is to discuss it under “mobility enhancement” section, and hence we will not further comment on it here. Finally, we would like to note that some companies indicated interest in fixed wireless deployments, which would make sense to continue discussing, though it is more a use case than a particular enhancement, so we expect it to impact several different sections independently.

3 – ZTE Corporation

We note that there is some overlap between MIMO, mobility and UL enhancement. So, in general, we are fine to split the MIMO into DL -MIMO and UL-MIMO, and meanwhile UL-MIMO may be considered as part of the UL enhancement. In Rel-18 L1-centric mobility can be merged into normal mobility.

Then, regarding DL MIMO, we have identified the following corresponding aspects based on the companies’ inputs: **codeword mapping enhancement, CSI enhancement, BM, mTRP operation, and some MISC issues.**

- #1 Regarding codeword mapping enhancement, i.e. 2 MCS or 2 TBs for ≤ 4 layers, the issue was from many real tests, and the proposal mainly on UL was supported by many operators based on RAN1 TEI discussion. We think it is better to have enhancement for DL as well in Rel-18 MIMO. We would like to check group’s views.
- #2 Regarding CSI enhancement, the flexibility of URLLC CSI triggering is an interesting topic, when another high latency CSI is being processing. Then doppler-domain related CSI codebook enhancement seems to be another hot topic. But, for CSI codebook enhancement, we should hold on a bit to see the market’s response for the previous three releases (TypeII CSI , eTypeII CSI , FR1 FDD reciprocity based CSI).
- #3 Regarding mTRP enhancement, we are open to consider simultaneous transmission cross multiple panel (STxMP) and more realistic assumptions for mTRP operation, like async . Then we realized some companies highlight coherent JT. But, coherent JT has been specified in LTE, but there are few corresponding deployments (unfortunately). Furthermore, for many cases, this coherent JT can be implemented in a spec-transparent manner. So, some justification on this coherent JT is needed.

- #4 Regarding BM, advanced tracking, refinement and reporting (as listed in issue 6 in Rel-17) for both DL and UL should be considered with high priority. Then we are open to further consider some further enhancement on unified TCI framework, e.g., for multi-band, or for multi-TRP. @Samsung and other companies, what enhancements on MB in this DL-MIMO agenda is needed for Rel-18, considering that most of BM related aspects are relevant to both DL and UL.
- #5 Regarding MISC issues, we are open to consider lower latency of acquisition (e.g., DMRS-based CSI reporting, at least for CQI), Asymmetric DL /UL for improving UL coverage & capacity (i.e, UL-only M-TRP operation), and latency and overhead reduction for beam management.

To summarize, we indeed believe that some future studies and clarification of motivation on each candidate objectives of DL MIMO are very necessary.

4 – Ericsson LM

For the *further CSI enhancements area*, the given example list in parenthesis should be extended to include accuracy and latency, meaning:

-
Accuracy: Reporting of post-PDSCH-decoding CSI (true CSI)

-
Latency-1: Early MIMO CSI reporting based on Msg3 trigger

-
Latency-2: Prioritized URLLC CSI over eMBB CSI

In the *evolved handling of multi-TRP and multi-beam*, more specific examples could be added in parenthesis. In our view, these are mixed traffic and mTRP-CSI

-
Mixed traffic: Simultaneous reception of eMBB and URLLC traffic where the latter use mTRP for robustness

-
mTRP-CSI: CSI feedback taking into account PDSCH repetition

Also, one more bullet should be added on *DMRS enhancements for PDSCH and PUSCH* to support increased number of co-scheduled UEs in MU-MIMO without increasing DMRS footprint/overhead

5 – Futurewei Technologies

Based on our reading of contributions, although there are a large number of proposals, R18 DL MIMO work should focus on a small number of items with clear motivation to avoid a larger than normal size WI. These include mTRP enhancements for non-closely synchronized scenarios which is not addressed in R17, latency reduction for multi-beam operation (issue 6 from R17), and MU-MIMO enhancements for high mobility, and cooperative MIMO which showed high potential to improve system capacity. For FR2 related work, it should be clearly stated that it is based on Rel-17 instead of Rel-15/16 framework.

6 – BT plc

From our perspective continuing work on enhancing practical DL MIMO efficiency is essential. We would like to clarify a few points on key proposed themes based on our reading:

#1. CSI enhancements (at least RWS-210075 Nokia, RWS-210093 Mediatek, RWS-210181 Samsung, RWS-210307 Ericsson) for enhanced support of mobility, further overhead and latency reduction:

- what is the proponents' view on the requirements for associated UE reporting?
- Our understanding is that currently there isn't even a Type II CSI reporting reflecting specifically MU-MIMO scenarios agreed in RAN4 despite techniques specified in RAN1. We believe it is important to ensure appropriate UE reporting is in place both for all mobility types.

#2. Larger number of UE Rx (at least RWS-210003 from Qualcomm, RWS-210203 from Rakuten and RWS-210093 Mediatek) - we would be interested to better understand following aspects:

- Is the target benefit here in single-user spatial multiplexing with higher layer count (8 or 12/16)? Or it is the extended communication range?
- How often conditions permitting these levels of multiplexing occur?
- Usage of 3/4 codeword – what are the expected gains relative to layer count?

#3. MU-MIMO:

- DMRS enhancements in RWS-210437 Huawei – we would welcome some more detail on 24-layer MU multiplexing, i.e. how often one would expect to see right conditions in the network to invoke such transmission.
- Assisted UE MU detection in RWS-210499 Apple – would you be able to elaborate on the expected scale of the impact?

#4. Distributed/Multi-panel FD-MIMO RWS-210181 Samsung and RWS-202180 Futurewei – what are the expectation regarding inter-panel coordination requirements, such as backhaul?

7 – Motorola Mobility UK Ltd.

[Lenovo, Motorola Mobility]:

Many companies have proposed Rel-18 DL MIMO enhancements related to beam-management, CSI enhancements, and multi-TRP transmission.

Beam Management:

- Most of the companies have discussed the key issues of latency and overhead especially for the case of larger number of beams, with enhancements including UE-initiated beam update/reporting, efficient aperiodic beam measurements, prediction-based beam-management and sharing/grouping of beam measurements/reporting across multiple UEs.
- In our view, discussion on the need and applicability of each of these enhancements to different scenarios is needed and based on that, prioritization can be done, if needed.
- Specific to prediction-based beam-management, several companies have indicated it as part of AI/ML topic, while some companies (including us) have indicated that it can be considered in MIMO for the scenarios where path prediction is relatively simple. In our view, group needs to discuss and converge whether prediction-based beam-management should be handled under the MIMO topic in Rel-18.

CSI Enhancements:

- A few companies (Ericsson, Intel, and others) have proposed studying CSI enhancements for multi-TRP URLLC schemes. In our view the Rel. 17 multi-TRP CSI framework can also be reused for multi-TRP URLLC schemes, albeit with a pessimistic CQI value and it is important to understand how significant the

impact of the lower CQI is on multi-TRP URLLC performance. In addition to the CQI recalculation, we would like clarification on what other enhancements do the proponent companies envision are needed.

- Regarding proposals on CSI enhancements for high-speed UEs, it seems that companies have different views on the scope of the enhancements, e.g., whether the enhancement is in the form of a new codebook type, or a new CSI reporting framework with fast CSI reporting configuration. In our view, further analysis is needed to assess the merits of the two approaches, as well as more discussion on the target use cases, e.g., drones, vehicles in highways, high-speed train. This will help to have a common understanding with well-characterized scenarios for the high-speed CSI enhancements.

- On CSI enhancements proposals for distributed MIMO and CSI enhancements for coherent joint transmission, they appear to be strongly correlated. We would like to better understand the scope of the enhancements being considered by the proponents, e.g., codebook enhancements, CSI-RS enhancements, CSI reporting configuration enhancements, etc. Also, clarification on whether the coherent joint transmission enhancements would focus on FR1 only or both FR1 and FR2.

Multi-TRP enhancements:

- In our view, the unified TCI framework and common beam feature of Rel-17 can be extended for both DL and UL multi-TRP operation. It is important to first understand the gains/benefits of coherent joint transmission (CJT) compared with specified NCJT scheme. We believe ideal backhaul is needed for CJT. We also think a common understanding is needed on the expected number of TRPs for multi-TRP transmission with CJT and NCJT in R18 including the number of TRPs for measurement and the number of TRPs for transmission to better understand the potential specification impacts.

In addition, any potential Rel-17 left overs - such as agreed lower priority topics on BFR for S-DCI multi-TRP and SFN-PDCCH which we think are unlikely to be completed in Rel-17 timeframe - should be included in Rel-18 MIMO scope.

8 – vivo Communication Technology

1. As UL MIMO related enhancement is discussed in separate item, there may not be clear boundary on DL/UL for some items, for example SRS enhancement could be for both DL and UL.

2. MIMO enhancement in Rel-18 should also include UE receiver performance improvement e.g. as discussed in RWS-210163.

3. CSI enhancement for high speed scenario is promising feature, which should also include UL signal e.g. SRS enhancement for CSI prediction at gNB.

9 – HuaWei Technologies Co.

We are positive on DL MIMO enhancements in Rel-18, similar view as many companies, shown in {0003, 0036, 0042, 0053, 0075, 0093, 0122, 0123, 0162, 0181, 0203, 0212, 0240, 0267, 0268, 0275, 0276, 0303, 0307, 0319, 0361, 0370, 0396, 0424, 0437/0438, 0440, 0499, 0497□0043,0141,0237,0250,0289,0291,0413, 0478,0509}.

For the DL MIMO enhancements, CSI enhancements on mobility UEs are proposed by a number of companies {0075, 0093, 0123, 0181, 0268, 0162, 0319, 0396, 0437}. Since mobility UEs are possible for FDD or TDD, CSI enhancements should be for both FDD and TDD cases, where SRS enhancements for TDD CSI acquisition (e.g., high SRS capacity to handle CSI aging issue) needs to be included in Rel-18 scope.

Enhancements on mTRP are mentioned by a number of companies { 0264, 0437, 0181, 0162, 0370, 0240, 0307, 0303, 0075, 0424}. We also share the view that mTRP should be enhanced in Rel-18. More specifically, in mTRP, coherent joint transmission should be enabled due to C-RAN structure is already deployed in real scenarios. For CJT, CSI feedback (FDD) and SRS (TDD) need to be enhanced to satisfy the requirements on accuracy of CSI for coherent joint transmission. Furthermore, much more UEs could be

co-scheduled for simultaneous transmission in the cooperated areas. To support such high order MU-MIMO transmission, DMRS needs to be enhanced.

In addition, it is known that high throughput comes from the accurate channel information acquisition and the accurate transmit precoding (based on the accurate channel information). However, there are many enhancements on MIMO in the releases from Rel-15 focus on CSI accuracy, but less discussion on the enhancements on precoding itself. As shown in our Tdoc, finer precoding (e.g., finer frequency-granularity) could provide obviously gains for both single TRP and multi-TRP. So, we propose to investigate the enhancements on precoding in Rel-18.

For multi-beam mechanisms that is primarily designed for FR2 but also applicable for FR1, we share similar view as in {0003, 0041, 0053, 0075, 0093, 0123, 0162, 0181, 0202, 0212, 0268, 0303, 0370, 0396, 0424, 0425, 0499} that beam management needs be further enhanced in R18. In particular, to facilitate the deployment of large-array FR2 gNB and UE, which can help achieve continuous Gbps coverage reusing existing macro site locations using narrow beamforming. For the beam management enhancements with large array, we suggest considering enhancements on intra/inter-cell DL and UL beam management procedures aiming for lower latency and overhead. With multiple panels at large-array FR2 gNB, to improve system capacity and spectrum utilization, we suggest considering enhancements to multi-user pairing mechanisms that can facilitate FDM and SDM multiplexing of multiple users.

10 – CATT

Our general view is that DL MIMO has been extensively investigated in past LTE/NR evolution with lots of features developed, while UL MIMO has been lagging behind in terms of performance, flexibility and robustness. We are open to DL MIMO enhancements on issues that are of high market urgency and system improvement potential, by considering existing features as implementation alternatives. Past 3GPP study (e.g. CoMP) could also be leveraged to understand the performance potential.

11 – Intel Corporation (UK) Ltd

We think that the DL MIMO enhancements should be considered in Rel-18 taking into account practical aspects and expected performance gains. For most of the proposals we think that study phase should be included in Rel-18 with proper evaluation using system level and link level simulations. Regarding detailed proposals we have the following comment / questions:

1. Beam management enhancement

- There is proposal on reduction of beam acquisition latency. Although the discussion on this enhancement is still ongoing in Rel-17, we think this aspect should be properly addressed for 5G NR.

2. CSI enhancement

- There is a proposal on CSI enhancement targeting URLLC mTRP transmission scheme. In our view this is important objective taking into account stringent requirement on CQI accuracy. In our view all implementation-based solutions are suffering from the accuracy issue to meet accurate target of BLER = 10^{-5} of the scheduled MCS.

· It would be great for companies having concern on this issue to clarify details of implementation solution and overall impact on complexity of such UE.

- There is proposal on CSI enhancements targeting mTRP support for < 1GHz. For this enhancement, the overall improvement of the user experience should be also considered taking into account CA configuration with other bands. It may be possible that the overall gain may not be noticeable due to relatively small amount of available spectrum.

· We are also wondering why the enhancement should be limited to ≤ 1 GHz bands and not ≤ 2.4 GHz bands, where small number of antennas is possible scenario due to FDD?

- CSI enhancement for fast mobility scenarios was proposed by many companies. We think this enhancement should be studied taking into account bursty traffic scenarios with dynamic interference that may change the preferred number of MIMO layers making long-term precoder prediction for the fixed RI difficult over long period of time.

3. Multi-TRP enhancement

- There is proposal on enhancement of mTRP scheme for non-ideal sync scenario or scenarios with large propagation delays. We think this proposal is important to address esp for FR2, where current RAN1 assumption of the Rx timing within CP can be easily violated even with ideal sync.

4. Transmission schemes related enhancements:

- There is proposal to support larger number of DM-RS ports. We think that this enhancement should be carefully studied taking into account enhanced precoding using Type II CSI or SRS based precoding, where the residual interference may not be significant in DL due to more accurate precoding. It should be further clarified why the existing DM-RS capacity with 24 sequences (2 groups of non-orthogonal DM-RS with 12 orthogonal sequences per each group in Type II DM-RS) is not sufficient to support MU-MIMO scenarios.

- There is proposal on enhancing CW to MIMO layer mapping scheme.

· We are wondering why mDCI framework can't be reused to support MCW scenario and why Rel-15 study indicate that SCW provides better performance comparing to MCW?

12 – Samsung Electronics Co.

CSI

-
Distributed RRH/antenna/MIMO: Several companies/operators have shown their support for enhancements to facilitate distributed RRH/antenna/MIMO usage especially targeting sub-1GHz bands. Discussion should continue pertinent areas such as transmission scheme, codebook, and interference measurement considering RRH selection, UL operations etc. This also includes system parameters pertaining to deployment scenarios (a part of EVM).

-
High-res CSI: CSI enhancements targeting higher speed scenarios is another area of interest among several companies. Companies can discuss candidate enhancements such as CSI enhancements based on time/Doppler-domain compression. In addition, although SVD-type compression for irregular antenna architectures (other than 2D ULA) hasn't generated large interest among companies, we suggest to continue discussion on this given the potential for DL throughput gain when more UL capacity (for feedback) is feasible.

MB: Efficient multi-beam operation is critical for FR2. Rel-17 introduced the unified TCI framework for beam management to reduce latency and signaling overhead. Building further on Rel-17, a number of further enhancements have been proposed in the contributions of many companies. These include:

-
Low latency/overhead for beam measurement/reporting, indication and training [x003, x075, x181, x212, x370, x396, x499], building on the Rel-17 framework such as the use of prediction-based beam management [x396, x181], reduced activation latency [x075], UE triggered aperiodic CSI-RS for P3 [x499].

-
Extension of the TCI framework to M-TRP ($M > 1$, $N > 1$) [x424] and more dynamic switching of joint and separate TCI states [x075].

-
UE initiated beam switching [x003, x053, x075, x093, x212, x303].

-
Enhancement of R17 common TCI state definition for CA scenario (inter-band, mixed numerology etc.) depending on what can be supported in Rel-17, and low latency/overhead multi-beam operations can be advanced MB features building on the Rel-17 MB framework

mTRP: We need to first justify the use case(s)/deployment scenario(s) – i.e., the necessity. As pointed out in several companies' contributions, enabling an asynchronous setting (for both FR1 and FR2) could be a starting point, which allows extended coverage and relaxed system requirements. Other use cases such as mixed single-DCI/multi-DCI for hybrid traffic need further discussions/justification on whether they are useful/common in practical systems.

13 – Xiaomi Communications

@all companies: According to contributions in MIMO session, we can find that enhancements on many issues have been proposed. Most companies focus on Multi-beam enhancement, multi-TRP enhancement, CSI compression via Doppler domain, frequency-selective precoding, Multi-layer for UL MIMO and distributed MIMO. We think each of them needs high workload, and we suggest to discuss the priority before deciding the scope of the WI.

@Ericsson: As for mixed mode single-DCI and multi-DCI multi-TRP in proposal 6, you mentioned that you mainly have TDM schemes in mind for single DCI part. So our first question is that, why not consider FDM scheme for single DCI part? The second question is that, it is possible that some resources allocated for eMBB will be pre-empted by URLLC of same or different UE, do you think TRP based or beam based pre-emption should be considered?

14 – NTT DOCOMO INC.

We believe UL enhancement should be one of the main features in Rel-18. Hence, DL MIMO enhancement should have limited scope compared to UL.

Following is our comments to some proposed topics:

-
HST, 996Hz Doppler shift: we believe it is important to support 500km/h@2.15GHz in bi-directional SFN via RAN4 demodulation requirement enhancement or RAN1 3-symbol gap TRS enhancement.

-
DL BM: It is good to consider DL BM enhancement in Rel-18. But similar as what we're discussing in Rel-17 MIMO now, the proposed schemes from different companies are quite diverse. We need to identify the enhanced schemes or directions for DL BM enh. before WI starts.

-
CSI enh.: It is good to consider CSI enhancement for high speed UEs. We can also consider some further enhancement based on Rel-17 MIMO CSI, e.g., CSI for URLLC.

-
Async mTRP: we are not so interested in it so far. But we're open to further consider it for inter-cell MTRP scenario (no need for intra-cell MTRP scenario).

-
Distributed MIMO: we noticed that some companies proposed NCJT enhancement (LG/KT/...) while some other companies proposed CJT enhancement (SS/FutureWei/...) for such distributed MIMO deployment. We need to clarify the deployment scenarios and benefits for each transmission scheme first.

15 – Guangdong OPPO Mobile Telecom.

We are supportive of further MIMO enhancement, e.g., CSI compression via exploiting time domain correlation. Two general questions regarding the coupling of MIMO and other topics are as below.

Q1. Can this topic also include potential enhancement for URLLC, e.g. CSI feedback for URLLC transmission scheme? Or these enhancement will be discussed in IIoT/URLLC?

Q2. It seems that there are many MIMO related objectives proposed by companies for AI/ML. How to balance the workload of MIMO enhancement and potential enhancement for AI/ML+MIMO maybe an issue.

16 – NEC Corporation

Based on our reading, for DL MIMO, a larger number of discussions are about beam management (BM), CSI, MTRP/panel, compared with other topics (note that L1/L2-centric mobility would be discussed in 'Mobility Enhancement' part). For BM and CSI, the major concern is on the efficiency, and for MTRP/panel, the interests are more on extending to new scenarios. More specifically, we have seen respective features attracting the most attention are as follows.

- BM (improve efficiency): UE initiated/assisted and/or event-driven BM, predictive BM
- CSI (improve efficiency): Doppler domain processing
- MTRP/panel (new scenarios): asynchronous MTRP, distributed antenna panel

Considering the large number of supporters, the objectives and features listed above can be the starting point for a more focused discussion. Before that, it could be a way forward to hear from potential opponents.

17 – LG Electronics Inc.

Overall, we think UL MIMO enhancements should be prioritized over DL MIMO enhancements in Rel-18 given many inputs from operators. For DL MIMO enhancements, we think that mTRP enhancements can be continued to improve service quality of both eMBB and URLLC. For DL MIMO, some companies proposed CSI enhancement for high velocity UE and some companies proposed further BM latency/overhead reduction. We have comments/questions on these enhancements:

- Re CSI enhancement for high velocity UE, companies propose time-domain compression codebook, Doppler based feedback, etc. Main motivation is for CSI overhead reduction. We wonder why this is critical enhancement for Rel-18 since high velocity UE could use non-PMI mode, where CSI overhead is very small.
- Re further BM latency/overhead reduction, Rel-16 BM and Rel-17 BM have been quite dedicated for this topic. We understand that there are many different proposals for BM latency/overhead reduction in Rel-17 on-going discussion and many of them are not likely to be specified in Rel-17 time frame. But this should not be a reason to reopen the door for all these various solutions in Rel-18, which will take quite a large TU again in Rel-18. If necessary, we prefer more focused goal for this.

18 – Spreadtrum Communications

In our views, R18 MIMO enhancement should focus on the features that can evidently improve system performance. Based on the contributions, most companies proposed further enhancements on UL MIMO, beam management, M-TRP, CSI. For UL MIMO, we will discuss it in UL enhancements. For beam management, overhead/latency reduction of beam measurement/reporting is an important topic, and the candidate options identified in R17 can be starting point. For STxMP, we think it's related to R17 MPUE, and we should wait to see how it goes. For M-TRP, asynchronous TRP deployment can be discussed. For coherent JT, we would like to see other companies' views. For CSI, some enhancements on the accuracy and latency can be considered, such as new CSI processing timeline. For codebook enhancement with time domain compression, it may not be friendly to UE due to the PMI calculation based on multiple CSI-RS resources. Besides, enhancements for particular application scenarios such as high speed, zero speed/FWA and vehicular DAS are also important topics.

19 – China Mobile Com. Corporation

CSI enhancement: Based on our reading, the directions of CSI enhancement proposed by companies are diverse. The enhancement includes high-resolution CSI reporting, post-decoding CSI feedback, overhead reduction, early reporting, etc. We suggest to focus on one or two directions to balance the workload.

Multi-TRP: Several companies propose to study the asynchronous scenario in M-TRP. In our view, the asynchronous scenario also exists in L1/L2 mobility. Whether this issue should be discussed in one agenda (e.g., DL/UL MIMO or mobility enhancement) or both agendas should be considered.

20 – MediaTek Inc.

We see some companies proposed asynchronous multi-TRP, which has potential for high additional UE complexity and significantly degraded performance gain (due to interference between signals) compared to the current synchronized baseline. Much more scrutiny is therefore needed before we agree to spend 3GPP time on such features.

With that in mind, please could proponents provide more clarity and quantification of the actual problem scenarios and envisaged associated performance expected in those scenarios? And preferably what they have in mind in terms of enabling this?

21 – Sony Europe B.V.

Higher order constellations and MIMO

The preponderance of LOS propagation in some deployments at 60GHz and above could create difficulty in raising peak data rates through high order MIMO as the channel would be rank deficient. At such high

operating frequencies, pencil beam forming can better create the LOS propagation and further improve SINR to allow the use of higher order modulations to increase the throughput.

We think the impact of phase noise at such high operating frequencies on higher order modulation will also need to be mitigated by studying some enhancements that may impact the constellation design itself.

Feedback Form 2: Answers/Comments

1 – Futurewei Technologies

We are also ok to continue discussing DL MIMO enhancements related to FWA/CPE type of use cases here. We also agree with a number of companies that L1/L2-centric mobility may be treated under mobility topic and is likely a RAN2/3 focused work considering R17 inter-cell beam management work. We also think that MU-MIMO with mobility is for both FDD and TDD systems and hence SRS enhancement should be included.

To MediaTek's question on asynchronous mTRP, we are open to discuss. With the current gNB synchronization requirements, the UE reception of channels from 2 TRPs are likely to not aligned within the CP especially for FR2. mTRP is a major feature to ensure high reliability and hence justify the need of asynchronous mTRP. Similar situation applies to uplink which request different TA towards different TRPs.

To BP's #4 question "regarding inter-panel coordination requirements, such as backhaul", we assume the question is for cooperative MIMO. Our proposal on cooperative MIMO scheme for interference probing and suppression requires some limited semi-static gNB coordination but no instantaneous coordination or information exchange among the gNBs. One way to implement the scheme, aka BiT (Bi-directional Training), is as follows:

-

Coordination stage:

gNBs semi-statically coordinate a common probing delay (the time gap between SRS probing and PDSCH transmission) and common SRS probing resources (e.g., set aside 1 or more OFDM symbols for UEs to send A-SRS for probing). "Common" means common to all cooperating gNBs.

-

Execution stage without instantaneous inter-gNB coordination or information exchange:

1. gNB pre-scheduling: each gNB schedules its PDSCH transmissions separately.
2. A-SRS triggering: each gNB separately triggers its scheduled UEs for A-SRS transmissions, and the A-SRS at least has the same FDRA as the scheduled PDSCH.
3. A-SRS transmission: UEs transmit A-SRS, which by gNB coordination are on the SRS probing resources.
4. PDSCH precoding adjustment: each gNB separately estimates interference on the SRS probing resources and adjusts PDSCH precoding for each of its scheduled UE.
5. PDSCH transmission: each gNB transmits the scheduled PDSCH with adjusted precoding on a slot according to the coordinated probing delay after the SRS probing resources.

The interference on the SRS probing resources carries information that can reflect "instantaneous" DL interference (i.e., associated with one-time scheduling outcomes) and can be useful for PDSCH precoding adjustment to suppress DL interference. Therefore, no instantaneous coordination, information exchange,

or knowledge of other cells' UEs is needed. Note that this is generally not the case for other cooperative MIMO schemes.

2 – LG Uplus

In commercialization point of view, we have concrete needs about CJT (Coherent joint transmission) based on our commercialization experience.

-

Regarding CSI (mainly for FDD), precoding matrix with finer granularity and various block-wise form is desired and, further, detail phase difference compensation measurement is desired in addition to TCI state.

-

Regarding SRS (mainly for TDD), SRS coverage enhancement is desired especially for high band spectrum.

-

Regarding backhaul, we thought assuming ideal backhaul (actually fronthaul) is sufficient so far, where at least 10 cells can be aggregated without consideration of the number of layers.

In long term research point of view, we think more antenna units with higher fronthaul capacity and smaller cell coverage is expected and CJT should be considered as a virtual single cell operation.

3 – Qualcomm Incorporated

To Apple's question on beam management related clarification of the latency/overhead reduction proposals for beam selection:

[Answer] As agreed in Rel-17, only up to one direction will be treated in each of the two groups. We think at least some directions not treated can be further considered in Rel-18. For example, if not treated in group 1, implicit beam update based on report and cross-CC SSB QCL indication can be further considered to reduce beam training & indication latency and overhead.

To BT's question #2 on larger number of UE Rx, addressed to Qualcomm:

[Question 1] Is the target benefit here in single-user spatial multiplexing with higher layer count (8 or 12/16)? Or it is the extended communication range?

[Answer 1] The target is to improve single user spatial multiplexing with up to 8 layers. The more Rx can help not only multiplex more layers, but also provide better interference rejection capability. We'd also like to consider different UE demod architecture.

[Question 2] How often conditions permitting these levels of multiplexing occur?

[Answer 2] It depends on the channel condition and UE antenna correlation. As we mentioned in the answer to the previous question, enhancement to improve interference rejection is another benefit even if the multiplexing level is not increased.

[Question 3] Usage of 3/4 codeword – what are the expected gains relative to layer count?

[Answer 3] On the one hand, more flexible scheduling can be applied using more codewords, each CW can use different MCS to achieve higher throughput. On the other hand, even if using 1/2 CWs, more Rx can significantly improve the throughput. For example, 8Rx UE may have more than 4 dB throughput gain and more than 50% throughput gain in both closed loop and open loop cases.

4 – Samsung Electronics Co.

Re Apple's question on potential beam management enhancements (as well as comments raised by several companies on the need for beam management enhancements), the main theme is to continue building on the features in Rel-17 (based on unified TCI framework). For example,

-

If Rel-17 unified TCI ends up only with $M=N=1$, Rel-18 should introduce extension to $M>1$ and $N>1$ to better support mTRP.

-

Rel-18 should introduce enhancements to reduce latency/overhead for beam measurement reporting and tracking to balance the fast beam indication introduced in Rel-17.

-

More advanced beam management schemes as suggested by other companies such as: use of prediction-based beam management [x396, x181], reduced activation latency [x075], UE triggered aperiodic CSI-RS for P3 [x499], group-based beam management [x181], UE-initiated beam switching [x003, x053, x075, x093, x212, x303] can also be investigated.

Re ZTE's comments

-

Beam management: We also suggest to handle DL and UL beam management in the same WI or area (e.g. evolution for DL MIMO) as they are tightly related in the unified TCI framework.

-

CW mapping enhancement: this issue was discussed extensively in Rel-15/16. Based on performance evaluation, it was observed that there is no performance gain with 2 CWs over 1 CW. We are unsure whether there is any need any benefits to discuss this enhancement again

-

CSI/codebook for higher speed: it seems that several companies perceive some potential real-life deployment impact for this enhancement. However, we do acknowledge that some investigation on potential gain is needed before committing to specifying features for this enhancement.

-

C-JT/D-MIMO CSI: although Type I multi-panel codebook can be a baseline, codebook enhancement can still be considered to achieve potential gains from distributed RRH (including different number of antennas for different RRHs). Furthermore, the Type II codebook can be enhanced considering multi-panel structure as shown in x181.

Re Motorola Mobility's comments

-
Predictive beam-management: we are open to discuss which topic area this could fall under (AI/ML or DL MIMO).

-
CSI/codebook for higher speed: in our view, the main potential enhancement for Rel-18 will be codebook design. The other enhancements (e.g. faster CS acquisition) can be considered if the overhead can be kept reasonable and performance can be maintained.

-
D-MIMO: the scope can include codebook design (analogous to C-JT), RS measurement, and reporting need for inter-RRH calibration and coherence. Re FR1 vs FR2, sub-1GHz (FR1) seems to be of higher-priority per operators' inputs.

Re Intel's comments on CSI enhancement targeting distributed RRH for <1GHz, as we discussed during two rounds, the limited spectrum in the frequency range is the main reason to enhance MIMO feature. As shown in x181, large gain is observed with 10MHz BW. The performance gain is mainly due to multiple RRHs, even though BW is small.

-
Note that our higher priority is sub-1GHz band based on the inputs from a number of operators. But we are also open to consider FR1 in general.

Re BT's questions/comments:

-
CSI: UE reporting may include components for time/Doppler domain compression (in addition to SD and FD compression in Rel-16). The mechanisms to keep the overhead reasonable will need to be considered.

-
Type II reflecting MU hypothesis: It is unclear how MU hypothesis can be measured for CSI reporting at the UE.

-
D-MIMO: for DL, both ideal and non-ideal inter-panel coordination can be considered. Since multiple RRHs are connected via fiber links to a central baseband processing, backhaul non-ideality is manageable.

Re LGE's comments on CSI for higher speed, it is true that transparent diversity-based scheme (non-PMI mode, or "semi-open-loop" CSI) can work in high speed FDD scenario. Our view is that some investigation on potential gain is still needed before committing to specifying features for this enhancement. Based on

some initial study, we see some potential gain over the transparent diversity-based scheme and hope to see if other companies can also confirm the initial finding.

Re Spreadtrum's comments on CSI for higher speed:

-

Multiple CSI-RS resources are not necessary to obtain Doppler component of the channel. A semi-persistent CSI-RS resource can be used for this purpose.

-

Other scenarios can also be discussed in addition to high speed, and if the need is justified and the scope allowing, they can be considered in the normative work plan

5 – MediaTek Inc.

CSI enhancements (high mobility as well as stationary UEs)

Answers to BT: On CSI enhancements, our motivation is to improve CSI resolution while keeping the overhead at bay by exploiting the channel's time domain correlation. This is applicable for high mobility and also stationary devices. We agree that RAN4 requirements would need to be defined for existing CSI reporting types, but stopping all new work would be a drastic response.

Vivo/Huawei points on SRS enhancements: Our proposal would be to focus the work on CSI enhancements.

Intel comments: The dynamic and non-stationary nature of interference in mobile network is a common problem regardless of UE's speed as the variation in interference may also arise in beamforming and scheduling. Such effects may be more pronounced in high speed scenarios. Whether special measures need to be taken requires more study.

LGE comments: The goal of time domain compression is to enhance DL throughput over non-PMI mode while keeping the CSI overhead at bay. We believe this can be achieved by properly designed CSI-RS transmission and corresponding compression techniques.

8Rx improvements

Answers to BT: Our motivation behind enhancing 8RX UE is to take advantage of the stationary nature of this type of devices and coupling this with the CSI enhancement proposed above. As a result, both SU and MU MIMO can benefit from the feature. How much SU-MIMO can be used depends on deployment conditions. For base station with large number of ports, the potential for multi-user spatial multiplexing should be significant.

Asynchronous mTRP:

We disagree with NEC (and others) proposal for prioritising asynchronous mTRP. So far it is very unclear as to the gain vs complexity. See our points from Q&A round.

6 – NTT DOCOMO INC.

To OPPO: Q1. Can this topic also include potential enhancement for URLLC, e.g. CSI feedback for URLLC transmission scheme? Or these enhancement will be discussed in IIoT/URLLC?

=> We think CSI feedback for M-TRP for URLLC can be considered. And if it is to be discussed, we think it is better to be discussed in MIMO other than URLLC since it is mainly related to MIMO CSI feedback framework.

To Xiaomi: @all companies: According to contributions in MIMO session, we can find that enhancements on many issues have been proposed. Most companies focus on Multi-beam enhancement, multi-TRP enhancement, CSI compression via Doppler domain, frequency-selective precoding, Multi-layer for UL MIMO and distributed MIMO. We think each of them needs high workload, and we suggest to discuss the priority before deciding the scope of the WI.

=> We agree discussion on priority is important. From DOCOMO perspective, the high priority issues include: HST with 996Hz Doppler shift, BM enh., and CSI enh. And the medium priority issues include: asyn mTRP, distributed MIMO.

To MTK: With that in mind, please could proponents provide more clarity and quantification of the actual problem scenarios and envisaged associated performance expected in those scenarios? And preferably what they have in mind in terms of enabling this?

=> As discussed in our contribution, it is important to support 500km/h@2.15GHz in bi-directional HST-SFN deployment in Japan, because we will have real deployment scenario.

7 – Intel Corporation (UK) Ltd

Answer to question from Mediatek on asynchronous mTRP deployment scenario.

In our view the additional UE complexity to support such scenario should not be significant. For example, in FR2, UE can still rely on single FFT operation, where FFT window setting should be panel specific instead of current panel common. The required specification changes to enable operation can be discussed further in RAN1. As a starting point we propose to consider TA issue and BM enhancement (to improve spatial isolation between panels). We also with CMCC proposal to consider such scenario for mobility enhancements similar to DAPS .

Answer to LGE comment on BM enhancement.

In our view the key issue of beam acquisition latency has not been addressed in RAN1. We think this enhancement is of higher importance comparing to latency reduction for beam indication being discussed in Rel-17.

Answer to OPPO question #1.

Since mTRP schemes for URLLC were developed under MIMO agenda item, the corresponding CSI enhancement should be also discussed under the same agenda item

8 – HuaWei Technologies Co.

Thanks for the comments, we have the following reply as following:

For the comments from ZTE #3: Based on our investigation, in NR deployments, quite high percentage network in some areas (such as China) are already deployed with C-RAN structure, in where Coherent joint transmission could be enabled in such structure. The situation is different as LTE. Furthermore, in LTE systems, CRS are always transmitted, which means very large overhead for coherent transmission. But, in NR, there is no such issue, all the CSI-RS and DMRS are UE specific configuration.

Then, with enhanced CSI and with enhanced RS design in standards could be very beneficial for coherent joint transmission. We also provided some preliminary evaluation results to show the performance gain of coherent joint transmission with CSI enhancements in our Tdoc, where obvious gain can be observed compared to NCJT. So, we believe coherent joint transmission are worth to be investigated in Rel-18.

For the comment from Ericsson: We agree with Ericsson, “one more bullet should be added on *DMRS enhancements for PDSCH and PUSCH* to support increased number of co-scheduled UEs in MU-MIMO without increasing DMRS footprint/overhead”.

For the comment from BT #3: We show the high probability of more than 12 layers for MU-MIMO transmission, where more 40% cases are required more than 12 MU layers in multiple TRP scenarios with RU=70% in our preliminary simulation. The DMRS enhancements need to satisfy the increasing requirement for MU transmission. For the detailed solution how to increase number of DMRS ports, we are open now, but in our initial thinking, the ports number increasing could be through introducing additional orthogonal cover codes or increasing cyclic shift, etc.

For the comment from Motorola on CSI and m-TRP for CJT: As we clarified in our contribution, the CRAN structure are with high percentage in real deployment for NR, where the coherent joint transmission could be enabled. Compared to NCJT, the antennas from different TRPs can be considered from the same gNB with joint scheduling and joint precoding. So, it is much more powerful to handle interference, more probability on high order MU pairing in a large cooperated area, etc. We also show the significant performance gain in our Tdoc compared to Rel-17 NCJT. In our evaluation, the number of TRPs for joint transmission is assumed up to 3 based on the RSRP gap no more than 10dB, and the measurement size is also assumed as 3 TRPs.

For vivo’s comment #1 and 3: We share similar view that SRS enhancements should be included in both DL and UL.

For the comments from Intel #4: DMRS enhancements with up to 24 DMRS ports is due to the clear requirements from real deployments: such as mTRP scenarios, UL industry use cases, and also there is requirements for XR and HD video applications, which is discussed in our Tdoc. It is known that high order MU pairing are sensitive with CSI and precoding. It is impossible there is no CSI error with type II CSI feedback or SRS based precoding (feedback delay also need to be considered), which will impact the MU pairing, especially for the case of higher order MU-transmission. With scrambling IDs to double DMRS ports, since there is high correlation between the two sequences, the performance will be degraded. As shown in our simulation, we can see a big gap between 16/24 orthogonal DMRS ports and 16/24 DMRS ports with scrambling IDs.

For the comments on CJT from DCM #5: In our understanding, distributed MIMO is the same as mTRP transmission with Coherent joint transmission. Compared to NCJT, the antennas from different TRPs can be considered from the same gNB with joint scheduling and joint precoding. So, it is much more powerful to handle interference, more probability on high order MU pairing in a large cooperated area, etc. We also shown the significant performance gain in our Tdoc compared to Rel-17 NCJT.

9 – Ericsson LM

We think the MIMO evolution need to have a balance between correcting shortcomings and inefficiencies of operations in the field, as identified by deployments and product development and on the other hand, future looking and high potential MIMO enhancements. It seems the number of TEI-17 proposals is increasing, which indicates that several companies have now observed actual problems from the field. These are often too large to fit into TEI, and needs to be handled by MIMO WI instead. These should have priority in our view since they address operators pain points. Then, there should of course also be room for new ideas, and Ericsson proposals is a mix of these two categories.

Reply to #1 (Apple): Regarding TRS less operation. The UE needs to perform coarse sync on the configured SSB, even if TRS is not configured. The UE can set the AGC using that same SSB. Whether there is need/benefit for some additional signalling of EPRE offset can be studied.

Reply to #7 (Lenovo, Motorola Mobility): Regarding the comment on reusing the Rel-17 multi-TRP CSI framework multi-TRP URLLC schemes, it should be noted that a BLER target of 10^{-5} will have to be met for URLLC data. Achieving such low BLER target with pessimistic CQI values is not efficient hence motivating the need for CSI feedback specific to multi-TRP URLLC schemes.

Reply to #13 (Xiaomi Communications): Regarding single-DCI and multi-DCI multi-TRP mixed mode, considering TDM schemes for the URLLC part is the simplest. This is because at any given time, the UE will be receiving PDSCHs via two TCI states (i.e., in a given symbol, the UE receives eMBB using one TCI state and receives TDMed URLLC using one TCI state). Since the use case for mixed mode is FR2, a UE with two panel can be sufficient if TDM schemes are considered for the URLLC part.

On the other hand, if FDM schemes are to be considered for the URLLC part, then the UE may have to receiving PDSCHs via three TCI states (i.e., in a given symbol, the UE receives eMBB using one TCI state and receives FDMed URLLC using two TCI states). This may require the UE to support simultaneous reception using 3 panels particularly when FDM schemes are considered for the URLLC part. But it is possible to limit the total number of TCI states to two (i.e., eMBB part is receive via TCI state #1, and the FDMed URLLC part is received via TCI states #1 and #2). We are open to discuss these possibilities.

To answer the second question, TRP based or beam based pre-emption is not needed in our view. The motivation for introducing mixed mode is to improve spectral efficiency for eMBB data while ensuring ultra-reliable low latency transmission for URLLC data in FR2. We think this can be achieve if the eMBB part and URLLC part are non-overlapping.

10 – Beijing Xiaomi Mobile Software

For the separate discussion of DL MIMO and UL MIMO, we agree that it is beneficial for more sufficient discussion. But we think after the separate discussion, it is better to discuss them together for consolidation since there are some overlaps such as RS enhancement and beam management.

As for DL MIMO, we think Multi-TRP/Multi-beam should be considered as high priority including some leftover from Rel-17. In addition, CSI enhancement considering Doppler domain compression can also be discussed for signaling overhead reduction.

11 – Nokia Corporation

Regarding the specific comments, please find the following responses from our side below:

Answer to #6 (BT):

We agree it is important to keep alignment between the WGs on how features are supported in the end, including proper requirements being developed in RAN4. For the CSI enhancements we mention in our contribution, the main objective is to track the channel variations more effectively, and for that we envision changes to CSI processing timeline latency reduction and/or new codebook enhancement in time-domain, which indeed imply changes in how that information is reported to the gNB.

Comment to #12 (Samsung):

We would like to clarify that we are not proposing UE-initiated beam switching, but to consider UE-assisted operation, with control at the gNB, as overall system operation needs to be accounted for as well.

Answer to #20 (Mediatek):

We understand that asynchronous multi-TRP operation is more demanding from UE point of view, however we see it as an important enhancement to make FR2 multi-TRP deployments truly viable, due to the

short symbol (and CP) duration with 120 kHz SCS. As discussed already in RAN and RAN1, for FR2 in particular there is opportunity to consider asynchronous reception due to the analog beamforming and potential multiple panels at the UE. Hence we find it useful to expand the Rel-17 framework to more practical scenarios in FR2 at least.

In addition, we would like to restate our views that based on the contributions and discussions so far, it seems that there is strong request from operators to focus on UL enhancements in Rel-18, including capacity driven enhancements and multi-TRP/multi-panel aspects. As by RAN chair guidance, the UL MIMO aspects should be continued under “UL enhancements” section, at least for the time being, but it would be good to clarify how the multi-TRP/multi-panel, which are also related to UL, should be continued in the MIMO section. CSI enhancements for medium/high velocity are clearly proposed by quite many companies, and it would make sense to continue discussing those further in this section.

Multi-beam operation is certainly relevant, but it may be difficult to align on the exact enhancements that are needed in the near future, due to strong dependency with ongoing Rel-17 work. In any case, this is already a relatively mature area, and hence further enhancements are expected to be based on needs arising from practical deployments, as somewhat discussed in the GTW session. As for L1/L2-centric mobility, the RAN chair guidance is to discuss it under “mobility enhancement” section, and hence we will not further comment on it here. Finally, we would like to note that some companies indicated interest in fixed wireless deployments, which would make sense to continue discussing, though it is more a use case than a particular enhancement, so we expect it to impact several different sections independently.

12 – Fraunhofer IIS

To LG Electronics Inc. comment on CSI enhancement for high velocity UE:

In general, there is a need to improve performance in mobility scenarios in real deployments whereas the focus is not only on high speed but also on moderate speeds. Multiple companies showed that performance degrades already at moderate speeds. Therefore, time domain compression codebook (Doppler based) is proposed in such scenarios to improve performance, to reduce the feedback overhead and to realize channel prediction at the gNB' side.

To Spreadtrum Communications comment on “codebook enh. with time domain compression”:

The total number of resources needed for PMI calculation over time can be less with time-domain (Doppler-based) compression compared to R15/R16 codebooks as due to the Doppler components in the CSI report less frequent CSI updates are needed.

13 – ZTE Corporation

Answer to #2 (Nokia), #8 (vivo), #10 (CATT), #13(Xiaomi), #17(LGE), #18(Spreadtrum), #19(CMCC)

As many companies raised, boundary on DL/UL MIMO for some detailed items should be clarified for subsequent discussion, and many MIMO related issues may involve both DL and UL. Consequently, we suggest that UL-only related items are discussed in the UL enhancement session, and then other items involving both DL and UL, and DL-only should be discussed in the DL MIMO session.

For instance, DL and UL parts corresponding to multi-panel/mTRP operation are highly coupled, and some enhancement (e.g., unified DL and UL TCI framework for mTRP, panel/TRP indication, beam collision, SRS, etc) may involve both DL and UL aspects. So we suggest to merge 'enhanced multi-panel/mTRP UL operation' and 'evolved handling of multi-TRP and multi-beam' in DL MIMO agenda.

Answer to #11 (Intel)

Regarding enhancing CW to MIMO layer mapping scheme, we do not think that mDCI framework can be easily reused to support 2 CWs/MCSs due to the fact that this issue is much more general in both sTRP and

mTRP cases. Since mDCI framework requests UE supporting very high UE capability and causes very large DCI overhead, it is not appropriate to enforce UE support mDCI capability for the sake of 2CWs/MCSs of sTRP scheduling.

Also, we do NOT agree Rel-15 study indicated that SCW provides better performance comparing to MCW. Support of SCW-only for ≤ 4 layers in Rel-15 is mainly due to low UE complexity and limited spec impacts. In fact, many companies provided simulation results proving that MCW can well outperform SCW. That is why LTE adopts MCW.

Last but not least, based on our real-field test (no doubt, there was no real test provided in Rel-15 discussion), MCW for ≤ 4 layers is very necessary in NR. That's why so many operators support this enhancement now.

Comment to # 4(Ericsson)

Regarding the following two aspects, it seems that it has not been discussed in your contribution. Some clarification is needed. In general, we think that the former can be left to gNB implementation, and the latter may be discussed in Rel-17 mTRP CSI, right?

Mixed traffic: Simultaneous reception of eMBB and URLLC traffic where the latter use mTRP for robustness

mTRP-CSI: CSI feedback taking into account PDSCH repetition

Comment to # 7(Motorola Mobility)

Regarding prediction-based beam-management, we are a big fan of this topic. As an initial stage, we prefer to treat this issue in AI/ML-related SID firstly, and after SID, we can further discuss how to move forward this issue.

Comment to # 12(Samsung)

Thank you so much for this summary. Regarding beam management, it seems that advanced tracking, refinement and reporting (as listed in issue 6 in Rel-17) for both DL and UL proposed by many companies should be considered with high priority. Regarding mTRP, we think that simultaneous transmission cross multiple panel (STxMP) is another hot topic.

Besides, regarding prediction-based beam-management, we are a big fan of this topic. As an initial stage, we prefer to treat this issue in AI/ML-related SID firstly, and after SID, we can further discuss how to move forward this issue.

14 – MediaTek Inc.

Answer to Apple question on beam management enhancement (covered in MediaTek paper RWS-210105):

For movement at high speed within a cell, where intra-cell beam switching is needed frequently, we see there is still room for latency and signaling overhead reduction, even Rel-17 introduced the streamline TCI framework.

We consider that at least the following would be useful:

1) UE-initiated beam switching: At least UE-initiate TCI activation according to beam measurement and reporting should be considered, where not only overall procedure is simplified but also UE can apply new beam with much less latency. RAN4 may also consider new requirements for TCI activation.

2) Beam switching for multiple UEs: For public transport like bus or train, beam switching is usually needed for a group of UEs moving together in the same direction and at the same speed. Current beam indication only can be sent to per UE, which leads to both large signaling overhead and latency. Enhancements to this scenario is needed.

15 – Motorola Mobility UK Ltd.

[Lenovo, Motorola Mobility]

General comment to all for BM enhancements:

We would categorize BM enhancements into two broad categories:

- Leftover/further evolution of features introduced in Rel-17 such as BFR for S-DCI multi-TRP and SFN scenario, further enhance unified TCI framework, etc.
- New/advanced features for introduction in Rel-18
 - o UE-initiated beam switching/reporting (including event-triggered reporting)
 - o Prediction-based BM has been proposed by several companies (either as part of MIMO evolution or as part of AI/ML). In our view, scenarios, where the UEs are moving in pre-determined/controlled path, such prediction-based mechanisms are relatively easier to realize.
 - o Some companies proposed UE grouping/sharing of beam measurements/reporting. In our view, such solutions should be considered in Rel-18, especially for scenarios where group of UEs is expected to follow similar path. In such cases, sharing measurements/reporting could greatly reduce the overhead associated with BM.

Comment/Reply to Nokia Corporation

For the enhancements that are considered as further evolution/leftovers from Rel-17, we agree that there is strong dependency on the on-going work and identifying all areas might not be possible at this point. However, some advanced features that are proposed by several companies are expected to be independent of on-going MIMO WI. Therefore, it makes sense to discuss them now.

Comment/Reply to ZTE

Please see our general comment on the potential new/advanced features that should be discussed for Rel-18. Also, we tend to agree that some of these features might be applicable to both DL and UL.

Comment/Reply to Intel

We agree that beam acquisition latency is also a key issue to be dealt with.

Comment/Reply to Guangdong OPPO Mobile Telecom.

We also agree that there is a quite a strong link of MIMO topics to AI/ML. However, we must realize that quite probably, no normative work might happen in potential AI/ML SI in Rel-18. Therefore, for potential MIMO WI, we should discuss some of the enhancements that can be handled (at least as a starting point) without the dependency on AI/ML. Please see our general comment on BM enhancements where we present our views on handling predictive BM in MIMO.

Comment/Reply to Samsung Electronics Co., Ltd

Generally, we also share similar views on advanced beam-management enhancements including UE grouping/sharing of beam-measurements/reporting and prediction-based beam-management. They should be discussed for Rel-18 BM.

On further enhancement on multi-TRP in R18, we think we can focus on the following aspects:

- 1) Asynchronous multi-TRP deployment, especially in FR2;
- 2) Extension of the unified TCI framework to multi-TRP($M>1$, $N>1$) scenario;
- 3) CSI enhancement to support dynamic TRP(s) selection for multi-TRP transmission in the scenario with larger number of coordinated TRPs.
- 4) Evaluate the gain of multi-TRP coherent joint transmission compared with multi-TRP non-coherent joint transmission specified in Rel-16.

2 UL enhancements

This section is targeted at identifying commonalities and interactions for UL enhancements.

Feedback Form 3: Questions/Comments

1 – Apple Hungary Kft.

UL transmission scheme enhancement

We see some companies (Qualcomm, MTK, vivo and so on) proposed uplink frequency selective precoding. We also observed that in Rel-15, Qualcomm proposed some simulation results showing frequency selective precoding can only provide performance gain for more than 4 Tx UEs. We would like to understand whether the frequency selection precoding is only for >4 Tx UEs. Could proponents clarify it a little bit?

UL multi-panel and multi-TRP

We have a question on one proposal to support simultaneous multi-panel transmission, which is proposed by Qualcomm, Nokia, AT&T and so on. We found to maintain more than 1 UL active panels would increase UE power consumption significantly, but multiple UL active panels could not provide performance gain for all cases, e.g. UEs in cell center. We would like to understand the target use case for this proposal. Is it for UEs without power consumption issue, e.g. car, or for all types of UEs? We have similar question on proposal to introduce >4 Tx UE.

2 – Nokia Corporation

There are several topics covered by the contributions listed for this particular section, and hence it would be good to try to isolate the aspects that are specifically intended for UL enhancements, in particular those that are not already covered by other sections/threads. From our analysis most of the contributions are in the area of coverage enhancements, UL MIMO, higher UL modulation (1024QAM), UL CA/DC enhancements, fixed wireless access enhancements, UE aggregation, and duplexing aspects.

Based on the description of other topics, and the chair's guidance so far, we would like to confirm the understanding that the focus of the discussion on this thread is on coverage enhancements, UL MIMO, higher UL modulation, and fixed wireless access aspects, leaving UL CA/DC, UE aggregation, and duplexing for the corresponding threads, as assigned by the chair earlier.

3 – ZTE Corporation

For this popular topic, below is our understanding based on the two rounds of email discussion and GTW discussion. We would like to check whether it is a common understanding or not.

- The target of UL enhancements includes both capacity and coverage enhancements.
- Many of the target use cases are from vertical industries, which means some URLLC requirements may also need to be taken into account.
- Majority companies have interests on CA/DC enhancements, which could be beneficial for both capacity and coverage.
- Lots of companies proposed UL MIMO enhancements for UL CW mapping enhancement, larger number of UL layers and frequency-selective precoding enhancements, which are beneficial for UL capacity and fit into UL enhancements very well. Regarding BM, most of BM related aspects are relevant to both DL and UL, and then we would like to check Samsung and other companies' views about BM enhancement in Rel-18.

- A number of companies also proposed power domain enhancements (including UE aggregation), coding domain enhancements (e.g., 1024QAM) and some leftovers from Rel-17 coverage enhancements. This needs more discussion on which enhancement should be taken for the potential study of UL enhancements in Rel-18.

4 – Futurewei Technologies

We agree that UL performance enhancement (including coverage, capacity, and latency) should be specifically addressed in R18. Multiple candidate technologies include flexible duplex (for coverage and latency), UL fast carrier switching (for capacity and UPT), UL MIMO (for FWA), UL power aggregation (need to check regulation), UE with high capability for special use cases. In addition, there has been a clear reluctance to support higher UE capability (especially UL TX) from UE vendors. It will be helpful to clearly understand the market needs and design for those needs. For example, CPE for FWA may be one of the realistic use cases. Suggest to have a study first in order to identify a small set of solutions to address the overall issues.

5 – Ericsson LM

Regarding **UL MIMO enhancements**, the use case, specification impact, and UE complexity tradeoffs vs. UL capacity gains can vary quite a bit with the UL MIMO technique. These were in our understanding principal obstacles that limited the UL MIMO schemes to what we specified during Rel-15.

For the **UL frequency selective precoding** and **>4 layer UL MIMO**, scheme, we have the following questions:

-
Are tens of bits (or less) needed for precoding signaling, or is it hundreds of bits or more?

-
Are gains found only for specific UE antenna configurations and at FR1, or are more general use cases supported?

o
If specific configurations are needed, what scenarios and use cases are targeted?

-
Can low PAPR operation be supported, or will the new schemes cost some PA efficiency or be only applicable to CP-OFDM?

For schemes targeting **coverage**, it has been debated during the NR coverage enhancement work whether various schemes actually target coverage and/or eMBB use cases or not. For example, Type B repetition can allow repetition across slot boundaries, but this can be seen as increasing scheduler flexibility or reducing latency rather than extending coverage. If such improvements are what is truly targeted, then the scenarios and use cases considered during specification work should reflect this. As another example, sub-PRB transmission can be a mechanism to achieve coverage at very low data rates while maintaining spectral efficiency. Such data rates may not be aligned with classic eMBB services, in which case they should be clarified further. Hence, we have the following questions on the proposed schemes:

-
For a given enhancement scheme, is the intention to increase the received SNR of a TB as compared to Rel-16, or is the intention to increase spectral efficiency, scheduler flexibility, or to reduce latency?

-
Are data rates lower than 16 kbps VoIP needed for performance gains? If so, what services and data rates are envisaged?

6 – Panasonic Corporation

Regarding UE Tx power aggregation (like proposed RWS-210199 from Rakuten), the UEs who are going to be aggregated are owned by the same subscriber? What is the relation on SIMs on them? Is the joint work/study between SA and RAN necessary?

7 – BT plc

We echo the need to address UL enhancements highlighted by other operators, and we would emphasize that identification of problems that need solving should be driven by deployment trends. To that end we agree with an earlier comment here by Futurewei (and we believe Ericsson and ZTE) that a reality check on actual UL issues and trends would be a good place to start in selecting specific techniques proposed in contributions.

8 – Lenovo (Beijing) Ltd

We think it is important to increase the capacity of UL MIMO in R18. This includes UL subband pre-coding, increasing the number of layers for SU- and MU-MIMO, and increasing the number of ports for (mostly) stationary UE such as CPE or security camera. For these high capacity UEs transmitting with CP-OFDM, the number of antenna ports can be increased to 8, with the corresponding change to DMRS and UL TPMI. For cell edge UEs transmitting with DMT-s-OFDM, the number of layers can be increased from 1 to 4. To further enhance multi-panel UE in FR2, simultaneous transmitting to two different TRPs shall be supported, including power control and beam management to each TRP.

We are uncertain of the UL only nodes proposed by some companies. From network deployment point of view, deploying a UL only node is not much different than deploying a traditional low power TRP, with almost identical site, backhaul, and power supply requirements. A traditional TRP supports both UL and DL traffic, and can be deployed either as part of a cell employing multiple TRPs or can be deployed standing alone with its own PCI. This offers much flexibility to the operator and is already supported. A UL only node only enhances the UL as part of a large cell while introducing several issues such as UL power control, beam management, etc. At one hand, if a whole suite of changes is required to support this feature, we think it is not worth the effort for the limited gain. On the other hand, if this requires minimal changes, it is better to have these UL only nodes deployed as UE-transparent network implementation.

9 – Apple Hungary Kft.

[Sorry for adding another comment that was missed in a copy-paste error]

Reposting with **full content**:

UL capacity enhancements

For the UL capacity enhancements, several companies (CTC, ZTE, Rakuten) proposed to support the UL 1024QAM. It is quite challenging to implement this feature for commercial terminals. Possibly the feasibility study can be done by RAN4 first. In addition, it could be better to clarify the detailed use case and UE type, e.g., CPE for FWA usage. Do any other use case and UE type the proponents have in mind?

10 – vivo Communication Technology

1. Various techniques are included in UL enhancement, some of them are mainly RAN1 related while other are RAN2 related. In our view, all those topics do not fall in same umbrella, different aspects should be separately summarized. It is not clear whether a dedicated SI/WI is needed, different parts may be included in the scope of other items. If dedicated WI is desired to make the scope clear, should not include all the aspects being discussed under this item.

2. UL MIMO enhancement is important for DFT-s-OFDM waveform as well, specification support to address hardware implementation at UE should also be in the scope. gNB receiver performance improvement should also be in the scope.

3. On higher order MIMO, e.g. 8 Tx in UL we don't see use as 4Tx hasn't been supported in RAN4 yet. If majority of companies see the need, it should be clarified that this is for special type of UEs such as IAB, CPE and the specific antenna structure.

11 – CATT

We also think UL enhancements are important in Rel-18. UL MIMO enhancement is one of most important aspects to be included in Rel-18 for UL enhancements especially considering that UL-MIMO has been stagnant in 3GPP for years. Both FR1 and FR2 can be investigated, without prioritizing one over the other. We support precoding granularity enhancement (in frequency and possibly spatial domain), multi-panel simultaneous transmission (in spatial domain), enhancements in ultra-high-density UL MU-MIMO (e.g. DMRS overhead/dimension enhancements), and if time allows, high-order MIMO up to 8 Tx.

There are interests from companies for UL coverage enhancements. Given that UL coverage enhancements have been studied in Rel-17 and there is an ongoing Rel-17 WI, it needs to be discussed what baseline performance (Rel-16 or Rel-17) is to determine the potential additional UL coverage enhancement requirement/techniques. Besides, for the techniques discussed but not adopted in Rel-17 due to different views from companies, we need to discuss how to reach consensus for Rel-18.

In addition, we'd like to note another potential technical direction for UL enhancement, which is transmission efficiency improvement via data and signaling compression. You can find more details in CATT contribution RWS-210405.

12 – Intel Corporation (UK) Ltd

We think that UL MIMO is important aspect for enhancements due to increased traffic loads in the UL, e.g. for video streaming. In our view it would be good to address UL performance issue through more cost-efficient deployment scenarios (e.g. Rx only capable TRP and low power TRP). In addition, some UE may also support simultaneous transmission using multiple panels that can be used to enhance peak throughput and reliability / latency.

Regarding enhancement to more than 4 MIMO layers, we would like to understand the urgency of such work in Rel-18 taking into account lack of 4Tx requirements in RAN4 and only one proposal to define such requirement in Rel-18? We think that 4Tx requirement should be defined first in RAN4 before starting work on more advanced scenarios with larger number of antennas and MIMO layers in RAN1.

13 – Samsung Electronics Co.

UL MIMO related:

-

Precoding: For CP-OFDM UL, coverage and spectral efficient enhancements based on FS precoding, high-res UL precoding based on precoder, and support for >4 SRS ports are potential enhancement areas that have support among several companies, hence can for further discussed.

-
UL multi-panel: Several companies [x123, x212, x240, x268, x361, x370, x396, x424] expressed supported for simultaneous transmission across multiple UE panels and/or to multiple TRPs. This can indeed be further discussed as an extension to the unified TCI framework introduced in Rel-17, e.g. with $N > 1$. Note that this largely depends on what will be specified in Rel-17 multi-beam enhancements (for FeMIMO).

-
Higher-rank:

- o We are open to considering/studying the benefit of > 4 layers per UE for CP-OFDM
- o Several companies [x075, x162, x307] suggested support of DFT-s-OFDM waveform in the UL for ranks greater than 1. DFT-s-OFDM targets users with limited power, typically cell edge UEs with poor geometries (hence higher rank transmission is atypical), in such scenarios, we find no justifiable benefit in supporting ranks greater than 1 with DTF-s-OFDM waveform. Note that this comes at the expense of more complex scheduling and MIMO decoding at the gNB (already discussed at length in Rel-15). Furthermore, one company [x307] suggested “faster than RRC” switching of the UL waveform, as the channel conditions at the UE change. We see little value in supporting this, as changes in channel conditions that warrant a waveform change happen at a rate commensurate with RRC re-configuration.

Overall we think that both coverage and capacity should be considered for UL enhancements in Rel-18.

For coverage enhancements, we can consider an objective with a limited scope focusing on initial access enhancements for FR2 (including for PRACH). Another possible area can be to extend the Rel-17 enhancements for PUSCH repetition Type A to PUSCH repetition Type B and to PUCCH for more efficient operation in the TDD bands of NR.

For UE aggregation, some proposals consider aggregation in power domain and/or spatial domain, and also mention support for mobility. It would be good to clarify how the UE aggregation would work (including benefits/feasibility) and what are the mechanisms that need to be introduced.

14 – Xiaomi Communications

We think UL enhancement is needed in Rel-18. Meanwhile the complexity of UE implementation should be evaluated carefully when considering potential solutions for NR uplink enhancements.

15 – Guangdong OPPO Mobile Telecom.

Based on our review of UL enhancement related tdocs, there is strong interest in continuing to enhance UL coverage, for example the enhancement on PRACH, PUSCH and PUCCH. In our view, it is important for 3GPP to continue this direction to further enhance the UL coverage.

There is also strong interest in improving the UL spectral efficiency through higher order UL MIMO, for example supporting > 4 layers, sub-band precoding, enhance UL DMRS. For us, it is a good direction for improving the UL performance. However, we think this scope shall exclude extending DMRS ports to > 12 since the use cases and benefits are not clear.

From our side, the scenario and benefit of the UL Tx switching between more than 2 frequency bands are not clear. Would the proponent(s) like to clarify that?

16 – China Telecommunication Corp.

A lot of companies proposed to further enhance the coverage of PUCCH, PUSCH, PRACH and discussed some potential solutions in their contributions. We have some general comments for UL coverage enhancement as follows:

1. From our perspective, we think further work for coverage enhancement is still needed. In Rel-17 SI phase on NR coverage enhancement, at least 10 coverage enhancement solutions are proposed and studied for PUSCH; 4 coverage enhancement solutions are proposed and studied for PUCCH. Due to some reasons, not all of the solutions with companies' interests are included in Rel-17 WI on coverage enhancement. Based on the performance gap between baseline and target performance for each bottleneck channel, there're still several dB gap. Since the gap exists, we think further enhancement is needed.
2. Since some coverage enhancement solutions are included in Rel-17 WI, some companies wonder whether re-evaluation work is needed to identify the bottleneck channel. In our view, there is no need to do the re-evaluation work, the bottle neck channels are clear for us.
3. Based on the simulation results in TR 38.830, potential gain of some solutions can be observed, such as: PUSCH repetition type B enhancement, PRACH repetitions, sequence based PUCCH, power domain solutions, e.g. FDSS w/ and w/o spectral extension for QPSK, and etc.

17 – NTT DOCOMO INC.

We agree the UL enhancement (including UE-throughput/cell-capacity/coverage enhancement) should be specified in Rel.18.

Following is our comments to some proposed topics:

-

UL dense deployment: We support, considering the large performance gain (Average gain:+610%, Edge gain: +740%).

-

Simultaneous multi-panel transmission in FR2: We think this would be necessary to support > 2 layers in FR2.

-

High order modulation > 4 layers : We think this is good enh. in Rel.18.

-

Frequency-selective precoding: We observed limited gain (Average gain: 2-3%, edge gain: 3-18%). But, we're open to consider it in R18. In addition, we need to further discuss/consider the priority of those enhanced features for UL.

-

Dynamic switching between CP-OFDM and DFT-S-OFDM: we think this is useful, because we can avoid RRC-reconfiguration to switch the waveform.

-
Multi-layer PUSCH for DFT-S-OFDM: We are not so interested in it so far, considering that multi-layer PUSCH for DFT-S-OFDM would increase PAPR. As long as "Dynamic switching between CP-OFDM and DFT-S-OFDM" is supported, we don't see the need of "Multi-layer PUSCH for DFT-S-OFDM".

-
UE Tx power aggregation (UE corporative MIMO): we think this is good topic toward 6G. But, there are lots of things to study: e.g. whether sidelink is used to communicate with different UEs, or others like Wi-Fi/Bluetooth is used for the communication between UEs. Whether it is feasible to use other UEs (which may be belong to other person) to help UL transmission in practical. And it may also have large impacts on both low layer and higher layer of 3GPP specification.

18 – NEC Corporation

UL MIMO is mainly for UL capacity enhancement. Based on our reading, the features attract the most attention are as follows.

- FR1: UL higher order MIMO, UL Sub-band precoding
- FR2: STxMP (simultaneous transmission across multiple panels), solutions when beam correspondence does not hold (e.g., TRP with Rx only)

It can be seen that most features listed above are only possible for high-end UE with relaxed restriction on complicity and power consumption. It is preferred to hear more from UE and chipset vendors on current and near-future capability of this kind of UEs.

19 – Huawei Tech.(UK) Co.. Ltd

The list of Tdocs provided for this topic by the RAN chair are: RWS-210003, 0033, 0036, 0042, 0053, 0056, 0075, 0076, 0122, 0149, 0160, 0162, 0181, 0192, 0199, 0203, 0212, 0220, 0240, 0268, 0275, 0276/0277, 0289, 0296, 0307, 0361/0362, 0370, 0396, 0403, 0424, 0436, 0440, 0459, 0479, 0507. Additional Tdocs seem to also be relevant to this area.

Uplink enhancements are critical for 5G–Advanced for both eMBB and non-eMBB services. Uplink enhancements in Rel-18 should strike a balance between enhancements for smartphones, IoT devices and CPEs. In particular, it is critical that some of the enhancements target improving uplink for smartphones with 2Tx, because supporting 4 concurrent layers or simultaneous transmissions on 4 carriers will still be too complex for most smartphones. UL MIMO enhancements for more than 4 Tx are largely not targeting smartphones but rather CPEs and certain IoT devices.

We see that a good number of Tdocs propose enhancements for UL Tx switching with carrier switching, with various motivations (throughput, latency, coverage, mobility), but the common point is allowing for low UE complexity (e.g. 2Tx). Tdocs 36, 56, 122, 199 explicitly mention UL Tx switching enhancements with the intention to allow UL Tx/carrier switching with more than 2 bands (Rel-16/17 which already support UL Tx switching across 2 bands). Then there is another group of Tdocs more focused on mobility enhancements, which are also relying on UL Tx switching with carrier/CG switching. UL dynamic switch while maintaining the DL is discussed in 0143, 0183, 0165, 0056, 0122 and 0036. 0369, 0449, 0143, 0183, 0165 and 0056 also mention there could be UL transmission capability limitation from the UE side, which would require UL Tx switching. UL carrier/UL CG switching proposals are spread across UL

enhancements, mobility and MR-MC. It is unclear where to have further discussion. Perhaps UL Tx switching mechanism could be discussed under UL enhancements, while how this is applied to UL carrier/CG switching can be discussed under mobility or MR-MC.

UL enhancements for CPEs and high-end IoT devices with 4Tx or more than 4 Tx are also relevant and should be pursued, i.e. UL MIMO with more than 4 layers. Some UL MIMO enhancements can be common to all UE types, i.e. frequency-selective precoding. We think that UL mTRP enhancements are also very important, especially for increasing the number of TRPs jointly receiving UL MU-MIMO paired UEs, which would require increasing the number of UL DMRS orthogonal ports. Uplink power control for UL mTRP can also be improved.

Other areas for UL enhancements are discussed under other topics and are also relevant for specific deployment scenarios, including UE aggregation (IIoT, public safety, etc), BS-BS cross-link interference (macro-small cell deployments with different DL/UL configurations).

20 – LG Electronics Inc.

We support UL enhancements especially regarding UL MIMO as a prioritized item for Rel-18. From our perspective, UL multi-panel transmission (STxMP) is an important feature which can highly improve UL spectral efficiency as well as robustness/reliability. For this topic, we should include FR1 application for vehicle distributed antennas as well as FR2 application given the 5GAA's input (RWS-210360). Another important UL enhancement is to support panel/TRP-specific TA. Based on our evaluation results (RWS-210240), it turns out that it is not realistic to use common TA for different TRPs/panels especially at high frequency bands.

21 – Spreadtrum Communications

We are supportive of UL enhancements in Rel-18. Basically, there are UL MIMO, UL coverage enhancement, UL CA, UE aggregation, UL power control proposals sub-topics for UL enhancements.

For UL MIMO, we are interested in the enhancements on improving UL capacity, especially UL frequency selective precoding. For >4 UL layers, we are open to discuss how to achieve it with limited signaling overhead. Regarding flexible waveform switching and multi-layer for DFT-s-OFDM, after 2 round of Q&A, still, we would like to see more elaboration on the necessity of the enhancements.

For UL coverage enhancement, we are open to the leftovers from Rel-17 can be further studied in Rel-18. One question according to RACH coverage enhancement, multiple RACH transmission has been proposed by many companies using the form of beam sweeping/repetition. It is better to further clarify the scope of this study, e.g., RACH-based BFR □ 4-step/2-step RACH, Contention-based/Contention-free RACH.

For UL CA, such as uplink fast carrier switching, more UL carriers associated with DL carrier etc. we share a similar view that uplink fast carrier switching can be studied in Rel-18. Due to limited UL CA capability and limited power. The current UL carriers/Cells are semi-static activated and dis-activated, which is lack of UL load balancing and adaptation among UL cells.

22 – China Mobile Com. Corporation

1. Overall comments on the uplink enhancement

The performance enhancements based on Rel-17 CE is limited due to limited resources, e.g. UE transmit power, stringent uplink time domain resources. Considering the tremendous needs for the uplink enhancements as proposed by many companies, enhancing the uplink performance through introducing more resources should be focused in Rel-18, such as

- 1) Utilize the transmit resources from current carrier frequency or other frequency bands, e.g. using the DL resources for UL transmission in the XDD, using lower frequency for UL
- 2) More transmit power, e.g. cooperation with other UEs for UL transmission, shorten the duty cycle to boost the power
- 3) Reduce the uplink propagation loss by introducing more receiving points, e.g. smart repeaters, RX only access node and etc.

For the cases without introducing additional resources from other carrier, the coverage enhancements should focus on the FR2.

2. Questions on the lower band MIMO

Is there any particular enhancements of MIMO focusing on the lower band, such as below 1GHz ?

From our view, current MIMO specification could support a large number of antenna ports. Then for the lower port numbers, it should not be a problem.

For the distributed MIMO for lower band (e.g. RWS-210361), could the proponents please elaborate more about the specific benefits for the uplink and downlink ?

3. Questions on the enhancements on waveform

Regarding to RWS-210307, could the proponent elaborate more about the benefits of dynamic switching between OFDM and DFT-S-OFDM. From the UE perspective, the DFT-S-OFDM could achieve a lower PAPR enabling a higher power efficiency for the uplink transmission. But the dynamic change of different waveforms could bring more complexity to the UE and increase the complexity of the scheduler. If 2 layer transmission is introduced for DFT-S-OFDM, is it enough for the improvement of cell edge UEs ?

4. Question and comments on flexible use of DL and UL carrier

Regarding to the RWS-210479 page 5 and 6, it is beneficial to flexible use more frequencies which the operators already have, no matter from the point of coverage or the uplink capacity.

For the page 6, the UL CA in idle/inactive state could bring more flexibility to UE to use the best carrier considering the coverage and traffic load.

Current UE should support the multiple frequency bands which announced by the operator already. From the hardware, there is no difficulty to work on single or multiple frequency bands. In some scenarios, when there are not higher data rate demands, UE could only work in one carrier for uplink and one carrier for the downlink. In this situation, there is no need to mandate the UE to support the CA capability to support the flexible use of DL and UL carrier.

23 – MediaTek Inc.

Regarding the proposal from different companies on Simultaneous Tx Multi-Panel UE, in terms of UE operation and complexity this brings new issues, and it is not obvious to us that the achievable practical gains would justify that.

Please could the proponents provide more info on:

- 1) The envisaged performance benefits and detail of the operating scenarios/conditions where they believe those benefits could be observed in practice.
- 2) The device types envisaged for applying such a feature, and maximum output power limits considered.

24 – EURECOM

We think that capacity and coverage-related UL enhancements are essential for Rel-18. Concerning coverage enhancements, it has been shown in the SI that there are still significant gains to achieve for the identified bottleneck channels. Moreover, several topics mention coverage enhancements as essential for their evolution, e.g. NTN and XR.

Feedback Form 4: Answers/Comments

1 – Futurewei Technologies

Overall, we'd like to get clarification that this topic (UL enhancements) is not only for UL MIMO enhancement but is more general to address UL problems raised by quite some operators and vendors. There are a large number of proposals related to this area. Though some proposals may eventually be included in other items, it is still beneficial to have an overall view on the needs for uplink and the features that really meet these needs before determining a small set of key things to do in R18. To us, features that can really address the issues/needs include UL dense deployment, UL fast carrier switching, flexible duplex, and high capability UE support and worth to spend resource on.

2 – Lenovo (Beijing) Ltd

We see the need to enhance UL for both higher capacity and better coverage in R18. However, the targeted UE types may be different for them. Capacity enhancement mainly targets high end UE with relaxed size/power consumption/cost constrains like CPEs or IoT devices such as wireless cameras. Simultaneous transmission from two panels can increase the capacity in FR2. Sub-band UL precoding can provide significant gain with reasonable increased DCI overhead. From our simulation, gain between 40% in throughput or 6.53dB can be achieved for 4 TX UE at low to mid-SNR with the total TPMI bits less than 100 bits. We see increasing the transmission rank for DFT-s-OFDM as a way to increase the capacity for relatively power-limited UEs. In R17 the UE needs to use CP-OFDM to transmit with rank 2. Given CP-OFDM has much higher PAPR than DFT-s-OFDM, it is a big jump from a UE transmitting with DFT-s-OFDM. Between rank 2 CP-OFDM and rank 1 DFT-s-OFDM, there is a big gap that needs to be filled. At least rank 2 transmission with DFT-s-OFDM shall be supported to fill this gap.

Coverage enhancement targets all UE types. In R16/R17 PUSCH and PUCCH have both been enhanced in various WIs. The baseline for coverage enhancement shall be R17. The top priority shall be to complete any unfinished R17 UL coverage enhancement topics. Besides that, we need to identify a set of specific channels/scenarios for UL coverage enhancement in R18.

3 – LG Uplus

We do not want to increase the device complexity as possible. In Rel-18 timeline, we thought that XDD for uplink throughput and coverage enhancement (service-enabling PUSCH throughput coverage) is essential and should be prioritized. Other schemes could be studied for long-term survey.

4 – Qualcomm Incorporated

To Apple's question on frequency selective precoding UL enhancement, addressed to Qualcomm:

[Answer] For frequency-selective precoding, our view hasn't changed, i.e., we don't see a need to have it supported for UEs with 2 or 4 Tx. Our proposal is to have a high-resolution UL TPMI enhancement which can support both wideband and frequency-selective precoding.

To Apple's question on simultaneous UL transmission for UL multi-panel and multi-TRP:

[Answer] We see multiple use cases for simultaneous UL transmission such as:

-

a) Latency/overhead reduction by parallel transmission for eMBB/URLLC/mobility w/o the need for cancelation/TDM (PUSCH+PUSCH, PUSCH+PUCCH, and PUCCH + SRS)

-

b) Flexible per-TRP UL transmission for multi-DCI based mTRP especially with non-ideal backhaul (more efficient resource utilization instead of ensuring strict TDMing)

-

c) Reliability for one PUSCH transmission with reduced latency as compared to TDMed PUSCH repetition (two beams in FDM/SDM manner for one PUSCH)

-

d) Increasing the peak UL data rate in FR2 (two layers per panel resulting in four layers).

5 – Samsung Electronics Co.

Re Apple's comment:

-

FS precoding is also applicable for 2 and 4 antenna ports. For 2 ports, the gain can be limited, but for 4 ports, the gain can be significant especially if dual-stage codebook is used. We have investigated this in Rel-15.

Re ZTE's comment:

-

For BM, we prefer both DL and UL should be discussed together in one WI (e.g. in DL MIMO evolution).

Re Ericsson's comment:

-

FS precoding overhead: the TPMI overhead depends on the UL resource allocation (# PRBs) as well as the codebook design. Since the TPMI overhead can vary depending on UL RA, two-part DCI design from, e.g. V2X, can be reused to avoid excessive TPMI overhead (e.g. if all TPMIs for all RBs are signaled regardless of the UL RA). For example, DCI part-2 payload can be of variable size depending on the UL RA.

-

FS precoding gain: The gain can be for both structured and unstructured antennae, but larger gain can be observed if antennae are structured, which is possible for CPE or car UE.

Re NTT DOCOMO's comment:

-
FS precoding gain: We observe significant gain with DL Type-I (dual-stage) codebook.

6 – LG Electronics Inc.

To questions from Apple and MediaTek on STxMP,

-
Use case/scenario: STxMP can improve reliability/robustness and/or increase UL spectral efficiency. For URLLC services, for example, if one panel is blocked by a certain material or its Tx power is reduced significantly due to MPE issue, successful UL transmission is hardly guaranteed even if UL repetition is applied. With STxMP, we can greatly increase the success probability in such cases if same data/layer is repeated across multiple panels. For eMBB services, for another example, it can be utilized to support higher rank transmission. For example, applying dual pol analog beamforming structure in FR2 could support up to rank 2 per panel. STxMP can increase the max rank to 4. Similar extension could be possible in FR1 from max rank 4 to max rank 8.

-
Operating condition: In our view, supporting STxMP mode or >4 Tx would be determined by UE capability. So, power-sensitive UEs can always turn-off this mode. Even for a UE capable of STxMP, STxMP mode would be enabled only when it is useful. For example, in our evaluation of RWS-210240, we applied STxMP only when RSRP difference of two active panels is less than a certain threshold (6dB). And if it is greater than the threshold, only one panel with highest RSRP was used.

-
Device type: We mainly consider this feature for vehicle UE in FR1 and some fixed devices like CPE in FR2.

7 – MediaTek Inc.

Frequency selective precoding:

Apple/NTT DOCOMO: Higher resolution UL CSI with low signalling overhead can improve performance over previously observed result if proper compression techniques such as the DL enhanced Type-II frequency domain compression are reused for UL.

Ericsson: For feedback overhead, we can use DL enhanced Type-II feedback overhead as an upper bound. It can also be limited by less frequent update targeting low mobility device. And the signalling can be carried by channels other than DCI. We believe that there are parameterized codebooks that can be adapted to arbitrary UE antenna configuration. FR1 will see the greatest benefit with UL frequency selective precoding, but applicability to higher frequency should also be investigated.

>4 MIMO layers

Vivo: Our target is CPE type of device. We are only targeting up to 8 layers.

Vivo/Intel: Lack of RAN4 requirements is a problem for different existing features and agree it needs resolution, but stopping future work seems a drastic approach.

Simultaneous Tx multi-panel:

We concur with the additional points made by Apple on the UE impacts. However, we would like to know whether this is for non-handheld devices mainly or more generally proposed?

8 – NTT DOCOMO INC.

To Apple/MediaTek (Target use case of simultaneous multi-panel transmission):

-

As we showed in p.6 of RWS-210268, it is difficult to utilize more than rank 2 in single-panel UL transmission in FR2. We assume simultaneous multi-panel transmission improves the rank provability in FR2 UL tx. Hence, our target scenario of simultaneous multi-panel transmission is UE with more than 2 MIMO layer in FR2.

-

To MediaTek (which device types): Our hope is that usual smartphone like UE can support simultaneous multi-panel transmission to improve customer experience of UL tx in FR2.

To Ericsson (which scenario has gain of UL frequency selective precoding and >4 layer UL MIMO):

-

>4 layer UL MIMO: Based on our SLS results (p.4 of RWS-210268), only indoor and dense urban can provide the gain in FR1.

-

UL frequency selective precoding: we observed the gain for UE with 4Tx in dense urban scenario FR1.

Answers to Lenovo (transparent NW implementation of UL dense):

-

We think spec. enhancement is needed to support the UL dense deployment. For example, there is no PL-RS from Rx only point, NW would need to inform PL value to UE.

Answer to CMCC (dynamic switching between OFDM and DFT-S-OFDM):

-

We think each waveform has benefit and gNB has motivation to switch the waveform (e.g. CP-OFDM: FDM between DMRS and PUSCH is possible, RB allocation is not restricted with multiple value of 2, 3, and 5. DFT-S-OFDM is good for power limited UEs). If dynamic switching is supported, gNB can avoid RRC reconfiguration to switch the waveform, which we believe beneficial for operators.

Answer to Intel (how urgent >4 rank is):

-

Although RAN4 only considers 2Tx MIMO so far, we assume RAN4 will support 4 layers later. RAN1's work is always earlier than RAN4, we believe it is good to enhance to >4 rank in some release. Since we'd like to enhance UL performance in Rel.18, we think it is good timing to support >4 rank in Rel.18.

9 – Intel Corporation (UK) Ltd

Answer to Lenovo comment on support of dense deployment scenarios, e.g. with Rx capable nodes:

1. As commented in the first round of discussion the deployment of such nodes would be much easier and more cost efficient due to no Tx capability of the nodes. One operator NTT DOCOMO indicated interest in such deployment scenario and showed significant (>100%) performance gains.
2. Rel-15 NR already supports the required features to enable such deployment scenario, i.e. uplink beam management using SRS and closed loop power control. We don't see significant workload to RAN1 to enhance these two features and achieve such remarkable performance gains.

10 – Ericsson LM

For UL, we have identified the following high priority issue from real deployments, which needs to be considered for Rel-18:

-
DFT-S-OFDM enhancements (including rank>1 PDSCH and dynamic switching with CP-OFDM waveform)

To answer to further comments this round on these two topics:

Answer to #13 (Samsung): As can be seen from our results in RWS-210307, rank 2 can be supported over the vast majority of the cell in a dense urban scenario, not just the cell edge. Allowing rank 2 or higher transmission for DFT-S-OFDM will therefore allow the UE to have better PA efficiency and/or better coverage of higher MCS throughout the cell. Since multi-layer DFT-S-OFDM is anyway supported in LTE, we see this as relatively low hanging fruit to support in Rel-18.

Regarding faster than RRC switching between CP-OFDM and DFT-S-OFDM, this is driven by needs observed by our product developers. We think that tradeoffs between DFT-S-OFDM and CP-OFDM operation are not limited to slowly changing factors, like the position within the cell, but are often a function of dynamic parameters, such as cell load, scheduling / link adaptation, fading, and/or antenna blockage. CP-OFDM does not have the restrictions on the number of PRBs that DFT-S-OFDM does and allows non-contiguous frequency domain transmission. This flexibility can be used to improve spectral efficiency when cell loads rise in a given set of slots. Furthermore, DFT-S-OFDM may require equalization or have degraded performance when delay spread quickly increases. On the other hand, if there is a deep fade or sudden blockage of an antenna, using DFT-S-OFDM instead of CP-OFDM can allow the UE to transmit at a higher power to improve performance, improving the link adaptation.

Answer to #17 (NTT DOCOMO): We would like to clarify that multi-layer DFT-S-OFDM need not increase PAPR, noting that it is supported in Rel-10 LTE UL MIMO. Also, as explained above, supporting multi-layer DFT-S-OFDM will allow the UE to reap the benefit of better PA efficiency than CP-OFDM and/or higher MCS throughout the cell, since rank 2 can be supported over the vast majority of e.g. a dense urban cell.

Answer to #22 (CMCC, question 3): Regarding if multi-layer DFT-S-OFDM is enough for cell edge UEs and if dynamic CP-OFDM to DFT-S-OFDM switching is needed, as we answer above, rank 2 can be supported over almost all of e.g. a dense urban cell, so UEs can benefit throughout the cell rather than just the cell edge from multi-layer DFT-S-OFDM. Also as in answer #13 above, there are a variety of tradeoffs between DFT-S-OFDM and CP-OFDM. DFT-S-OFDM has limitations on the number of PRBs, lacks support for non-contiguous frequency domain allocation, and the possibly needs equalization in multipath channel conditions. On the other hand, DFT-S-OFDM improves the power efficiency and/or the achievable MCS as compared to CP-OFDM. As such we see the tradeoffs to be a function of dynamic parameters, and therefore dynamic switching mechanisms between CP-OFDM and DFT-S-OFDM can be beneficial.

11 – vivo Communication Technology

Answer to #1 (Apple): we are not supportive of >4Tx in UL, if majority of companies want it then it would be better to clarify the type of UE, potential antenna structures before starting discussion. It is impossible for handheld device to supporting >4Tx and RAN4 has not specified performance for 4Tx yet.

Answer to #13 (Samsung), #22 (China Mobile): support of multiple rank DFT-s-OFDM and more dynamic switching between waveforms are somehow address similar issue. Since 2Tx is mandatory in UL, the network configures CP-OFDM waveform to support rank>1 UL MIMO. The main point is that, although spec supports RRC reconfiguration of waveform, which is slow, in reality we noticed that the network tends not to do that and thus DFT-s-OFDM waveform is never used in reality.

12 – Nokia Corporation

Answer to #1 (Apple) and #23 (Mediatek):

Power consumption is indeed an issue that needs to be considered in general, and it is important to discuss potential UE and network power consumption impacts in all features. While in some scenarios it might not be relevant to activate more than one panel, there are many different types of UEs and scenarios where different balance needs to be considered between power consumption and reliability and data rate. For example one may consider URLLC as well as FWA scenarios. Similar considerations apply for >4TX UE.

In addition, we would like to restate our views that there are several topics covered by the contributions listed for this particular section, and hence it would be good to try to isolate the aspects that are specifically intended for UL enhancements, in particular those that are not already covered by other sections/threads. From our analysis most of the contributions are in the area of coverage enhancements, UL MIMO, higher UL modulation (1024QAM), UL CA/DC enhancements, fixed wireless access enhancements, UE aggregation, and duplexing aspects. Based on the description of other topics, and the chair's guidance so far, we would like to confirm the understanding that the focus of the discussion on this thread is on coverage enhancements, UL MIMO, higher UL modulation, and fixed wireless access aspects, leaving UL CA/DC, UE aggregation, and duplexing for the corresponding threads, as assigned by the chair earlier.

13 – Huawei Tech.(UK) Co.. Ltd

Answer to OPPO: up to now CA capability means that a UE needs at least N Tx (at least 1 Tx per band) and needs to support simultaneously transmitting on N UL bands, in order to just be configured with N UL bands. So far, most of the commercial mobile phones, approximately 80%, only support 2TX RF chains. The only possibility is to do RRC re-configuration in order to change UE UL to other bands. The benefit of extending UL Tx/carrier switching from 2 bands to more bands is to allow dynamically allocating limited power and TX resource to the best UL carriers for a UE. For example, for a given slot, when one of the active TDD bands/cells is downlink, UE can be switched to another TDD band which is uplink according to the TDD configurations, or to an FDD band with the best channel condition, or to a band/cell with most spare RBs being able to provide higher UL data rate, or to a TDD band/cell where the network needs SRS transmission from the UE to support the DL.

14 – CATT

UL frequency-selective precoding

- Number of Tx: In our view this should be supported for at least for N-Tx, N = 4 and N>4 (if supported in higher-order MIMO Rel.18)
- Overhead: We observed significant performance gain in our contribution, along with several other companies (e.g. Qualcomm). As commented by other companies, overhead of UL FS precoding is an inherent

signaling issue that needs to be studied together in the feature itself, along with possible UL PMI codebook enhancement. The general goal should be to reap most of the gains of UL FS precoding without significant control signal overhead increase over existing UL DCI.

Multi-panel joint transmission

· The use case includes high performance equipment (e.g. CPE, IAB, car), as well as traditional mobile handset devices.

High order MIMO over 4Tx

· The use case is motivated by high performance equipment (e.g. CPE, IAB, car) that are less constraint by power/form-factor than traditional mobile handset devices.

Ultra-high-density enhancement

· DMRS overhead reduction can be enhanced without increasing the maximum number of DMRS ports for MU-MIMO (12), as the probability of R-user multiplexing ($R \leq 12$) keeps increasing as UE density increases, so it is beneficial to study DMRS overhead reduction. That being said, DMRS overhead reduction and extension of maximum DMRS ports (beyond 12) are not competing proposals.

15 – Xiaomi Communications

For the UL enh. in R18, UL MIMO, UL CE, UL CA, etc. are proposed. We are more interested in the UL MIMO enhancements, and different enhancements should be targeting different UE types with respective of UE cost and complexity.

As by the RAN chair guidance, we think SRS and DMRS enhancements should be considered both in UL and DL and a separate bullet should be added.

16 – ZTE Corporation

Answer to #1 Apple

AS1: In our contribution RWS-210479, the evaluation result of frequency selective precoding with 4 Tx is provided, and clear performance gain (>10%) is observed. It is expected more performance gain in case of UE with >4 Tx, we can further evaluate in the normative work phase.

AS2: For simultaneous multi-panel transmission, we agree that it could be applied to the case where UEs without power consumption issue. But, it can also bring benefits for other cases, e.g., cell center UEs, for which the throughput could be improved due to more transmission layers used. Note that, we also provided some evaluation results in RWS-210479, and we find about 32% UPT improvement could be obtained for cell center UEs by applying simultaneous multi-panel transmission. But, this issue is a little bit difference from frequency-selective precoding, we also identify some benefits that UL multi-panel and multi-TRP can also apply to ≤ 4 Tx UE and smart phone. As in a typical evaluation assumption, the UE with two back-by-back panels and a total of 4 Tx is considered.

Answer to #9 Apple,

Yes, we think UL 1024QAM could be first studied for CPE for FWA. If it is included in Rel-18, starting with RAN4 study first could be reasonable.

Comment to #2 Nokia

For the purpose of clarifying corresponding aspects, we have similar understanding.

Comment to #4 Futurewei and #12 Intel

For higher UE capability with more UL TX, we share the view that CPE could be one use case. In addition, there could be other realistic use cases in vertical industries, such as the devices in the car and large machine controllers in factory etc.

We are open to further discuss whether SI or WI is more appropriate.

Answer to #5 Ericsson

AS1: Regarding UL frequency selective precoding and >4 layer UL MIMO, affordable DCI size is expected if a single DCI is used to carry all scheduling information. Otherwise, we may need to consider two stage DCI or two linked DCIs. This enhancement is mainly for capacity improvement, we think it is more appropriate for CP-OFDM. If UE suffers PAPR issue, DFT-S-OFDM can be configured. Regarding the scenarios/configurations, we use 4 Tx antenna configuration which is a normal use case.

AS2: In our view, one main motivation of UL enhancements is for high UL throughput, and URLLC requirements should also be considered for some use cases from vertical industries, e.g., machine vision. Based on our observation, it seems many proponents have similar views on this. So, our understanding is the schemes that are beneficial in terms of spectral efficiency and latency/reliability can also be considered.

Comment to #7 BT plc

We are open to further discuss whether SI or WI is more appropriate.

Comment to #22 CMCC

Regarding the your 'Question and comments on flexible use of DL and UL carrier', we are glad to see that you also think it's beneficial to flexibly use of the DL/UL carrier, and support UL CA for idle/inactive mode. We also think the flexible association of DL and UL carrier should be an optional feature, and the determination of the association should be controlled by network to adjust to the use cases/scenarios.

Comment to #8 Lenovo, # 11CATT, #15 OPPO, #17 NTT DOCOMO, #18NEC, #21 Spreadtrum

We agree that UL subband precoding and >4 layers are important aspects of UL MIMO enhancements and could be supported in Rel-18.

3 Mobility Enhancements

This section is targeted at identifying commonalities and interactions for Mobility Enhancements.

Feedback Form 5: Questions/Comments

1 – Apple Hungary Kft.

A few companies have proposed DAPS with DC, we are wondering on the logistics of this (and whether the intention is worth the complexity). We understand that DAPS + CA might be the next enhancement (which has complexity, but is geared towards the 0ms interruption), but with DAPS+DC, what would be the actions on the SCG?

Is the intention that SCG change would be like legacy only the MCG does the DAPS? Or something else would be added to the PSCell/SCG?

2 – Ericsson LM

RAN4 indicated that for simultaneous ULs in DAPS was not feasible in Rel-16 for FR2. Do we expect that this limitation is no longer applicable? In our understanding an enhanced Make-before-break approach could also be considered, and we assume that it would not have the issues RAN4 highlighted for Rel-16 MobEnh.

3 – ZTE Corporation

For the L1/L2 triggered CHO or cell switching, we want to clarify whether the ping-pong HO will still be an issue and shall be avoided? If ping-pong HO shall be avoided in the L1/L2 triggered HO, then it is not clear whether L3 filter (e.g. FilterConfig) or L3 timer (e.g. time to trigger) shall be reused, and with such L3 filtering and L3 timer, whether we can still call it as L1/L2 triggered CHO/cell switching?

Then, regarding L1-centric mobility, we are open to further study inter-DU and RRC-involved mobility in Rel-18. In our view, RAN1 may lead UE -initiated L1/L2 reporting/handover, and others, whilst RRC-involved HO procedure, may be left to RAN2.

4 – MediaTek Inc.

Given the need to make sure that all mobility requirements and the whole protocol stack is taken into account, we believe that any mobility enhancement work in Rel-18 should be led by RAN2 - enabling more of a top-down approach compared to how "L1/L2-centric inter-cell mobility" was handled in Rel-17.

5 – vivo Communication Technology

1. Mobility enhancement should consider all possible enhancement including L1/L2 centric mobility, enhancement based on DAPS, CHO however duplicated functions should be avoided. For example, with the L1/L2 centric mobility in Rel-17, and potential enhancement in Rel-18, the interruption could be optimized. There may be no need for DAPS + DC/CA, which will introduce much complexity for the UEs.

2. We think mobility based on UL-centric measurement should also be included for study for both connected mode and idle mode. It is beneficial for the handover reliability, especially for ultra dense deployment or high speed scenario.

3. For L1/L2 mobility, measurement and report for both synchronized and non-synchronized scenarios should be considered, including e.g., timing offset configuration/reporting, inter-cell measurement latency/overhead/power consumption reduction, interference measurement due to non-synchronized reception.

6 – CATT

In general we support mobility enhancements in Rel-18.

1) From the previous discussions, we observe a relatively strong interests on the scenario where both high data rate and experience continuity are required, that we also agree. Along this line, we could further consider solutions such as DAPS+CA/DC. We understand there are some concerns on increased complexity, but this can be further discussed once there is common understanding on the scenario and requirement .

2) We'd also suggest to consider in Rel-18 some work to ensure the mobility features that we specified in previous release can work together well. One example is CHO+DAPS. We expect the additional complexity may be low for those.

3) We'd also like to check if companies are interested in enhancing the inter RAT mobility btw NR and LTE for UEs in inactive state. We see some benefit in both UE and NW side.

4) Given L1/L2-centric mobility based on Rel-17 beam management framework has been down-scoped in RAN#92e, we are open to continuing the down-scoped scenario in Rel-18.

7 – Lenovo (Beijing) Ltd

Some companies have the concerns for supporting DAPS+DC considering the UE complexity because UE is expected to maintain four legs at the same time. It is true that UE has to maintain four legs if SN is changed as well. In addition, Inter-Master Node handover with/without SN change is supported in the legacy handover. If SN is not changed, UE can maintain three legs during handover.

Many companies support L1/L2 centric mobility to be included in the Rel-18. It was agreed in RAN2#114 meeting that intra-DU should be prioritized in L1/L2 centric mobility. If L1/L2 centric mobility is supported in Rel-18, we also can study the case of Inter-DU(Intra-CU) and Inter-CU in Rel-18.

8 – Samsung Electronics Co.

RAN2/3 work: Rel-17 introduced inter-cell beam management within the unified TCI framework. RAN2 defined two scenarios: Scenario 1, which is targeted for Rel-17, is for receiving from a neighboring cell, through beam indication, without changing the serving cell. Scenario 2, which is not targeted for Rel-17, triggers a serving cell change as a result of beam indication of a neighboring cell beam. Furthermore, inter-cell beam management, in Rel-17, is targeting intra-DU and intra-frequency scenarios. Several companies [x003, x055, x093, x123, x162, x181, x212, x268, x307, 396, x499] expressed support for scenario 2 and/or expanding L1/L2-centric mobility to inter-DU/inter-frequency scenarios. We can discuss further how to expand the support of beam-management-triggered inter-cell mobility in Rel-18, starting with the Rel-17 framework and extending to include the relation with other mobility schemes such as conventional L3 handover, DAPS and CHO. It is expected that this work is RAN2-centric (with some works in RAN1 and RAN3).

RAN1 work: Additionally, dynamic beam measurement/reporting for multiple (serving and non-serving) cells can be beneficial for seamless connection at cell edge. The support in Rel-17 can be the starting point for enhancements in Rel-18 if some works in RAN1 are required.

9 – Nokia Corporation

We see several common themes in proposals from multiple companies:

-

Further reduction to the UP interruption time during mobility, with special emphasis on FR2 where DAPS has not been specified

-

HO robustness combined with short (or zero) UP interruption time in multiple scenarios (e.g. NR SA, CA and MR-DC).

-

Faster mobility procedure execution time (e.g. via RACH-less HO, L1 mobility)

As the CHO/DAPS would provide the baseline performance, studies could be needed to understand the gains compared to those.

The mobility work would likely need to be RAN2-led, but effort is additionally needed at least in RAN3 and RAN4 (and potentially also in RAN1).

10 – HuaWei Technologies Co.

There are various aspects proposed in mobility area. We see the areas can be categorized as below:

1. L1/L2 mobility

We understand there is a wide support for having L1/L2 mobility, including RWS-210449, 0212, 0268, 0307, 0396, 0093/0105, 0123, 0075, 0303, 0162/0165, 0202/0199, 0227, 0464, 0369, 0003/0004, 0143, 0183/0181 and 0384 from MIMO, mobility and MR-MC papers. The applied scenarios addressed inter-cell mobility and many companies also propose to have similar principle to CA and DC cases. There is also good support to have UL dynamic switch with maintenance of the DL, this was discussed in 0143, 0183, 0165, 0056, 0122 and 0036 etc. Quite a few companies also mentioned there could be UL transmission capability limitation from the UE side, including 0369, 0449, 0143, 0183, 0165 and 0056 etc. Therefore we think the L1/L2 mobility can consider

- 1) The serving cell change scenarios for standalone, CA and DC deployment;
- 2) To take UE capability into account, avoiding increasing UE RF complexity

Regarding UL carrier/UL CG switching, it is proposed by companies in UL enhancements, mobility and MR-MC and then it is unclear where we have further discussion. We think it should be good if this can take place in one area so that all companies understand where to provide views, and we'd like to ask where to discuss this aspect, e.g. in UL enh, mobility or MR-MC?

2. CHO optimization

- 1) For CHO+DAPS (0449, 0055, 0078, 0151, 0196, 0283, 0384 and 0400), we consider this may be helpful to support both reliability and Oms.
- 2) For other CHO optimization area, we see companies' views are quite diverging, e.g. CHO for inactive, CHO within CHO, CHO for FR2-specific optimization, CHO for NG-based handover, etc. We see no convergence on these directions and better sufficient gains analysis can be provided.

3. DAPS with CA/DC (003/004, 0055, 0151, 0196, 0227, 0275, 0283, 0369, 0384, 0400)

There are also quite a few companies proposed DAPS with CA/DC, however this increases UE complexity to support 4 legs during handover. We are wondering whether such higher UE capability can be commercialized in near future or such enhancements are only targeting those high-end UEs instead of normal smart phones?

4. Other enhancements including RACH-less, MBB, data forwarding etc.

- 1) It is a bit unclear to us how MBB can apply to FR2 as in our view the problem of DAPS for FR2 could also be applied to MBB, and this is better to be clarified by proponents.
- 2) For RACH-less HO, this can be applied to both FR1/FR2 and we think if this can be used for L1/L2 mobility, it can get better performance rather than a L3 handover.
- 3) For other higher layer enhancements, we do not see wide support and proponents can provide sufficient analysis on the gains. From our side, we understand the data forwarding needs to be improved as shown in RWS-210449, as currently the latency caused by Xn/X2 interface for data forwarding would bring around 10ms delay, the similar issue was also described in RWS-210078. To facilitate the services like URLLC, XR etc., this aspect is worth consideration.

11 – NTT DOCOMO INC.

Regarding L1/L2-centric mobility, in order to help FR2 PCell deployments, we are supportive to further study inter-DU scenario in Rel-18, including the study of its gains (e.g.. how much handover delay can be reduced vs ping-pong tolerance). We also see some relationship between inter-DU L1/L2-centric mobility and inter-gNB coordination (inter-DU mTRP) from architecture point of view.

12 – Guangdong OPPO Mobile Telecom.

Mobility enhancement should be an important aspect of R18 NR evolution. To be specifically, we support further handover enhancement for CA/DC, e.g., DAPS for CA/DC, CHO+CPAC. For the other interruption time reduction solutions than DAPS, e.g. MBB and RACH-less HO, we think they can be considered especially for UEs which do not support DAPS. Regarding L1/L2 centric mobility, it will depend on R17 progress but it at least includes the scenario 2 (L1/L2 mobility model). The mobility issue in FR2 can also be considered in R18, i.e. DAPS for FR2-FR2 handover.

Some company proposed faster RLF declaration. We would like to know better how a UE declare a faster RLF. Would some proponent clarify it?

13 – China Telecommunication Corp.

Regarding to reduce data interruption in FR2, except for DAPS enhancement for FR2, we also think other solutions should be considered such as RACH-less Handover or MBB Handover. Besides, the L1/L2 triggered CHO-like approach or dynamic switch approach can also be the potential solution to reduce data interruption, and we are wondering whether the UE autonomously switch to the target cell or the network triggers the switch by L1/L2 signaling? And is there any L3 signaling impact?

Regarding to UL Signal based mobility procedure, it may lead to an increase in UE energy consumption since the UE may need to report the uplink reference signal frequently, how to deal with such problems? And except for the UL signaling design, what's the other potential impact on the specifications?

14 – Xiaomi Communications

1. Throughput during DAPS need to be improved to support new services, e.g. XR. But in the meantime, UE complexity should be considered.
2. CHO should be enhanced to improve the mobility robustness performance in FR2.
3. CHO+DAPS could be used to achieve 0 interruption and high robustness at the same time for some stringent service.

15 – NEC Corporation

We understand the L1/L2-centric mobility gets many supports from companies, whereas we have a general concern on how to progress this. As we have already seen in Rel-17 MIMO, although many solutions proposed in RAN1, without RAN2 enhancements in parallel, it is difficult to make progress especially considering cases like inter-DU, serving cell change, etc. So, we think that before the work is approved, a guideline on how to progress should be sufficiently clarified. For instance, which WG should lead the work, RAN1 or RAN2? And how to improve the interaction between WGs?

16 – China Mobile Com. Corporation

Regarding to L1/L2 mobility, we have the similar view with ZTE and NEC. We are not sure whether the inter-DU scenario is practical, e.g., frequent ping-pong may happen due to without involvement of L3. We also expect that this work is led by RAN2, with the involvement of RAN1 and RAN3.

17 – China Unicom

It is a common view that mobility enhancement in R18 should be a RAN2-lead topic, and the following potential scope have been discussed in RAN Workshop, i.e. L1/L2 solutions for R18 Mob enhancement,

DAPS enhancement, CHO+CPAC, (CHO and/or CPAC) +DAPS, make-before-break, RACH-less and other potential solutions.

Both FR1 and FR2 should be supported in mobility enhancement topic in R18, and the following issues can be further discussed in R18:

- (1) Support both L1/L2 triggered solutions with RRC-involved and L1/L2 centric solutions, as well as evaluating performance gains and impacts on other WGs
- (2) support the DAPS for NR-CA in R18 to support “0ms” interruption for both FR1 and FR2, as well as minimize the UE complexity. Further discussion on whether to support DAPS for the NR-DC scenario.
- (3) consider to resolve the UE fast reselection issue for 5G RAN sharing scenario.
- (4) discuss on whether to support make-before-break and/or RACH-less for NR, and take LTE solutions as baseline.
- (5) further discussion on whether to support CHO+CPAC, (CHO and/or CPAC) +DAPS, and inter-RAT CHO.

Feedback Form 6: Answers/Comments

1 – LG Electronics France

We think in general mobility enhancement issues should be led by RAN2 and any issue requiring close inter-WG works should be clarified in the WI description in the first place.

We think the followings are useful for Rel-18 mobility enhancements:

- - mTRP based mobility enhancements
 - o Enable L1/L2 centric mobility for dynamic mobility
 - o mTRP based fast recovery/failure avoidance

- - CHO/CPAC enhancements for mobility robustness
 - o Fast recovery or failure avoidance by using CHO candidates

- - DAPS enhancements for higher data tput during DAPS HO
 - o DAPS with CA/DC

2 – LG Uplus

We have the same view as LG Electronics above. In addition, we thought maximum 3-leg DAPS for MR-DC (incl. EN-DC, NE-DC, NR-DC) HO with Pcell change is prioritized and 2-leg DAPS for SCG change as well. DAPS for high band is also preferred. In data stalling issue depart from latency, we expect DAPS with DC have benefit. Regarding complexity concerns for DAPS with DC, we thought L1/L2 centric

mobility have same complexity increase since L2 packet should be maintained for multi-leg. We could agree that there is no L1 complexity issue.

3 – Samsung Electronics Co.

RAN1 led the L1/L2 centric mobility discussion in Rel-17. We anticipate that most of the RAN1 work for beam measurement/reporting and beam indication will be complete in Rel-17. The left-over work for scenario 2 and inter-DU L1/L2 centric mobility is mainly impacting RAN2 and RAN3, potentially with a small RAN1 impact. Therefore, it seems reasonable to have this objective led by RAN2.

We agree with ZTE, NTT DOCOMO and CMCC that the ping-pong transfer of calls between cells, especially for inter DU-case, for L1/L2 centric mobility should be minimized and avoided as much as possible. One of the motivating use cases of L1/L2 centric mobility is high-speed mobility (e.g. HST and US highways). In these scenarios UEs are moving at a high speed. A UE rapidly departs the coverage area (rapidly increasing path-loss) of a cell and enters that of another cell (rapidly decreasing path-loss) making the ping-pong effect less likely. We are open to further study and analyze this issue.

4 – NTT DOCOMO INC.

Comment to NEC's question: *We understand the L1/L2-centric mobility gets many supports from companies, whereas we have a general concern on how to progress this. As we have already seen in Rel-17 MIMO, although many solutions proposed in RAN1, without RAN2 enhancements in parallel, it is difficult to make progress especially considering cases like inter-DU, serving cell change, etc. So, we think that before the work is approved, a guideline on how to progress should be sufficiently clarified. For instance, which WG should lead the work, RAN1 or RAN2? And how to improve the interaction between WGs?*

==> We expect mobility, including L1/L2-centric mobility, to be led by RAN2, with RAN1/RAN3 involved. After L1/L2-centric mobility procedure is decided by RAN2, LS can be shared with other WGs like we usually do.

5 – China Telecommunication Corp.

Generally, we support the mobility enhancements in Rel-18, and we want to clarify following issues based on the Phase1 email-discussion:

Answer to #1 Apple Hungary Kft.

Regarding to the DAPS+DC, we think the main intention is to reduce data interruption for inter-MN handover scenarios, if PScell also changed during the inter-MN handover procedure (i.e. inter-MN handover with PScell change occurs), then we think enhancement for PScell change procedure should also be considered, such as DAPS-like PScell, which can reduce the data interruption in SN side, in this approach, the UE needs to support more than 2 legs at the same time. Considering the UE complexity, we can restrict the maximum number of the active serving cells. The applicable use cases and potential approaches can be further discussed.

Answer to #12 Guangdong OPPO Mobile Telecom.

Regarding to the Fast Failure Detection, we think this is mainly for FR2 scenarios, the current RLF declaration is based on DRX and since the radio conditions change rapidly in FR2, there will be few seconds before RLF is declared, so optimizations to reduce the failure detection time should be studied, such as introduce new DRX cycle length especially for FR2, other solutions to declare faster RLF can also be considered.

6 – Nokia Corporation

We agree with others that **this work should be led by RAN2** (as has been usually done for mobility-related enhancements). The details of the timing and whether study is first needed can better be discussed once we progress on the scope.

That said, we roughly see the following potential areas of work:

-

FR2 interruption reduction: Reducing UP interruption time for FR2 handovers

o

The work should consider existing FR1 mechanisms (e.g. DAPS, CHO) and, if needed, specify additional mechanism required by FR2

-

Efficient mobility procedures for FR1/FR2: Allow mobility robustness and/or high data throughput with interruption reduction and optimize existing mechanisms

o

The work should consider at least DAPS+CHO, DAPS+CA/DC, enhancements for CHO, CHO with MR-DC and CHO failure recovery mechanisms

o

Cell reselection enhancements can also be considered under this objective

-

Faster mobility for FR1/FR2: Consider how the mobility procedure execution time can be reduced

o

The work should consider at least RACH-less HO and L1 mobility (based on Rel-17 mTRP)

7 – HuaWei Technologies Co.

Q1. Whether to support simultaneous ULs support in DAPS for FR2: Ericsson

Due to lack of multi-panel support resides UE, we understand the limitation is valid in Rel-16. In Rel-17 UE is enhanced to have multi-panel feature as an optional capability. If UE supports this, the limitation for FR2 on DL seems not valid anymore and we understand Rel-16 DAPS already supports TDM on UL by the network, and thus we are not sure whether eMBB adds anything here?

Q2. Whether L1 measurement is sufficient for L1/L2 mobility: ZTE, CMCC

It should be first clarified by the companies what the L1/L2 mobility is referring to. Our understanding is that in R17 L1/L2 mobility is mainly specific for FR2 and the assumption is L1 measurement is applied. Here we understand from companies input for Rel-18 that L1/L2 mobility means dynamic switch via L1/L2 signalling among pre-configured carriers/cells/CGs, which are considered now generically for both FR1 and FR2. We did not see there is any problem to call it as L1/L2 mobility. Regarding the details of measurement, e.g. based on either L1 or L3, or optimizations, we think it can be a separate issue and dependent on the scenario, for FR2 mobility L1 may be more suitable, and whether we can add some optimization to ping-pong can be further discussed during detailed solution discussion.

Q3. Either UE-centric L1/L2 mobility or NW-triggered L1/L2 mobility: CTC

We understand the essence of both approaches are dynamic switching via L1/L2 signalling among pre-configured carriers/cells/CGs. At this stage, we are supportive of the dynamic switching, and comparison

of these two approaches can be discussed during detailed solution discussion, and from our side we think network controlled manner is better as mobility needs to consider both UE radio conditions and network load balancing etc..

Q4. Which group is Leading group of L1/L2 mobility

We share the same view as other companies that L1/L2 mobility should be led by RAN2, and with coordination with RAN1 and RAN3 if needed. As many companies proposed, this discussion addresses multi-carrier case and we think common principle can be discussed together.

In addition We think as long as the UE has limitation on UL transmission, this would be a general problem for multiple carriers cases. However there is no such limitation on the DL, and thus we think the UL capability limitation should be taken into account and mechanism for UL switch should be discussed specifically in addition to dynamic cell change.

Regarding LGU+'s comment on DAPS with CA/DC, we understand the major difference is L1/L2 mobility does not increase the RF capability as it uses dynamic switch, but DAPS with CA/DC requires double RF capability for the UE and this is why we think the complexity level is not the same for the UE side. We support to consider 0ms for CA/DC case, but maybe not necessary to always use DAPS with CA/DC to fulfill this requirement.

8 – vivo Communication Technology

Answer to #13 (China Telecom)

That is true, the UE needs to transmit UL signal periodically. But the additional power consumption is marginal, based our evaluation, for example, assuming tx power for UL signaling is 23dBm with the period of 1.28s, addition 4.7% power consumption will be increased for UL signaling tx. Details could be found in our contribution RWS-210161.

Regarding the potential impacts on the specification, we think the first part is UL signal transmission, which depends on the UL signal design; the second part is neighboring cell needs to receive UL signal from UEs, and potential network coordination, but details could be up to further discussion.

9 – Ericsson LM

Answer to #10 (Huawei) about make-before-break: our understanding is that DAPS require simultaneous UL transmissions (at least for feedback to source) we believe this was the cause for the issues RAN4 raised for DAPS in FR2. We so far have not understood why these issues are no longer valid.

We think that an enhanced version of make-before-break can considered which does not rely on simultaneous transmissions (and perhaps also not simultaneous receptions). This would then address the issues RAN4 raised for DAPS in FR2.

10 – ZTE Corporation

Answer to #10 (Huawei)

We share the view that it would be nice to have clear guideline to clarify in which email thread such enhancement should be discussed.

For the fast cell group switch, considering the fast cell group switch is similar as the Multi-connectivity with selective activation, which is one of the main topic in CA/DC enhancement (e.g. multiple SCG is configured to UE, and one of them can be activated in a more efficient & dynamic manner), and the role change in CA/DC (e.g. role change between SpCell and SCell, and role change between MCG and SCG) has been discussed before in CA/DC aspect, we have slight preference to discuss the fast SCG change and role change in CA/DC in the email thread for CA/DC enhancement.

For the question about MBB V.S. DAPS for FR2, from our point of view, simultaneously transmission to both source and target is not required in MBB, which make MBB easier to be applied in FR2.

Answer to #12 (Oppo)

For the fast RLF declaration, one issue we observed is the evaluation time of Radio Link Monitoring and Beam Failure Detection, which are defined as a function of DRX cycle length. We understand the intention is to save UE power consumption. However, similar as other measurement operation, it seems reasonable to perform more frequently measurement in case the radio condition is bad, thus one alternative solution in our mind is to have different requirement on the evaluation time for different cases. For example, the DRX cycle length will only be taken into account in case the radio condition is good (e.g. an valid RSRP can be measured and the RSRP is higher than a threshold), and a shorter evaluation time will be required when the radio condition is poor (e.g. ignore the DRX cycle or stop DRX operation when radio condition is bad).

Answer to #13 (China Telecom)

For the dynamic cell switching approach, we think both UE triggered and NW triggered shall be considered. For both UE triggered and NW triggered cell switching, the resource should be pre-configured by L3 signaling. For the UE triggered approach, the criteria for switching will be configured by L3 signaling as well.

Answer to #15 (NEC)

For the L1/L2-centric mobility, we think we can separate the discussion for inter-cell Multi-TRP operation without RRC involved (i.e. the switching operation among different TRPs is transparent to RRC layer) and L1/L2 triggered L3 mobility (e.g. RRC will be involved in the cell switching procedure). For the enhancement to inter-cell Multi-TRP operation, we think it can be discussed in FeMIMO, which is similar as Rel-17. However, for the L1/L2 triggered L3 mobility, since RRC will be involved and lots of impact on L3 seems required, we think the corresponding discussion should be led by RAN2.

11 – Intel Corporation (UK) Ltd

General Response to comments:

Based on the interest from companies, for mobility enhancements in Rel-18, the following scenarios are important:

- Scenario 1: Mobility enhancements on FR2, especially low interruption;
- Scenario 2: XR requirement on consistent data rate with low interruption during handover;
- Scenario 3: low interruption + reliability simultaneously during handover;
- Scenario 4: Low interruption on switching of PSCell, switching between MCG and SCG, etc;

For scenario 1 and 4, we think that fast cell group switching with one activated cell group at a time (FFS on L1/L2 or L3 triggered mobility) is the good solution;

For scenario 2, DAPS+CA/DC can resolve the problem. DAPS+CA will not add additional UE requirement on how many legs the UE shall support, compared with DAPS (2 legs). For DAPS+DC, 3 or 4 legs are required depend on the use cases. The scenario 2 should target to high end UEs that can support XR;

For Scenario 3, DAPS+CHO is helpful;

We believe that the leading group on mobility topics should be RAN2, and RAN1, 3 and 4 may be involved.

Note: the name of “L1/L2 based CHO or mobility” is too limited, implies the solution discussed in Rel-17 under FeMIMO. To cover more scenarios, we would prefer to have a general name “fast cell group switching” for the discussion in Rel-18.

Responses to #1 Apple:

The motivation to enhance DAPS with DC is same as the purpose for DAPS with CA, i.e. to support consistent data rate with low interruption during handover. We believe that this is an important requirement for XR.

DAPS with DC could be that the UE will maintain the transmission/reception between source MCG/SCG and target MCG/SCG simultaneously. It is also related to how many legs the UE can support in Rel-18 (similar proposal in CA/DC enhancements.). If the UE can only support 3 legs, then we can consider the scenario that MCG change without SCG change case, and/or SCG change without MSG change.

Responses to #2 Ericsson:

For the scenario that the UE cannot support simultaneous ULs in DAPS, we understand that single UL approach should be considered. It would be good to have a common solution, e.g. fast cell group switching with only one activated cell group at a time can also be applied for this scenario. We can consider this as a possible ‘enhanced Make-before-break solution’.

Responses to #3 ZTE:

Regarding L1/2 triggered CHO, RAN2 has sent LS to RAN1 on whether L1 measurements (i.e. measurements not using L3 filtering) are used for triggering L1/L2 centric inter-cell mobility. We do agree that further discussion is needed on whether L3 filter/timer should be used on top of L1 measurement or not.

In our view, the basic intention for L1/2 triggered CHO/cell switching and RRC involved HO procedure is to have preconfigured target/candidate cell (group) configuration, and then the UE will do the switching (e.g. bi-direction) based on network request, e.g. L1, L2 or RRC signalling or preconfigured condition. It can reduce the latency, and also improve the reliability. Considering the common part, we call it as fast cell group switching instead of L1/L2 triggered CHO or mobility since this proposal is meant to cover many scenarios, e.g. switching of Pcell, switching of PScell, switching between SPcell and SCell, switching between MCG and SCG, and is based on the extension of R16 mobility enhancement solution. We think the leading group should be RAN2 since the main work should be done in RAN2.

12 – Sony Europe B.V.

(China telecom).

In our views we don’t think it will increase a UE power consumption if UL RS is used for mobility decision. The power consumption benefits are documented in TR38.802 section 9.1.4.

We point that there is an existing UL RS that can be reused for this purpose, e.g. UL SRS for positioning.

13 – China Unicom

Many companies provide their views on L1/L2 solutions, DAPS enhancement, CHO enhancement, and MBB/RACH-less solutions, but there are also some key issues left to be clarified as follows:

Answer to #3 ZTE, #14 NTT and #19 CMCC.

L1/L2 solutions include measurement and dynamic switching mechanism. For the measurement mechanism, L1/L2/L3 measurement solutions can be applied. Thus ping-pong can only happen in L1 measurement scenario, which can be solved by network implementation or by a similar filtering solution like L3.

For the dynamic switching mechanism, L1/L2 commands can be applied to indicate to the target cell and beam with no ping-pang impact.

Answer to #15 NEC Corporation.

Regarding standard impacts, we understand inter-cell beam management in R17 can be considered as baseline for L1/L2 mobility for FR2. So it requires RAN1 involvement in this case. However, other than that, we guess more work should be done in RAN2 and RAN3 in terms of pre-configuration, execution and completion and mobility-specific aspects like RRM and RLF. Note that we need also consider the CU DU split and inter-DU so RAN3 is also impacted, and different WGs can make progress on this topic better by LSSs.

Answer to #16 China Telecom.

For L1/L2 triggered CHO-like solution, UE sends L1/L2 signal to selected candidate cell when pre-configured conditions are met, and network responds with a new L1/L2 signal to complete the cell switch. Alternatively, UE may send L1 measurement report or even SRS-like signal to target cell. After that, target cell triggers cell switching. The impact of L3 signaling depends on implementations and that part can be discussed in the WI phase.

4 Additional topological improvements (IAB and smart repeaters)

This section is targeted at identifying commonalities and interactions for Additional topological improvements (IAB and smart repeaters).

Feedback Form 7: Questions/Comments

1 – ZTE Corporation

For smart repeaters, clarification on following are needed:

1) For the relationship between IAB and repeater, according to contribution review, it seems that different technical directions and scenarios for evolution of these different types are proposed. From our understanding, these two types should be treated and discussed separately.

2) For the necessary protocol support part, in some contribution, I noticed that RAN2 is involved, does it imply that higher layer, e.g., MAC or RRC, should also be involved to support the functionality, e.g., interpretation on the TDD pattern, TCI information or identification of smart repeater. If so, the benefits of smart repeaters over other types of nodes may be limited.

Moreover, for the controlling part, both joint and independent deployment for smart repeater and IAB is proposed. For these two cases, is there any difference on controlling mechanism design? If multiple approaches should be considered, the complexity will be dramatically increased. We prefer to avoid considering joint deployment in the first stage.

Since smart repeater is active entity, which may lead to significant interference including unexpected power boosting for the adjacent channel or adjacent cells. For this part, it's preferred to conduct solid study firstly on mechanism and impacts on the RF part and interference management.

2 – FirstNet

Smart repeaters are pass through entities providing data path carrying means for analog UL/DL signals from/to UEs thus extending both network coverage and sidelink coverage extensions essential to public safety personnel. This topic is essential to public safety in Rel-18.

3 – Futurewei Technologies

For smart repeater, feasibility study is needed first in RAN1/RAN4 for aspects like beam adaptation at the repeater.

4 – Apple Hungary Kft.

Is the vision to treat IAB and smart repeaters as a same category? How about the various other categories of coverage enhancements proposed for IAB as mobile, nomad and NTN based ones? Will they be all treated under the same bucket of “Relay enhancements” or is it that each of these enhancements should be done independently? Also how does congestion management look like with these different relay nodes in the networks?

5 – AT&T

We believe that IAB and Smart Repeaters can be complementary not competing solutions with distinct deployment scenarios. However, Smart Repeaters can certainly benefit from leveraging existing IAB work especially with regards to resource configuration and timing alignment/synchronization solutions since much of the required control signaling would be similar (although likely a subset/simplified in case of repeaters which share the same cell as the “parent” node).

6 – Samsung Electronics Co.

As a general comment, it should be clear about justification/motivations/use cases why concurrent work/s-tudy items for these different types of evolution paths of relay are necessary in Rel-18.

For IAB, ensuring reliability has been one of main objectives since Rel-16. In this sense, it should be clarified what is a target use case to ensure IAB reliability on unlicensed band.

And finally, in this WS, we can observe several aspects raised for Rel-18 IAB enhancement. Some of them are related to other Rel-18 topics, e.g., NTN. So, it would be better to justify the importance of those aspects in Rel-18, and give some prioritization.

Regarding smart repeater, we think the technique may have potential to enhance coverage, while mitigating interference. However, control signaling between gNB and smart repeater which is necessary to support beamforming/TDD awareness is not clear. Therefore, control signaling part should be clarified first.

Also, how to deploy with IAB should be clarified.

7 – Xiaomi Communications

For smart repeater, we are wondering whether the smart repeater is transparent to Rel-18 UE.

For IAB, we think the Rel-18 IAB should support mobility for the vehical use case and support various access technologies including WiFi.

8 – Lenovo Mobile Com. Technology

We are wondering that whether IAB and Smart Repeater can be discussed together since they are two different types of relay scenarios.

And as for the IAB, local service at the intermediate IAB node has been proposed by some companies (e.g. QC, ZTE...), which means the RAN node needs to support the function of local break out . However, it may not be an IAB specific issue and may be discussed in the crossFunc section just as the network coding.

9 – Guangdong OPPO Mobile Telecom.

Some questions for IAB part:

Q1: For IAB, mobile IAB is proposed by many companies. For node-mobility-aware cell selection/handover, would some proponent elaborate a bit on its impact to UE?

Q2: Regarding NTN-based backhaul, would satellite be categorized as a “donor node” or some new topology should be defined?

Q3: For Side-link based inter-IAB communication, is this inter-IAB communication between IAB-MT and IAB-MT? If yes, Would this IAB-sidelink be categorized as the 3rd communication link of IAB node besides parent link and child link (which could be a brand-new IAB topology — it is mesh anyway), or it is part of “child link” from specification point of view (so that at least some of the Rel-17 spec can still be used)?

Two questions for repeater: If the control plan terminates at PHY

Q4: would a brand-new DCI is needed in order to avoid the dependency on RRC-signaled TDD configuration?

Q5: Q2: is this control plane not having any HARQ mechanism (current spec puts HARQ entity in MAC)?

10 – vivo Communication Technology

There seems to be some commonality between smart repeater and RIS, for example, the control signaling that may be introduced for smart repeater could also be applicable to RIS? Would be good to hear other companies view on this aspect.

11 – China Unicom

We share the view that RIS should move to “Additional topological improvements (IAB and smart repeaters)”, and the title can be revised as “Additional topological improvements (IAB, smart repeaters and RIS)”.

12 – HUAWEI TECHNOLOGIES Co. Ltd.

[Huawei, Hisilicon] We would like to echo the comment from Samsung (and others): we should clarify justification/motivations/use cases/scenarios for this area. Why the concurrent work/study items for these different types of evolution paths of relay are necessary in Rel-18?

13 – KDDI Corporation

For smart repeater, we think it is necessary to discuss whether smart repeater needs to study what kinds of features can be considered as “smart” parts and how much gain can be expected by them, and then discuss which features should be specified based on the results of the study. Regarding signaling, our understanding is that for smart repeater, dynamic control of PHY layer (e.g. beams of smart repeater) is directly performed from the gNB side, which is a different direction from IAB. However, we believe it is also necessary to have a consensus on such signaling framework and/or architectures through the above study if it is needed.

14 – Ericsson France S.A.S

If a smart repeater requires a control connection with a gNB, and if the ambition level is to standardize all aspects of smart repeaters, it seems appropriate to also specify such a control interface. Depending on what the architecture will look like, this will require RAN2 and/or RAN3 involvement (RAN3 in the past specified the Iuant interface which might look similar in some aspects, although smart repeaters may

require additional functionality from such an interface). Without the specification of such an interface, the only way to control a smart repeater would be via proprietary OAM.

Regarding interference, it is important to consider that if there is a potential to cause co-channel interference from a widespread deployment of repeaters, then the adjacent channel interference may increase too, so an interference study should consider both.

Is the proposal to indicate bandwidth to repeat on a per-operator, or per-carrier basis or also potentially repeating part of a carrier (in the frequency domain)?

15 – Nokia France

There are many divergent suggestions related to enhancements for IAB and smart repeaters. Before discussing the detailed proposals, an important and beneficial first step would be to try to reach a common understanding on the particular scenarios that might be addressed by (a) IAB, (b) Rel-17 repeaters, (c) enhanced IAB, (d) different flavours of smart repeater.

If it is possible to reach such a common understanding on the scenarios, it would be very helpful to avoid multiple solutions addressing similar scenarios and associated market fragmentation.

Feedback Form 8: Answers/Comments

1 – LG Uplus

We think IAB and smart repeater aim different deployment scenario and capability. In our viewpoint, smart repeater should be similar as current RF repeater deployment in order to compensate macro O2I shadow area. Radio RF repeater (wireless) and optical repeater (wired) should be considered in scope together.

Regarding IAB, our target is for specific usage such as mobile IAB or HAPS to require reliability and resilience.

2 – Qualcomm Incorporated

To ZTE

Thank you for the comments.

Both, IAB and smart repeater aim to provide Uu coverage extension for FR1 and FR2. IAB accomplishes this through the addition of cells, while the smart repeater extends the footprint of existing cells. As pointed out by AT&T in Round 3, based on deployment scenario, one or the other of these solutions may be more beneficial. Indeed, both solutions can be combined, i.e., the smart repeater can extend the footprint of an IAB-node.

Separation of signaling: There is a benefit to separate the control for smart repeater and IAB. Based on protocol layering, IAB is controlled by the IAB-donor-CU via L3 signaling (RRC, F1-AP) while the smart repeater should be controlled by the gNB-DU (or IAB-DU) via L1/2 signaling (DCI and/or MAC CE). In this manner, the IAB-donor does not have to be aware of the smart repeater. Also, deployment of smart repeaters can be scaled to large numbers/high density. Note that the signaling support for the smart repeater is expected to be rather minimal.

Interference-related issues from smart repeaters should certainly be discussed.

To Apple

Thank you for the comments.

Regarding the vision of smart repeater vs. IAB, please see our comments given to ZTE.

Mobile, nomadic and NTN-based use cases have primarily been proposed for IAB. This makes sense since stationary IAB has already been standardized. Smart repeater efforts may want to start with the establishment of a baseline solution in Rel-18. Also, IAB and smart repeater are technically very different. These aspects need to be considered when defining the RAN WG efforts for Rel-18.

To Samsung

Thank you for the comments.

On the different Uu-relay evolution paths: Please see our comments to ZTE and Apple.

On reliability for IAB-U: Your comment presumably addresses unlicensed backhaul. The large bandwidth available in unlicensed spectrum motivates using IAB for backhauling. In the 60GHz range, the use of narrow beams will certainly enhance reliability. Further, optimizations that combine medium access with radio resource allocation present another opportunity to improve reliability.

Using IAB for NTN: It remains to be discussed if NTN-related use cases should be considered for Rel-18 IAB.

Combining smart repeater with IAB: Please see our comments to ZTE.

To Xiaomi

Thank you for the comments.

UE-awareness of smart repeater: There is no apparent technical reason why UEs would need to be aware of smart repeaters. Such UE-awareness might be considered as optimization for Rel-18 UEs, which is up to discussion during the corresponding SI/WI.

Support for WiFi access on IAB-node: IAB can carry non-F1 traffic over BAP/IP, and it could therefore be used for the backhauling of traffic from a WiFi AP that is collocated with the IAB-node. Note that such architecture has not been considered in TS 23.501, and it might therefore need discussion by SA2.

To Lenovo

Thank you for the comments.

Joint discussion of IAB and smart repeater: Please see our comments to ZTE and Apple.

Local service at IAB-node: The local breakout at the IAB-node can use the existing SA2 architecture. It implies that a CU-UP and a UPF are collocated with the IAB-node, and the corresponding control plane interfaces, E1 and N4, are routed via IP back to CU-CP and CN, respectively. The novelty relates to the routing of these interfaces over BAP, which is an IAB-specific topic and should therefore be handled by an IAB-WI.

To OPPO

Thank you for the comments.

Node-mobility awareness for mobile IAB: Node-mobility-awareness for UE handover decisions can be restricted to the IAB-donor-CU and does not require any IAB-related awareness on the UE.

IAB for NTN: Questions have been raised in rounds 1 and 3 if IAB is considered for regenerative satellites. From technical perspective, mobile IAB solutions could be considered for these use cases. The detailed scope of mobile-IAB use cases needs to be determined in follow-up discussions.

DCI-based smart-repeater control: Details on the use of DCI and its type for smart repeater control need to be discussed by RAN1. It is unlikely that the same DCI 2-5 is used for repeater control as for availability signaling in IAB.

HARQ-awareness of smart-repeater control: The smart repeater can remain agnostic to HARQ since HARQ is handled by the MAC on the gNB-DU.

To Vivo

Thank you for the comments.

We share the same view that the control signaling designed for smart repeaters can be leveraged for RIS too.

To Ericsson

Thank you for the comments.

Smart repeater control signaling: We agree that the smart repeater control signaling needs to be standardized. RAN2/3 may get involved, e.g., for smart repeater indication to RAN and for smart repeater authorization.

Smart repeater interference: We agree that smart repeater interference needs to be considered in the discussions. Bandwidth adaptation may indeed be needed for interference management.

To Nokia

Thank you for the comments.

Differentiation between smart repeater and IAB: Please see our replies to ZTE.

Enhanced IAB (e.g., mobile IAB, IAB for NTN): Please see our reply to Apple.

3 – Sumitomo Elec. Industries

We share similar view as LG Uplus.

Regarding deployment scenario of smart repeater, one of the important purpose of smart repeater is coverage compensation for O2I and indoor scenarios. We also prefer to think about both wireless repeater and wired repeater in the same scope.

4 – Nokia France

We still have the same observations as in the first round:

There are many divergent suggestions related to enhancements for IAB and smart repeaters. Before discussing the detailed proposals, an important and beneficial first step would be to try to reach a common understanding on the particular scenarios that might be addressed by (a) IAB, (b) Rel-17 repeaters, (c) enhanced IAB, (d) different flavours of smart repeater.

If it is possible to reach such a common understanding on the scenarios, it would be very helpful to avoid multiple solutions addressing similar scenarios and associated market fragmentation.

5 – Sony Europe B.V.

We agree with China Unicom that RIS should be moved to "Additional topological improvements (IAB and smart repeaters)", and the title can be revised as "Additional topological improvements (IAB, smart repeaters and RIS)".

6 – Fraunhofer HHI

To OPPO Q3, #9:

We envisage that mobile IAB could inherit some of the Rel-17 spec features from sidelink (SLe), which could be part of the „child link“ from the specification point of view. With a direct connection to other UEs via PC5, mIAB nodes could directly benefit from enhanced sidelink features, e.g., groupcast via PC5 or more efficient resource management by utilizing inter-UE coordination techniques. We are also open to specifying inter-IAB communication between IAB-MTs.

7 – CEWiT

Response to OPPO:

Thanks for the comment.

Yes, in the case of the regenerative type of payload case satellite can be donor but in the case of transparent payload, the ground station (gNB) will be a donor.

In our view, dynamic coordination between IAB nodes (E.g., between two parent nodes) is an essential feature. Yes, we agree that communication between IAB-MT and IAB-MT is one of the options to establish dynamic coordination. But we are open to discuss other options as well. Our intention is not to extend sidelink as such to IAB networks, but to study the possibility of reusing the methods in sidelink to IAB networks as well. To the second question, yes the IAB sidelink should be considered in addition to parent and child links.

5 Misc. RAN1/2/3 improvements: set 1

This section contains five sub-chapters (5.1 - 5.5) for additional topics relevant for eMBB evolution and a generic one "Others" (5.6) for topics which are not categorized in any topic 1 - 5.5.

5.1 UE power savings

This section is targeted at identifying commonalities and interactions for UE power savings.

Feedback Form 9: Questions/Comments

1 – ZTE Corporation

Many UE energy efficiency techniques have been specified from Rel-15 Rel-17, which can serve the power saving purpose in diverse scenarios, such as UE of different capabilities/traffic pattern. For the further evolution of UE power saving, we think the additional power saving gain and application scenarios should be well justified. We are open to discuss the power saving schemes in the areas, such as XR, redcap, UE with ultra-low power mode.

2 – Ericsson LM

UE power savings have been considered in Rel 15/16/17 particularly with dedicated WIs in Rel 16 and Rel 17. Several features have been specified to reduce the connected mode and idle mode NR UE power consumption, e.g., C-DRX, DCI format 2-6 to enable wake-up signaling, cross-slot scheduling, PDCCH monitoring adaptation, MIMO layer per BWP enhancements, RLM/BFD relaxation, UE assistance information for power savings, RRM relaxation, paging early indicator, false paging reduction, and provision

of connected mode TRS to idle mode UEs.

The developed tools, when implemented, provide a significant reduction in UE power consumption, leaving not much space for additional features to provide meaningful gains for eMBB. Furthermore, they have reached a level of maturity that can be used even in non-eMBB applications or provide a base for further developments in those areas e.g., Redcap. While the topic of UE power saving is important, a general work item is not needed in Rel-18 and UE power savings can be discussed in the work items, e.g., Redcap, XR, AI/ML, MIMO, etc.

3 – Panasonic Corporation

Regarding UE power saving of RWS-210168, in GTW, there were discussion related to serving cell related measurement, which we also feel sympathy. Then 3 options were answered. One is to focus stationary. The last one was to design mobility related reference channel. We were not able to hear/understand the second option. Could you explain/elaborate these three options again?

Regarding UE power saving of RWS-210168, slide 11 describes "Range". Is this coverage? If so, we think it may be related to the frequency used. Is the coverage independent from the used frequency? If so, why?

4 – Apple Hungary Kft.

Generally speaking, we are open to consider further UE power saving enhancements because it is very critical for end-user experience. For some power saving enhancements that are targeted for particular use cases, it is more appropriate to handle them in the corresponding WIs such as XR, RedCap, sidelink, etc. However, low-power wake-up radio is a new technique that may be investigated as a generic UE power saving enhancement.

5 – Motorola Mobility UK Ltd.

We think that UE power saving can be discussed in respective relevant WI (e.g. XR and RedCap). In particular, ultra-low power wake-up radio can be discussed under RedCap. Potential enhancement for secondary DRX group and DRX/PDCCH monitoring enhancement for UL dominant traffic can be discussed under XR.

6 – vivo Communication Technology

Similar as in Rel-17, we think UE power saving item is to study/develop power saving features commonly applicable to all UE types (e.g. non-redcap, redcap, ...), we think same principle can be applied to Rel-18 discussion as well

In RWS-210168, an SI of ultra-low power wake-up radio from UE power saving perspective is proposed. Given this is a new area. and the significant power saving gain (potentially 100 1000x times power saving for IDLE mode) and general applicability to various device types, we think a separate study item is needed for this technique.

Response to Panasonic's comments:

Ultra-low power wake-up is not limited to stationary scenario, others e.g., nomadic, low-mobility scenario is also considered. And solutions to mobility scenario can be studied in the SID.

Currently, three options can be considered to address the mobility issue when UE is monitoring AZP/VLP WUS,

- a) Option 1: no measurement, applicable for certain scenarios for example it is a stationary sensor
- b) Option 2: relaxed measurement, applicable for certain scenarios for example based on cell type, low mobility condition and so on.

c) Option 3: design new low power RS to enable simple link measurement, the measurement can be operated by this separate low power WUS receiver.

We think it is worthwhile to study it. In general it would be beneficial to consider wider application scenario as much as possible.

7 – CATT

We would like to study the low power/passive receiver for triggering UE wakeup as proposed in RWS-210168. The low power/passive receiver of UE wakeup would further minimize the UE power consumption, in particular in the scenario when UE does not have activity more than 95% of time. The low power/passive receiver of UE wakeup would not only be used for eMBB but also other vertical features, such as RedCap, IoT (in particular wearable device).

8 – Samsung Electronics Co.

For LP-WUS, some further clarifications and discussions are needed:

1. Typical use cases/traffic: Is this for RedCap UE, stationary UEs or all UE type? It is good if this LP-WUS can apply for all type of UEs and traffic. However, we think this might be more suitable for stationary UE, otherwise, how to relax measurement and ensure the reliability of WUS/paging needs to be carefully studied.

2. Is LP-WUS mainly for IDLE mode/inactive, or also can be used for active mode? We think LP-WUS might be more suitable for IDLE and potentially inactive mode. Whether this can be benefit in active mode should be further discussed. It may have low power consumption compared to power consumed as per R17 idle/inactive mode operation. However, the power consumption in idle/inactive mode operation may not be significantly contributing to total power consumption.

3. During SI phase, the power model for LP-WUS monitoring needs study, as well as the cost/size, reliability and mobility/measurement (if applicable).

4. The potential impact on the network, e.g. coexistence with legacy UEs and system overhead, need to be considered during the study.

For enhancement of DRX operation, we are open to investigate the enhancements for XR services. But, we are not convinced by the necessarily of enhancements on DCP for the secondary DRX group. In addition to WUS for DRX ON duration, the DCP also supports SCell dormancy indication that are independent from DRX group configuration.

9 – MediaTek Inc.

For R18 UE power savings topics, the following are generic evolutions that can contribute to next-level of energy efficiency enhancement for NR advanced:

-

Conditioned on whether and how serving cell measurement can be reduced, wake-up radio (WUR), as 802.11ba, can be introduced to further extend the battery life. It is noticed that WUR can also be applied to gNB power saving, similar to WIFI where UE can wake up WIFI base-stations.

-

Power saving adaptations in cell/TRP/beam-dimension as R15-R17 mainly focus on frequency-domain and time-domain power savings. There is potential to enable joint UE and network power saving.

-
Note: XR power saving can leverage R17 PDCCH monitoring reduction enhancements

For the technology development, a common workplace/item is suggested for the above generic evolutions. Scattered developments are **NOT** efficient from the following lessons learned in R16 and R17:

-
R16 2nd DRX was specified in a separated TEI, but interaction issue with other R16 power saving features remains open, requiring additional R17 (R18) work to resolve it.

-
R16 SSSG switching is developed in NR-U, but additional work in R17 UE power saving enhancements is on-going to extend it to eMBB

-
R17 REDCAP SI has dedicated power saving optimization, but REDCAP work item finally suggests to reuse legacy and R17 power saving issues.

Given the non-trivial topics and the lessons learned from R16 and R17, collecting R18 UE power saving enhancements in common workplace/item is suggested. Potential joint investigation with gNB power savings can be further discussed.

10 – Xiaomi Communications

For the power saving, it is an important area for 3GPP to investigate. So we are open to discuss all these enhancement.

Question for AZP-wakup (Maybe vivo can help us to clarify):

1) For the network and UE alignment, the answer is that UE can send a message to the network once it operates in monitoring the AZP-wakup. Do you mean the UE needs to initiate the RA to tell the network if the UE is not in connected? Our concern is that this would lead to more power consumption.

2) Our product team wants know the cost of the extra receiver. Do you have some estimated numbers in price to show this?

3) Concerns about the use cases. Technically it is better used for stationary scenario and low-speed UEs. We are afraid it is not friendly for our smart phones.

For other parts:

We are open to study other aspects, e.g., dual DRX enhancement.

11 – Nokia Corporation

In our view there is no need to have again a dedicated work or study item in UE power saving considering that specific solutions and features have already been developed in Rel-15, Rel-16 and Rel-17. Instead UE power efficiency should be one metric to follow in different work and study items together with other metrics like network energy efficiency, complexity and performance. The aim should not be to define many alternative UE power saving features, which only start fragmenting feature support in the practical deployments, devices and networks, but rather we should ensure that when deploying new features also UE and network power efficiency are well taken care of when developing new solutions and enhancements.

12 – HUAWEI TECHNOLOGIES Co. Ltd.

We share similar view as RWS-210168 that low-power wake-up radio is one important aspect to be studied for further power saving, for e.g. sensors, wearable devices and smartphones. Low-power wake-up radio for redcap power saving is also proposed in RedCap-related proposals (RWS-210007, RWS-210314, RWS-210085, RWS-210050, RWS-210504). We observed that there are some commonality between low-power wake-up radio and passive IoT (proposed in RWS-210331, 0041, 0302, 0350, 0453, 0509). Some study outcome for low-power wake-up radio can be used as reference for the study of passive IoT, and vice versa.

13 – Spreadtrum Communications

In RWS-210168, it is proposed that the VLP-WUR and AZP-WUR can be studied in R18 to further reduce the UE power consumption for low-mobility or stationary UEs. We support the proposal, and agree to study the low power wakeup receivers for different UE types, e.g. eMBB, RedCap, NB-IoT and eMTC. It can be a separate topic.

In other contributions for UE power saving, companies express the willing to further enhance UE power saving, including the leftover issues and the new enhancements. In RWS-210312, the company thinks UE power saving can be scatted across the different topics, and there is no need for a separate topic. However, we think UE power saving can be discussed in a separate topic or jointly discussed with network power saving. In our experience, if UE power saving is discussed in the other topic, the evaluation methodologies and analysis cannot be guaranteed to be like that done in UE power saving topic, and the actual power saving gain cannot be ensured. Therefore, we think UE power saving can be discussed in a separate topic or jointly discussed with network power saving.

14 – Sony Europe B.V.

Energy harvesting

There has been a lot of discussion about energy harvesting and we think that there are two different understandings of what the term means. Some companies are considering harvesting power from the incident RF energy; other companies are considering the implications of UEs operating on ambient harvested energy. We think it would be useful to make a clear distinction between these proposals.

In Monday's GTW session, vivo presented their very interesting contribution RWS-210168. In the document, the decision point between almost zero power receivers (AZP) and energy harvesting seems to be based on the assumption that energy is harvested based on incident RF energy. If we harvested ambient energy (such as solar, vibration etc) and made some protocol enhancements, might energy harvesting look more promising than almost zero power receivers (AZP)?

Feedback Form 10: Answers/Comments

1 – Futurewei Technologies

After 2 releases of dedicated UE power saving work, further dedicated work needs good justification. Low power WUS may be a direction that worth the effort as it has the potential for power saving gain on top of pre-Rel-18 features while at the same time has significant amount of standards impacts. And it should be studied first before nominal work.

2 – Verizon UK Ltd

Comment: It is true that many Rel-16 power saving features have yet seen the field. Part of the reasons are

the heavy product/product inter-operability dependency and the difficulties in field testing and deployment. Nonetheless, we are still supportive of continued power saving effort, in hope to find something better because UE power consumption is such a critical issue. For this reason, we think LP-WUS at least worth a look. We also agree with Vivo et. al, that it is better to be a generic feature targeting wider user cases and UE types.

3 – vivo Communication Technology

Thanks a lot for companies interest to our proposal (RWS-210168/169) about ultra-low-power wake-up signal.

We have following answers:

Answers to #4(Apple), #7(CATT), #12(Huawei), #13(Spreadtrum), Round2#2 (Verizon)

We share the same view that the low power wake-up receiver can be used for all type of UEs and consider it as general enhancement.

Answers to #3 (Panasonic),

(1) For motility□

Ultra-low power wake-up is not limited to stationary scenario, rather we would like to study more use caes including nomadic, low-mobility scenario is also considered. And solutions to mobility scenario can be studied in the SID.

Currently, three options can be considered to address the mobility issue when UE is monitoring AZP/VLP
-Option 1: no measurement, applicable for certain scenarios for example it is a stationary sensor

-Option 2: relaxed measurement, applicable for certain scenarios for example based on cell type, low mobility condition and so on.

-Option 3: design new low power RS to enable simple link measurement, the measurement can be operated by this separate low power WUS receiver.

We think it is worthwhile to study it. In general, it would be beneficial to consider wider application scenario as much as possible.

(2) Yes, the ‘range’ here means the coverage. And it is dependent to the used frequency. The number here is roughly estimated based on some typical frequency values, such as 900MHz and 2GHz. It is derived from receiver sensitivity. The receiver sensitivity differs among step 1/2/3. The distance for each can be calculated from sensitivity by using the same pathloss formula assuming same frequency.

Answers to #8 (Samsung),

(1) We agree to investigate a unified ultra-low-power wake-up mechanism applicable for all UE types rather than restricted to REDCAP UE. In general, ultra-low-power wake-up may not be beneficial for high mobility scenario as measurement may have to be updated frequently, while for scenarios with limited mobility, we think it is worthwhile to study it. In general, it would be beneficial to consider wider application scenario as much as possible.

(2) This ultra-low power wake-up signal/receiver is mainly proposed for reducing power consumption in idle/inactive state. We are open for connected mode if use cases are clearly identified. For example, a less power consumption wake-up receiver in connected mode compared to PDCCH monitoring can be used, such that connected mode power consumption can be further reduced.

(3) Agree with Samsung that power model, cost/size, reliability and mobility/measurement need to be addressed in the study item.

(4) Yes, coexistence with the legacy signal/channels is important aspects need to be addressed.

Answers to #10 (Xiaomi),

(1) gNB and UE alignment on the usage of AZP receiver is to avoid UE miss wake-up, since NW knows the UE status and can transmit the wake-up signal or paging correspondingly. We believe the typical use case should be that the state transmission is infrequent.

(2) The chipset cost can be estimated based on the die size. From literature, the size of such envelope detection receiver based on 65nm CMOS can be designed as small as 1mm * 1mm. And it is expected that the cost increase is marginal for such a small die size. We can further discuss the cost in the study item.

(3) Smart phones, wearables and sensors when stay in stationary or low-speed can make use of the AZP wake-up receiver. So it is friendly to all type of UEs but could have more benefit for some scenarios.

Answers to #14 (Sony),

Agree with Sony's observation on energy harvesting. The energy harvesting can be categorized as follows,

Alt 1: harvesting power from the RF energy

Alt 2: harvested energy from ambient energy (such as solar, vibration etc)

Furthermore, AZP wake-up is a power saving feature, therefore can work irrespective the energy harvesting methods.

Specifically, alt 2 does not need 3GPP to define any specification on how the UE harvesting energy. For our initial proposed power consumption target for AZP wake-up receiver, e.g., 100uW, many ambient energy harvesting approaches, such as solar and vibration can satisfy under certain conditions.

Therefore, the AZP wake-up receiver can work based on Alt 2 energy harvesting.

4 – Guangdong OPPO Mobile Telecom.

Reply to Huawei's comment:

Regarding comments about the commonality of Zero-power IOT with outside power sourcing and power saving signal, it seems too earlier to draw conclusion that they share the common parts. The difference is one is for UE to have no energy supply inside and the other is to save its internal energy. In our contribution 0041 mentioned by Huawei, the consideration more for the requirement side. So, they may not naturally in same study.

5 – Sony Europe B.V.

#2 (Ericsson). While we agree that many power saving features have been specified in previous releases, we think that those features have not addressed the case of power saving combined with low latency. We think that power saving with low latency is addressed to a large extent by support for almost zero power receivers (AZP) and energy harvesting.

#6 (vivo). We think that we would generally need to consider the implications of LP-WUS on mobility. The options that you have provided in response to Panasonic are interesting. We would also add transmission of UL mobility signals. While this may appear counterintuitive, it may be better to spend energy transmitting a signal in the UL for a short time rather than listening to the DL for a long time. Mobility is basically one of the aspects that should be studied and we do not want to downscope that study at this stage.

#8 (Samsung). We think that LP-WUS can be used for all types of UE and traffic. On (2), we think that the power saving gains for LP-WUS are more applicable to IDLE mode

Response to vivo answer (#3)

How the energy is harvested from solar, vibration etc is not in the scope of 3GPP. That has always been clear to us. The issue with UEs that rely on such harvested energy is that they have low amounts of energy available that are intermittently available and will be replenished. This has protocol implications, as also observed by other companies, including Ericsson. For such a device, the network would not want to engage in a long connection with the UE and the UE would have to transmit in a power efficient way, possible with reduced power.

6 – MediaTek Inc.

Thanks for the good discussion. In promoting and landing UE power saving features to real deployments, we see challenges of IODT tests with efforts dramatically increased with number of power saving features. In this regard, unified power saving features applicable to **wide UE types and use cases**, and **both UE and gNB power savings** are strongly recommended as the target for Rel-18 power saving enhancements. WUR (as 802.11ba) and spatial/cell-domain power saving adaptations are two possible candidates we suggest to investigate in Rel-18.

5.2 Extending up to 114 GHz

This section is targeted at identifying commonalities and interactions for Extending NR operation up to 114 GHz.

Feedback Form 11: Questions/Comments

1 – NTT DOCOMO INC.

On 52.6-71GHz enhancement, we understand that some proposals come from Rel-17 objectives which might be leftovers, while some others seem new topics. The former ones (i.e., potential Rel-17 leftovers) may be difficult to be identified further here at this stage since Rel-17 WI is now on-going. The latter ones (i.e., potential topics not included in Rel-17 WI scope) might be worthwhile to discuss here to identify where companies stand regarding such new topics.

On beyond 71 GHz, we think the views/proposals shared by companies so far would have a good alignment somehow, especially from technical perspective. It looks like majority believe at least some fundamental aspects, e.g., waveform, RF models, channel models, etc, would be needed to unlock this band. Perhaps one question which could be good to solve here would be when to unlock beyond 71 GHz spectrum in 3GPP. We feel it could be a good approach to form a common understanding on the urgency to specify this band in 3GPP in a bit more detail.

Another point may be the relationship between technical topics and targeted frequency band. For example, beam management related enhancements, which were proposed in the tdocs by some companies, can be seen as "an enhancements for 52.6-71GHz", "a new functionality for beyond 71GHz", or both thereof. It might also be good to observe further which technical topics could be needed for which band a bit more.

2 – TELECOM ITALIA S.p.A.

Is there any market demand for solutions above 71 GHz? This topic will likely require a lot of 3GPP resources with benefits to be understood

3 – Charter Communications

A new waveform may be introduced for frequencies up to 114 GHz. However, Intel is proposing a general waveform study for 52.6-114 GHz in 0366. How would a new waveform coexist with the Rel-17 waveform in 52.6-71 GHz? Is it assumed that the network would time-division multiplex legacy and new UEs?

4 – ZTE Corporation

We are open for the study of waveform for >71GHz. We also share the view that the use case and urgency of the normative work can be further discussed, as some companies mentioned during the clarification phase.

5 – Futurewei Technologies

Overall, we'd like to understand the urgency to work in R18 on support of beyond 71 GHz band. Note that the work of support 52.6 – 71 GHz is still ongoing in Rel-17 with much challenges to finish on time and likely needs some further work. It is also expected to be very controversial to introduce new WF in NR to support this band if it is not a simple extension of 52.6 – 71 GHz band.

6 – Apple Hungary Kft.

7 – vivo Communication Technology

For more efficient discussion, we think it would be good to further split the discussion into two parts

- 1) Enhancements to NR between 52.6GHz 71GHz
- 2) Study of NR beyond 71GHz

8 – Motorola Mobility Germany GmbH

For B52.6-71GHz enhancements, proposals have indicated that potential leftovers from Rel-17 will need to be handled in Rel-18. Although, the work is still on-going and it will become clear only at the end of year, but companies foresee topics such as receiver assisted LBT, directional LBT and potentially others might not be fully specified in Rel-17. Some companies have also indicated new areas of enhancements that are not within the scope of ongoing WI. One such topic being coverage enhancement for NR operation from 52.6-71GHz. Additionally, some companies have indicated URLLC operation in NR unlicensed bands at 60GHz.

In our view, we should discuss and identify the need to have a WI on enhancements for NR operation between 52.6-71GHz. Regarding the leftover items, we'll still need to monitor the progress in Rel-17. However, we should at least try to identify new enhancements. We should consider at least:

- Coverage Enhancement aspects in this FR
- Beam-management enhancements considering larger number of beams
- Further channel Access enhancements in 60GHz

For extension of NR operation from 71-114.25GHz, several proposals identify the need to extend the NR operation from 71-114.25GHz including new waveform study. However, the contention point is on whether there is an immediate need to consider this extension in Rel-18. Some companies have pointed out that this is essential to support ultra-wideband operation in licensed bands and provide better support for the identified use cases. Essential aspects under this topic include new waveform (including DFT-s-OFDM for DL) analysis, identifying new PN models, antenna models, etc.

In our view, we should discuss and identify the applicable scenarios/use cases and the potential band/frequency/spectrum that can be used for 3GPP beyond 71GHz. Based on this, discussion on the timeline for introducing the SI for NR extension beyond 71GHz should be considered. In terms of technical aspects, companies seem to have similar views to consider following items as a good starting point:

-
Identifying evaluation methodology including PN models, antenna models, PA model, channel models and potential performance metrics.

-
New waveform study (including DFT-s-OFDM for DL)

9 – CATT

From the contributions, we observed there are mainly two aspects of potential interest in this area. One is further enhancement for 52.6 71GHz, the other is the study of beyond 71GHz. First of all, we would prefer a progress approach where at any time only one WI or SI is conducted. Then for specific aspect, regarding further enhancement of 52.6 71GHz, currently there are only two contributions. The proposals are good starting point, but we still need further discussion to reach consensus within the group. For beyond 71GHz study, we believe this is needed at certain time. However, we also need to consider the overall situation, and the timeframe of Rel-18. Therefore the priority and timeframe of this study item need further discussion.

10 – Samsung Electronics Co.

In our understanding, the topic of extending NR to 114 GHz has two sub-issues: 1) Enhancement to Rel-17 work on extending NR to 71 GHz; 2) New study on waveform for up to 114 GHz.

For the first sub-issue, at this moment, it seems hard to make a judgement on the necessity of enhancement to Rel-17 work on extending NR to 71 GHz, since the work is still on-going.

For the second sub-issue, the urgency of the study should be investigated and justified first, before discussing the details of the scope for study.

11 – Guangdong OPPO Mobile Telecom.

We have some question for the work on extendign up to 114GHz.

Q1: High frequency includes FR2.2 and above 71GHz up to 114GHz (use FRx to indicate it just for convenience). How to arrange the work of FR2.2 and FRx in Rel-18? Separate WI/SI for for FR2.2 and FRx, or a joint WI/SI for them, or only focus on one of them in R18?

Q2: For FR2.2 enhancement, some contributions mentioned the coverage enhancement and power consumption enhancements. They are intersting proposals. We would like to know what the potential enhancement direction in mind? Would some propopnents like to clarify the potential enhancements for these two aspects.

Q3: For FR2.2 enhancement, beam management enhancement was proposed by several companies, we would like to know what are the enhancement aspects to address what issues?

Q4: For FR2.2 enhancement, higher order QAM or non-uniform constellation was proposed, we understand that the higher order QAM is mainly to boost the throughput but what the motivation is for non-uniform constellation is not very clear to us.

12 – LG Electronics Inc.

As several companies already commented, study/work scope for NR extending up to 114 GHz can be divided into two parts: one is the enhancements for Rel-17 52.6-71 GHz WI and the other is introducing new frequency band from 71 GHz to 114 GHz. For the former one, we don't have a strong opinion for its necessity but it is highly dependent on the progress of Rel-17 WI. So, it would be preferable to judge its necessity after 3Q21'. For the latter one, waveform study including legacy waveforms (e.g., DFT-s-OFDM) should be the good starting point but its priority can be determined by considering operator's needs and other potential study/work items.

13 – Spreadtrum Communications

These contributions mainly proposed two issues, one is the leftovers of Rel-17 52.6-71GHz, and the other is the study of new waveform for above 71GHz.

We are interesting in continuing to study the leftovers of Rel-17 52.6-71GHz in Rel-18. However, the scope of 52.6-71GHz has been discussed at the last plenary meeting, and there are not many conclusions on reducing the scope. Companies believe that it is too early to narrow down the scope of 52.6-71GHz, considering that the WI is ongoing in RAN1. For the same reason, it is early to discuss the details of the leftovers of Rel-17 52.6-71GHz.

An important reason for the introduction of the 52.6-71GHz WI in Rel-17 is that 60GHz frequency band has great commercial demand and there are other technologies competing in this frequency band. However for above 71GHz, we are wondering whether there is an urgent commercial demand in this frequency band.

14 – Huawei Tech.(UK) Co.. Ltd

Our understanding of the proposals addressing frequencies up to 114 GHz is that they are targeting at longer-term support, e.g. starting with only investigations on waveform and numerology at first in Rel-18, and potentially revisiting some channel modeling aspects. We think the targeted frequency bands and deployment scenarios should be further discussed for better scoping such potential study. Our understanding is that most of the bands between 71 GHz and 114 GHz available for IMT are limited to fixed services, while some bands are already available for mobile services and perhaps in the future more bands will be available for mobile services. Thus a study on waveform and numerology should be targeting for both fixed services and mobile services.

Regarding leftovers from Rel-17 NR extension to 52.6-71 GHz, while such leftovers would need to be further checked in December 2021, we currently don't see any critical leftover beyond what is already in the scope of Rel-17 at least in terms of physical and higher layers. For smartphones and IoT, we think that we should first let the market develop based on Rel-17 before considering further enhancements for 52.6-71 GHz. If enhancements for 52.6-71 GHz are considered for Rel-18, then priority could be given to coverage.

15 – Ericsson LM

In our view, Rel-18 timeframe is too early for potential discussions on FR up to 114 GHz. A better timeframe would be 6G when the 3GPP technology has become more mature.

Feedback Form 12: Answers/Comments

1 – Intel

General response to comments from following companies (NTT Docomo, Telecom Italia, ZTE, Futurewei, vivo, Motorola, CATT, Samsung, LG Electronics, Spreadtrum, Huawei, Ericsson):

From Intel's perspective the waveform study for high carrier frequency is similar to ML/AI or full duplex study in that it is an investment of resources for future specification development. Especially for waveform development, if new waveform is found to be beneficial to be introduced there are still several aspects that require study on how to adapt and apply to existing NR features (let alone determine which frequencies it should apply to). The study could also serve as useful input to 6G studies in the future. So, we think it is important to start the study as early as possible.

In terms of waiting for market development or finding urgency, there is no good way to objectively assess this. Ultimately, approval of SI/WI (for any items) is based on interest levels of individual companies. The whole point of the specification is to have a system defined so that it can be used for development and deployment in the future. Beyond 52GHz work and study from Intel's opinion is no different. For Intel perspective, we do have strong interest for above 52GHz band, and think it would be valuable for current and future deployments of NR.

Response to Charter:

We expect the waveform SI should include any potential impact with coexistence with existing NR operations/features. Based on the outcome of the SI, 3GPP can decide what the next step should be (including whether new waveforms should be applied to 52-71GHz band and such).

Responses to Apple:

For the continuation of enhancement for 52-71GHz, we believe there are areas that we think will be useful for enhancements beyond what will be leftovers from Rel-17. For example, supporting of positioning, optimization for fixed wireless scenarios, coverage enhancements, higher peak throughput, improved energy efficiency, etc. None of the features/cases mentioned are covered by the Rel-17 WI. On top of this, we can consider additional aspects that are leftovers from Rel-17 based on what progress is made for Rel-17.

For positioning, IAB, V2X/ITS vertical area support in above 52.6GHz, we are open for discussion on how the work will be categorized, either packaged together under enhancements for 52-71GHz or separately in each WI domain. We believe this may depend on whether there are separate WI for each of positioning, V2X, and IAB.

For beam management enhancements, as Apple mentioned we believe there is likely benefits to consider LBT optimization for beam management (given that Rel-17 beam management is mainly focusing on timeline aspects), fixed wireless deployments, and supporting even larger arrays than nominally considered for existing FR2.

We also agree with Apple that there may be some RAN2 aspects that may be considered to improve RTT compared to what is being considered for Rel-17.

Responses to OPPO:

For the merging of the SI for FRx and WI for FR2-2, we think merging these two might not be good idea. Simply because one is for study and other is targeted for WI. It would complicate the overall work. Also, the interest level for companies could be different. So, we suggest discussing them somewhat separately.

For coverage enhancement, power consumption, beam management aspects, while detail scope requires further refinement and discussion, we provide some thoughts in our responses in [RAN-R18-WS-eMBB-Intel] NWM document.

For consideration of non-uniform constellation, this was just an example and further discussion is needed on whether this should be part of the WI scope. With this said, from our understanding the required SNR

operating point with using non-uniform constellation can be lower compared to traditional QAM constellation. Therefore, this improvement could be used to either relax the EVM requirement and/or to keep the existing EVM requirement and improve throughput performance. Given that RF implementation is quite challenging for higher carrier frequency, any improvements to provide better implementation margin in RF is quite interesting and worth further investigation.

2 – Motorola Mobility Germany GmbH

General comment to all companies

We tend to have similar views as Intel on both the areas related to further enhancement for NR operation from 52.6-71GHz and extension of NR operation beyond 71GHz including waveform study

NR Beyond 71GHz

Some companies have raised the question about the immediate market need on extending NR operation beyond 71GHz. With ultra-wideband licensed bands in this FR, we see at least a strong motivation for fixed wireless access use cases. However, in terms of timeline, we believe that a good amount of time is needed to study the waveform (including determination of evaluation methodology) and potential necessary changes. We would expect this SI to last in Rel-18 entirety and any normative work might happen only in Rel-19. But, if we further delay this SI to Rel-19, then normative work could possibly end up in Rel-20. In the long term, we also see this area as a strong pre-cursor to evolution towards 6G as well. Therefore, in our view, it is the right time to start a SI in Rel-18 with focus on waveform study and potential specification changes.

B52.6 Enhancements

For further enhancements on beyond 52.6GHz, we tend to agree that it might not be possible to fully realize the leftovers from Rel-17 at this point. However, there are some new aspects that have not been considered in Rel-17 including coverage enhancement, further beam-management enhancement with larger number of narrower beams, URLLC operation in 60GHz unlicensed bands, etc. In our view, we should discuss at least the new aspects for the potential WI on further enhancements for beyond 52.6GHz in Rel-18.

5.3 CA/DC enhancements

This section is targeted at identifying commonalities and interactions for CA/DC enhancements.

Feedback Form 13: Questions/Comments

1 – Apple Hungary Kft.

Regarding the scenarios described by RWS-210143 - Multi Radio Multi Connectivity for Rel-18, the requirement of an operator with several chunks of spectrum to use this BW for NR, can partly be solved by CA with timing of inter-frequency CA.

We would like to know if this is not practical for the same operator. While having Multi-DC on different chunks of spectrum does solve the non-ideal backhaul, it brings in additional complexity of having separate RLC/MAC/PHY, while the intention was to just use the separate segments of spectrum. This actually leads to the requirement from Charter (RWS-210210) and is probably easier in terms of spec impact as well as implementation impact. Would like to request company views on this.

We can also think in the direction of async CA (no slot/frame alignment) which is an intermediate between CA and DC, but this also has some complications.

2 – Nokia Corporation

We see that number of companies have indicated need for further protocol and RAN4 requirement enhancements on CA/DC. In our view protocol and requirement enhancements would form good basis for the scope of Rel-18 CA/DC enhancements and would provide fast mean for practical deployment related improvements.

3 – Ericsson LM

Regarding the discussions on Multi-connectivity (i.e. DC with more than two cell groups): Typically, all frequencies in all nodes provide best performance/capacity. However, it may be so that e.g. a pico-layer uses a different set of frequencies than the macro-layer. Are we here anyway assuming a deployment scenario where different picos use different frequencies? If all picos use the same frequencies also single-connectivity UEs benefit since they can do Carrier Aggregation between all the frequencies.

Do we assume that for Multi-Connectivity with three cell groups, there will be three uplinks, or will this be solved by some other enhancement?

4 – ZTE Corporation

CADC enhancements are key to unlocking the opportunities for the operators to exploit a wider range of spectrum that will be available. Based on the company inputs, we have noted that FR2 is a key target area for CADC enhancements as mentioned by a number of companies and the following broad objectives seem to be the target areas that companies have in mind:

- robustness improvements
- interruption reduction
- fast failure detection and recovery

Multi-connectivity with selective activation seems to be popular solution among companies and we think this is a good area to pursue whilst keeping UE complexity low (e.g. limiting number of active CGs to a low number).

With respect to other areas, we have a few comments:

For the LTE/WLAN aggregation, we are wondering whether and how to ensure the QoS in WLAN branch, and whether some enhancement will be required in WLAN to enable this? For example, some L2 measurement has been introduced in NR to measure the latency (e.g. Average over-the-air interface packet delay), and whether similar L2 measurement should be supported in WLAN as well. Since the RAN based LTE/WLAN aggregation will be transparent to CN, and the aggregated WLAN branch will be considered as part of NG-RAN from CN perspective, we hope the WLAN can achieve similar QoS requirement to ensure the consistency of user experience in NG-RAN.

Fast role change in CA/DC (e.g. role change between MN and SN, and between SpCell and SCell) can be used to improve the robustness. Considering this can also be used to reduce the mobility interruption time (e.g. Multiple cell groups can be configured with selective activation, and the stored cell group can be activated as either MCG or SCG with fast role change operation), we think it can be considered as one alternative to L1/L2 triggered CHO, and we are wondering in which section such feature should be discussed, in CA/DC enhancement or in mobility enhancement?

5 – MediaTek Inc.

Regarding multi-connectivity:

-
Capacity improvement target can be achieved by 2 legs/CGs with CA, and load balance across different SNs can be improved by fast SN switching. Supporting simultaneous 3 or more legs/CGs seems not necessary, and we have strong concern on the significant UE complexity increment for 3 or more active legs/CGs.

-
Service continuity target should not be restricted to SN. We suggest to develop fast SN switching as part of R18 generic mobility enhancement that can cover both MN and SN and combine the design of fast inter-cell beam switching, as suggested in RWS-210105.

-
Reliability and latency improvements for existing DC framework is suggested to effectively support new use cases of low-latency eMBB. In particular, split bearer enhancements for DL and UL (as suggested in RWS-210094 and RWS-210234) are recommended.

Jointly considering the CA cross-carrier enhancement demand in flexible spectrum fusing, generic item of further DC/CA enhancements in R18 is therefore suggested.

6 – vivo Communication Technology

The boundary between 5.3 CA/DC enhancements and 5.4 flexible spectrum fusing is a bit unclear, would be necessary to define the scope clearly to facilitate future discussion.

7 – CATT

In general we support CA/DC enhancements in Rel-18.

1) we are open to discuss potential CA/DC enhancement based on eDCCA work in Rel-17. It would be good to first discuss on motivations and use cases for further DCCA enhancements.

2) We support MRMC discussions in Rel-18. There are two aspects, i.e., a) the number of configured/active 'legs', and b) how to switch between configured legs if supported. We observe already some initial discussions among companies and we are open to continue. As a starting point maybe the summary in RWS-210517 can be a reference.

8 – HuaWei Technologies Co.

There is wide interest on supporting multiple SNs(>2) and dynamic switch/selection among multiple SCGs (0004, 0138/0140, 0143, 0165, 0183, 0192, 0227, 0234, 0401, 0467), some of them also mentioned dynamic switch/selection among carriers. We are interested on this as well. It may need further clarification that irrespective whether it is dynamic switch/selection among >2 SCGs or carriers, how many activated SCGs/carriers can be considered by the UE at the same time, as this would have different impacts on UE capability requirement. This seems also relevant to mobility discussion as other companies commented.

For 0094, 0165, 0258, we think they are relevant to flexible spectrum integration and we provide our comments there. For 0276 and 0457 we see discussion takes place in UL enhancements and DL MIMO. Other proposals for higher layers seem diverging with very few companies proposing, and we are not convinced whether there are sufficient gains for these proposals and better the proponents can provide more detailed analysis.

9 – China Telecommunication Corp.

Generally, we think CA/DC enhancements is one of the essential topics for Rel-18, which can provide operators with more effective network control.

As network operator, we notice that more 5G frequency bands will be unlocked and bring wider bandwidth, higher throughput and larger capacity for the users. To make better use of spectrum resources and meet the requirements of new services are our major motivations for future network deployment. In order to support higher bandwidth and capacity requirements, we are more interested in extending MR-DC to MR-MC (>2 legs), which is also proposed in many company contributions. Besides that, we think MR-MC can also help guarantee the service continuity and low latency in mobility scenarios.

According to the 2 round pre-meeting email discussion, many companies showed their interests in or supported multi-SN connectivity. Considering the UE implementation complexity and RF capability limitation, we suggest first discuss the limitation of simultaneous UL transmissions and DL receptions and potential solutions, such as fast SCG activation and UL selective activation raised in several company contributions and also in the previous email discussion. Besides, from our point of view, other objectives including bearer management, UE capability management, measurement aspects can also be further discussed.

For NR-WLAN aggregation, we are considering further using WLAN networks to increase hotspot throughput and provide supplementary coverage for weak coverage areas. With the development of Wi-Fi 6 (i.e. IEEE 802.11.ax), WLAN is still expected to be widely deployed by operators/vertical industry enterprise. WLAN industry chain is more mature and has a large number of commercial terminals or equipment, which have lower cost and are easier to deploy. Therefore, we suggest to further study NR-WLAN interworking at RAN level to provide Ubiquitous Connection for network users in the future.

10 – Guangdong OPPO Mobile Telecom.

Based on our review on DCCA related contributions, most companies have interest on the multiple SCGs (i.e. more than one SCG). From high data rate requirement and more flexible SCG management, we also see the benefit to support more than one SCG in R18.

-

Question for more than one SCG: Whether it is also for mobility performance improvement, e.g. there is only one activate SCG at a time and the SCG activation/deactivation can be performed dynamically?

-

Question for SRS on dormant BWP: SRS is not supported on dormant BWP in R17 and one deactivation SCG. If we support it in dormant BWP, whether it is also for SCG deactivation case?

11 – Xiaomi Communications

For the DC/CA enhancement, it is an important area for 3GPP to investigate to improve capacity.

For the MR DC enhancements (>2 legs), in order to decrease the UE complexity, we think it is better the maximum number of active cell groups should be up to two cell groups for both downlink and uplink. Otherwise, if we have 3 legs for downlink and 2 legs for uplink, we need to consider PUCCH forwarding between SNs.

For other enhancement, e.g., Early measurements, L1/L2 signaling for activating/switching CG, anchor carrier etc, we are open to discuss all these enhancements.

12 – Samsung Electronics Co.

We understand MR-DC with more than two cell groups will bring two major benefits to operators: (1) peak throughput enhancement by aggregation of multiple gNBs/DUs/FRs/RATs, (2) mobility enhancement by fast switching of nodes. However, more than two uplink transmissions may have uplink power shortage. Thus, the enhancements should be based on the current assumption of at most two uplinks at the same time. On the contrary, downlink does not have any UE power problem, so more than two active cell groups can be fine to increase the throughput. We saw a number of companies fully or partially agreed the motivations (183, 140, 143, 165, 004, 227, 283, 327, 401, 436, 464).

13 – Lenovo (Beijing) Ltd

-

Regarding multi-carrier scheduling for CA enhancement, as observed by many companies, clear benefit on signaling overhead reduction can be achieved. Actually, this is an evolution of Rel-17 two-cell scheduling via a single DCI. We support a thorough study in Rel-18 with extension to more than 2 carriers in FR1/FR2 and for scheduling in both DL and UL. Meanwhile, in order to maintain a reasonable DCI payload size, we think the two-stage DCI can be a good starting point as two-stage SCI specified in Rel-16 V2X.

-

Regarding fast SCG switch, possible Rel-18 L1/L2 mobility conclusion (e.g. intra-DU) could be reused as much as possible for R18 fast SCG switch/(de)activation. Possible solutions to achieve fast SCG switch/(de)activation inter-DU or inter-CU can be discussed as long as the overall latency is reduced compared to legacy inter-DU or inter-CU SCG change. For the scenario raised by some companies, e.g. 2 UL and 3 DL at the same time, it could be beneficial to clarify if that means 2 activated SCG?

Feedback Form 14: Answers/Comments

1 – LG Uplus

We are interested in fast UL switching for CA. We need to study how to maintain UL synchronization and to manage SCells engaged with CA by which criteria.

2 – Samsung Electronics Co.

Comment to #1

Since DC assumes non-ideal backhaul between nodes, we think Multi-Connectivity is an easier extension to add a new node of different FR without changing network requirement. It's true that operators have multiple available spectrum bands and it is not practical to aggregate them as one network node (e.g. for non-co-located DUs). We see the current DC limits not only implementation but also deployment scenario in the current situation.

Comment to #3

The scenario would be different. If an operator wants to maximize throughput by aggregation of more than three nodes, a typical scenario could be a different set of frequencies of picos, e.g. FR1+FR2+>52GHz. If an operator wants to enhance mobility performance, picos would use the same frequency. We think the current CA does not benefit for mobility, because only one UL cell can be configured when dual-

connectivity is configured, e.g. LTE+NR DC. When the SpCell is broken, whole CG may not be used anymore.

Samsung thinks for multi-connectivity with three cell groups, three uplink may be configured but at most two uplink cells can be active at a given time by considering UE's two UL transmitters. Such enhancement needs to be discussed in WG level but we think total spec impact should be minimized.

Comment to #5

Our motivation of MR-MC is that CA cannot be used for capacity improvement due to the following reasons: (1) Each DU may not have its dedicated uplink (at least PUCCH), so UL forwarding is needed for both control information and user packets. In this case, an ideal backhaul between two DUs with different FRs shall be guaranteed. It is not always possible and moreover cost ineffective from operator perspectives (2) One single PUCCH for CA with different FRs of different SCS e.g. FR1+FR2 CA will make HARQ process stalling issues due to difference of slot duration.

We also think UE implementation impact should be minimized. From UE perspectives, asynchronous CAs with 3 cells and MC with 3 cells will not be much difference. In that sense, MC will not bring significant complexity to UE side.

Comment to #10

Yes, we see the fast SCG switching among more than one SCG can be used for mobility purpose to reduce interruption.

3 – China Telecommunication Corp.

Generally, we think CA/DC enhancements is one of the essential topics for Rel-18, and we want to clarify following issues based on the Phase1 email-discussion.

Answer to #1 Apple Hungary Kft.

Regarding *whether inter-frequency CA can partly solve the scenarios described in RWS-210143*, we think probably not. In the actual network deployment, 5G gNBs are constructed phase by phase. Considering the 4G frequency refarming in the future, the former deployed eNBs/ gNBs might not be able to co-locate with the gNBs deployed later. If it is hard to deploy ideal backhaul, CA might not solve the capacity issue.

Regarding *the intention of MR-MC*, we actually more focus on further increase capacity and guarantee mobility service continuity by means of better using spectrum of different frequency bands including FR1 and FR2, as well as high and low frequency hybrid network deployment scenarios in the future. Regarding how to better use the fragment of spectrum, we share similar views in our contribution RWS-210147 to study flexible spectrum fusing in Rel-18.

Answer to #3 Ericsson LM

Q: Do we assume that for Multi-Connectivity with three cell groups, there will be three uplinks, or will this be solved by some other enhancement?

A: Considering the UE implementation complexity and RF capability limitation, we think having at most 2 simultaneous UL transmissions would be more feasible in Rel-18. Regarding the number of cell groups,

we think we can have more than one SCG configured (at least 2 SCG configured), and activate/ deactivate an SCG among the configured SCGs dynamically based on certain criterions.

Answer to #4 ZTE Corporation

Q: For the LTE/WLAN aggregation, we are wondering whether and how to ensure the QoS in WLAN branch, and whether some enhancement will be required in WLAN to enable this?

A: Generally, we think NR-WLAN aggregation at RAN level can achieve common radio resource control and management. We can consider how to ensure the QoS requirements from RAN level. Whether some enhancement will be required in WLAN may need further study or discussion.

Answer to #10 Guangdong OPPO Mobile Telecom.

Q: Whether it is also for mobility performance improvement, e.g. there is only one activate SCG at a time and the SCG activation/deactivation can be performed dynamically?

A: In our opinion, the answer is YES. We think MR-MC can also help guarantee the service continuity and low latency in mobility scenarios.

Answer to #13 Lenovo (Beijing) Ltd

Q: For the scenario raised by some companies, e.g. 2 UL and 3 DL at the same time, it could be beneficial to clarify if that means 2 activated SCG?

A: In our opinion, having at most 2 simultaneous UL transmissions would be more feasible in Rel-18. For the DL receptions, we are open to further extension to 3 legs. Regarding whether 2 UL and 3 DL at the same time means 2 activated SCG, we think we can have further discussion later.

4 – HuaWei Technologies Co.

Regarding UL limitation raised by several companies, we think "2 activated" could be realistic for Rel-18. As long as there is multi-carrier deployment, such limitation exists while the downlink has no such limitation. So we think such UL limitation needs to be addressed for multi-carrier case, and this may be better discussed in UL enhancements or mobility.

5 – ZTE Corporation

Answers to #1 (Apple Hungary Kft.)

From our point of view, the intention of Multi connectivity is not only to aggregate chunks of spectrum but also to provide better robustness, especially for FR2. With multiple configured connectivity, a fast switch mechanism among configured connectivity can be enabled, with which the NW can switch UE to connectivity with better quality in a more efficient and dynamic way, in case the radio condition in serving connectivity turns bad sharply (e.g. due to the blockage) .

Answers to #3 (Ericsson)

We think Multi-connectivity can bring benefit to both scenarios where different picos use the same or different frequency. As many companies mentioned in the paper, the Multi-connectivity can be used to improve the robustness, especially for FR2. For example, UE may detect multiple pico around itself using the same frequency , and NW can configure the picos detected to UE as Multi-connectivity, especially for picos (DU) controlled by the same CU. Once the radio condition of serving pico turn bad sharply, the NW can switch the connection to another pico in a more efficient and dynamic manner based on the framework of Multi-connectivity.

Multi-connectivity with selective activation (i.e. more than two cell groups can be configured but only two of them can be activated simultaneously) seems to be popular solution among companies and we think this is a good area to pursue whilst keeping UE complexity low.

Although the fast role change in CA/DC (e.g. role change between SpCell and SCell, and role change between MCG and SCG) can be used to reduce the interruption in mobility as well, considering this is mainly about CA/DC operation and the similar issue has been discussed before in CA/DC aspect, we have slight preference to discuss the fast role change in the email thread for CA/DC enhancement.

Answers to #10 (Oppo)

For the question “Whether it is also for mobility performance improvement”, We think it can be used to improve the interruption time for SCG change.

For the SRS for deactivated SCG, from our point of view, the main intention is to support SRS in dormant BWP. But we think it can also be used for SCG deactivation case to accelerate the SCG activation, especially during the period when TAT is still running.

6 – MediaTek Inc.

Thanks for the good discussion. While we support enhancing NR capacity across CA/DC domain, enhancements should be carefully identified considering minimum UE complexity increment; otherwise a feature without the support of cost-effective UEs may easily encounter limited popularity.

For capacity enhancement, we would like to remind a CG can already include multiple frequency ranges. Even within a given frequency range, there can aggregate quite a few carriers (e.g. in FR2), which is sufficient for a UE to run any data heavy service (e.g. XR). Larger system capacity can be achieved by properly distributing UEs in different SNs without requiring each UE to simultaneously connect to multiple SNs. In this regard, fast SN switching that can be enabled via mobility enhancement looks a better way forward than multiple SNs, at least from UE perspective.

5.4 Flexible spectrum fusing

This section is targeted at identifying commonalities and interactions for Flexible spectrum fusing.

Feedback Form 15: Questions/Comments

1 – Nokia Corporation

It is somewhat unclear why the logical paradigm shift away from individual spectrum blocks managed as cells and aggregated together with the CA framework to individual spectrum blocks aggregated together as one multi-band cell is in itself offering some benefits. That is, it would be important to understand what cannot be realized with the existing CA framework.

Hence we should identify and detail each expected benefit from the number of approaches suggested and study if the targets should be adopted on the CA/DC enhancement work rather than working for potential introduction of a new logical concept for aggregating individual spectrum blocks when CA framework was introduced specifically for this purpose.

2 – Futurewei Technologies

We understand the motivation of the related proposals and support to efficiently utilize these spectrum

blocks. However, some clarification is needed first on the relationship between things like bands, carriers, BWPs, and cells. Is the proposal to define signal cell (RAN2 focused) or single carrier (RAN1/4 focused) over multiple bands? Shouldn't we consider first much simpler solution by extending the CA framework instead of dramatically change the existing design of cell/carrier?

3 – Panasonic Corporation

Regarding the slide 2 of RWS-210210, it shows the channel allocation of 600 MHz, 1900 MHz and 3550 MHz. By handling these frequency resource as a single cell, we agree SSB/SIB and other control overhead can be reduced from time/frequency resource perspective. On the other hand, if spatial reuse aspect is considered (i.e. cell densification). it may imply the same cell coverage among 600 MHz, 1900 MHz and 3550 MHz and it could be inefficient on the efficiency. Could you share your thinking related to cell densification when the used frequencies are so different?

4 – Apple Hungary Kft.

5 – China Mobile Com. Corporation

Among the 5 contributions listed related to flexible spectrum fusing, **idle/inactive state enhancements** have been mentioned by,

- RWS-210147: Simplify SSB designation
- RWS-210402: overhead reduction for common signals incl. e.g. SSB, SIB etc.
- RWS-210441: system information (e.g. SSB, SIB, RMSI and OSI) and paging of a serving cell can be broadcasted only in one of the multiple DL carriers; Based on the SSB and SIB, UE can choose any one of the UL carriers for initial access;
- RWS-210334: System information of the cell can be broadcast only in anchor frequency resource; The anchor and all non-anchor frequency resources can be chosen by UE for initial access

Connected state enhancements has been mentioned by all the 5 contributions, including enhancement of multiple frequency resources/carriers scheduling, fast carrier switching/activation, PDCCH overhead reduction, etc.

Besides the 5 contributions, we also notice some other contributions proposed idle/inactive state enhancement under other topics such overhead reduction and/or flexible initial access among multiple frequency resources/carriers.

We think it is desirable to use one unified framework, such as single cell solution for both idle/inactive and connected state enhancements, to reduce system overhead and cell management cost and to improve spectrum efficiency.

And at the same time, the multiple frequency resources/carriers operation **should not be based on CA capability**, which means for UEs without multiple active frequency resources capability still can benefit from the unified framework, for example, flexible selection or switching between frequency resources.

6 – MediaTek Inc.

For flexible spectrum fusing,

-
It is a important application of generic CA enhancements for overhead and efficiency improvement. For technology development perspective, we suggest to pursue further CA enhancements in R18 with emphasized use case of aggregating inter-band carriers with resource limitations (e.g. smaller BW)

-
Re-modeling multiple CCs to a single CC may not be necessary. For specific overhead reduction target, developing cross-carrier scheduling enhancement with one DCI for scheduling multiple (≥ 2) carriers can already fulfill the target based on existing CA framework.

7 – Qualcomm CDMA Technologies

We would like to better understand the scenarios that the proponents envision and target. In particular, we wonder about (1) what combinations of carriers/bands are considered, e.g., multiple carriers in the same band, multiple carriers in different bands but in the same range (e.g., low bands, mid bands, or mmW bands), multiple carriers in different bands in different ranges; (2) what types of deployments are considered, e.g., whether or not the multiple carriers are co-located/synchronized.

8 – vivo Communication Technology

1. The boundary between 5.3 CA/DC enhancements and 5.4 flexible spectrum fusing is a bit unclear, would be necessary to define the scope clearly to facilitate future discussion.
2. For spectrum fusion, we think some more discussion would be needed to see the clear justification for it. If the main motivation is for overhead reduction (for broadcast channels, scheduling DCI etc), it could be done with some enhancements to existing CA framework, for example by introducing anchor carrier for IDLE mode, and enable joint multi-cell scheduling for CONNECTED mode. Also, its implication/impact to UE hardware implementation and power consumption should also be carefully evaluated.

9 – CATT

We observe that the main motivation of the enhancements is quite aligned among the proponents, which is to improve the utilization of fragmented spectrum resources. The main areas for potential enhancements include overhead reduction, cell management simplification etc. To aggregate multiple fragmented spectrum resources into one cell is a common framework proposed by the proponents. In the next step, we suggest companies to discuss and align their understanding on the targeted scenarios (e.g., frequency ranges, etc.) and potential benefits of single cell with non-contiguous spectrum. Then in the next step we could look into detailed technical work scope.

10 – Samsung Electronics Co.

We sympathize with Nokia/Futurewei's comments. It would be better to understand what is possible and what is not possible from current CA framework to achieve the claimed benefits in the proposals. For example, Rel-17 cross-carrier scheduling enhancement is targeting offloading of DL control signaling. The impact on existing UE should also be looked into.

11 – Xiaomi Communications

Questions:

Q1: Is there any band limitation for fusing, such as is there a total maximum bandwidth after fusing?

Q2: What are the target bands? All fragmented bands or adjacent bands in FR1?

Q3: Are the bands before fusing into a cell band are co-located bands or not

Comments:

- 1: Reuse NR Rel15/16 as much as possible, such as targeting one BWP is activated in one time.
- 2: Adjacent band below 3GHz should be prioritized and the RAN4 impact should be identified.
- 3: A WI for Rel_18 can be expected, SI may not be necessary.

12 – China Telecommunication Corp.

@Charter RWS-210210

Question1: We agree with most of objectives as including based on CA enhancement, impact to RAN1, 2 and 4. Only concern for one objective saying leveraging the NR-U intra-band guard-band, we would like to inquire more elaboration for the reason. Because in our understanding, firstly this is a RAN4 issue not RAN1 issue; secondly, the carriers are inter-band carriers not intra-band carriers, they will not be really moved to intra-carrier. The intra-carrier is a logical concept to integrate the bandwidths from different carriers to one virtualized bandwidth.

Question2: Regarding the scenario of 600/1900/3500MHz, we wonder if considering SSB cost reduction i.e. one SSB allocation. If so, then whether it is feasible to compensate the sync timing, path loss or QCL difference as the scenario covers low-mid-high bands.

@CMCC, RWS-210334, @Huawei, RWS-210441

We would like to continue the discussion for load balance issue due to the SSB, SIB1, OSI, Paging are allocated in the anchor band. Do you think if it is feasible that e.g. OSI and Paging information are designed to be more flexible and could be indicated to be assigned in other non-anchor bands?

@CATT, RWS-210402

Regarding the scope of “Co-existence with legacy UE if any” we have a question for clarification.

13 – Guangdong OPPO Mobile Telecom.

3GPP always try to find more efficient utilization of spectrum. The concept of the flexible spectrum fusing is interesting. In order to better understand this proposal, we have the some questions for clarification

Q1: What’s the impact on UE? Wheter to support concurrent UL transmission from multiple UE Tx chians or not? It will have large impact on UE hardware and power comsumption.

Q2: We would like to know its impacts to and/or requirements on duplex of aggregating bands

14 – ZTE Corporation

We agree with the intention of flexible fusion. Based on our understanding, there are basically two approaches to achieve this flexible fusion.

Approach#1: A single cell contains multiple carriers from different bands

Approach#2: Flexible DL and UL carrier aggregation as discussed in RWS-210479. One cell still contains one DL carrier and on UL carrier. But the DL carrier and UL carrier in one cell can come from different bands. Meanwhile, Multiple cells can share the same DL carrier or share the same UL carrier.

Approach#1 needs to redesign structure of “cell” and it is more like keeping more than one active BWPs in each cell. Approach#2 tends to reuse the legacy cell structure and CA framework. Based on our understanding, Approach#1 and Approach#2 can serve the same purpose. The two approaches can both

reduce the potential L1 overhead, e.g., SSB and PDCCH. Take Approach#2 as an example, if multiple cells share the same DL carrier, then the SSB can also be shared among different carriers.

During the online presentation, companies claimed that Approach#1 can also reduce the L2 and L3 overhead. We want to follow up this discussion and have one question for clarification. What's the detailed L2/L3 overhead that Approach#1 can reduce?

15 – Ericsson LM

@Charter RWS-210210:

Q1: If SSB/SI signals are not sent on a band or carrier that is part of a cell with multiple carriers, these carriers will not be accessible for initial access or measurements. Will this impact the use of these carriers by legacy UEs?

Q2: Creating a single cell with multiple carriers will not resolve any of the implementation issues that RAN4 deals with for CA. On the other hand, this will likely create additional RAN4 work. What is the anticipated specification impact for specifying a single cell with multiple carriers?

Q3: If potential scheduling improvements such as a single DCI scheduling multiple cells are specified in Rel-18 for CA, what are the additional benefits from a single cell with multiple carriers?

16 – Huawei Tech.(UK) Co., Ltd

The list of Tdocs provided for this topic by the RAN chair are: RWS-210147, 0210, 0334, 0402, 0441.

Tdocs list under the topic of “flexible spectrum fusing” have much commonalities, the main commonality being to consider multiple bands as one serving cell in order to reduce overhead from control signaling (e.g. single DCI scheduling multiple carriers). With the additional assumption that the multiple bands are collocated and within a certain frequency span, overhead can be further reduced by providing reference signals common to the multiple bands, e.g. providing SSB in only one of the bands. There are initial differences in the proposals on the baseline framework, which would need to be clarified. For example by better understanding what would it mean defining “flexible spectrum fusing” on top of CA framework? What does it mean defining a single virtual serving cell covering multiple carriers with one active BWP per carrier?

We think it would be good to clarify the relation between various proposals related to multi-band operation, which may currently be classified under two topics: “flexible spectrum fusing”, “CA/DC enhancements” and “mobility enhancements”. It may be more efficient to look separately at proposals targeting efficiency improvements or mobility enhancements, and focus on the efficiency improvements in this topic (flexible spectrum fusing).

The following Tdocs are also relevant to this topic:

Tdoc 0094 listed under CA/DC proposes “Cross-carrier HARQ retransmission and cross-carrier HARQ feedback”, which would be a natural consequence of defining a single virtual cell across multiple carriers. “Enhancement of multi-carrier scheduling” with “Full scheduling flexibility for massive carrier aggregation under limited UE blind decoding complexity” would also be relevant for efficiency enhancements discussed under Flexible spectrum integration.

Tdoc 0165 listed under CA/DC proposes “Anchor carrier can be introduced for idle UE, only SIBx transmission in anchor carrier” as well as “Proposal3: Study, and if agreed specify PDCCH of P(S)Cell/ SCell

scheduling PDSCH/PUSCH on multiple cells using a single DCI within FR1 and FR2”. This is also relevant for efficiency enhancements discussed under Flexible spectrum integration.

Tdoc 0258 listed under CA/DC proposes single DCI scheduling multiple carriers. This is also relevant for efficiency enhancements discussed under Flexible spectrum integration.

Tdoc 0122 is listed under several topics but not here, although it clearly mentioned “Wide-band transmission across several bands with the same cell”.

17 – Lenovo (Beijing) Ltd

-

Since this topic is quite relevant to CA enhancement, do companies think this topic is necessarily combined with CA enhancement?

-

Regarding the performance gain of no SSB/SIB-1 on the non-anchor carriers, considering NR already support the configurable SSB/SIB-1 periodicity, is significant performance gain achieved on the non-anchor carriers with a quite sparse SSB/SIB-1 configuration?

-

Regarding coexistence with legacy UE, due to no SSB/SIB-1 on the non-anchor carriers, legacy UE can't access on those carriers. Is the performance degradation of legacy CA capable UEs accepted?

-

For the carrier without SSB/SIB-1, it seems like a variant of extension carrier which was discussed ten years ago. Do companies think it is necessary to repeat the work?

Feedback Form 16: Answers/Comments

1 – Nokia Corporation

We would like to note that the SSB-less SCell is supported by the NR Rel-15 already (please see the Rel-15 UE capability scellWithoutSSB). The practical issues are related to UE AGC/sync acquisition typically requiring at least band-specific signals for the UE to latch onto. 3GPP does not impose SSB on the UEs, the UE implementation constraints impose the need for the networks to transmit such a signal, and it is not a property of CA vs. spectrum integration without CA.

As Ericsson noted, more generally, the RF related aspects that complicate CA are not a property of CA either, but a result of using multiple band blocks simultaneously. These apply also if the CA framework is replaced with something else. For spectrum integration under one cell, there would be an obvious necessity for RAN4 to define spectrum block band and bandwidth combinations supported by the UEs in a similar fashion the CA band combinations have been defined today.

We believe that the benefits expected from spectrum integration should be achievable within the CA framework and this way avoid a major redesign of the logical construction of the specifications to achieve the same. Thus the expected gains should be detailed and the delta to the current CA specification identified so that the beneficial improvements can be worked on.

2 – LG Uplus

We are interested in this concept and, further, hope it can be combined with DSS in order to gather pieces of fragment surplus radio resources and fully utilize them. However, still, we are not sure it could be realized since it is unclear to us how to enable RRC connection maintenance, camping for the SSB-less carrier, TA maintenance and so on.

3 – China Telecommunication Corp.

Answer to #1 Nokia, #4 Apple, #6 MediaTek, #7 Qualcomm, #8 vivo, #10 Samsung, #11 Xiaomi and #17 Lenovo

We think the scenarios and scopes for flexible spectrum fusing are much clear and related proposals could be found in amounts of 10 companies including RWS-210147(CTC), 0334(CMCC), 0402(CATT), 0441(Huawei), 0479(ZTE), 0032(DT, T-Mobile USA), 0122(Orange), 0210(Charter), 0199(Rakuten Mobile).

For the scenarios, we suggest to focus on FR1 fragmented bandwidths in multiple carriers (e.g. CBW<=50MHz per carrier), which will cover the proposed scenarios of 700/800/900MHz, 1.8G/2.1GHz in 0147 and 0402, 1.9G/2G/2.3GHz in 0304, 600/1900/3500MHz in 0210.

For the scope overlapping with CA enhancement, we think at least the cell management and overhead reduction are not overlapped with CA enhancement.

The cell management includes carriers selection/switching, CA enhancement to support more uplink carriers than downlink carriers, single cell enhancement to support more SUL carriers concurrent transmission. Which was proposed by 9 companies above mentioned.

The overhead reduction includes simplifying SSB, SIB, OSI, Paging resources to be allocated in one anchor carrier. Which was proposed by 5 companies above mentioned.

Therefore, we propose to add the detailed objectives for Flexible spectrum fusing in the workshop summary as

Flexible spectrum fusing

-Focus on the FR1 fragmented bandwidths in multiple carriers (e.g. CBW<=50MHz per carrier)

-Cell management and overhead reduction

4 – Huawei Tech.(UK) Co.. Ltd

Answer to Qualcomm

The combinations of carriers/bands should be within several hundreds of MHz sharing similar large-scale channel characteristics, therefore these carriers/bands will have similar coverage. The combination of carriers/bands within FR1 can be prioritized. The combination of intra-band carriers within FR2 can also be considered if time allows in Rel-18. The scenarios of co-located multiple carriers/bands is prioritized.

Answer to Xiaomi

Answer to Q1: It is UE capability which can be discussed in RAN4.

Answer to Q2: The scenario of adjacent bands in FR1 should be prioritized.

Answer to Q3: The scenario of co-located bands should be prioritized.

Answer to Q2 of China Telecom

We think it is feasible to put OSI and Paging information in other non-anchor bands by the indication on the anchor band if a UE is not required to monitor both bands at the same time.

Answer to OPPO

Answer to Q1: most RAN4 UE RF requirements defined based on carriers are independent of features (except for UL-MIMO). Those requirements should be kept unchanged. The basic UE capability is not to support concurrent UL transmission. Similar as for CA, UE can optionally support concurrent UL transmission.

Answer to Q2: The scenario of fused bands with same duplex should be prioritized.

Answer to Lenovo

Answer to Q1: Sparse SSB/SIB-1 configuration will lead to large delay for initial access and resynchronization for current CA. Introducing SSB/SIB-1 sharing can reduce overhead and keep performance simultaneously.

Answer to Q2: It depends on the deployment. If there are legacy UEs which need to access the other band, operators can also decide to send common signaling in that band. However, multi-band serving cell could provide flexibility for deployment, e.g., for spectrums re-farmed from LTE, there is no need to send common signaling as no legacy NR UEs are served.

Answer to Q3: We think it would be worthwhile to standardize SSB/SIB-1 sharing among multiple carriers/bands as long as it can bring benefits. In addition, based on SSB/SIB1 sharing, other enhancement such as supporting BWP-like operation among multiple carriers and simplified RRM should also be considered in Rel-18 to improve the performance of aggregating scattered frequency bands.

5 – China Mobile Com. Corporation

Answers to common comments about the difference and benefit compared with CA:

-

The proposed solution in RWS-210334 does not necessarily require CA capability for UEs, with reduced system overhead, such UEs can still have flexibility to choose frequency resources for initial access and realize fast frequency resource switching for connected state.

-

System overhead is reduced. SSB, SIB and paging information are only broadcast on anchor frequency resource, for common system information, there is no need to repeat them on different frequency resources as long as they belong to the same cell, especially for re-farmed frequency resources. Even for frequency resource serving legacy UEs, where system information and paging are needed for legacy UEs, the paging for R18 UEs is only transmitted on anchor frequency resource, the paging overhead related to R18 UEs can be reduced. With frequency combination based elastic cell, the overhead for neighboring cell configuration related to non-anchor frequency resources can be reduced.

-
For RRC idle/inactive state,

Flexible initial access frequency resource selection with reduced overhead compared CA. CA is only applied to connected UEs. For idle/inactive UEs, it can only camp on one cell and initiate cell access from the corresponding carrier (or SUL). Therefore, it cannot realize flexible offloading during initial access. Traditionally, to realize offloading during initial access, multiple carriers each corresponding to one cell need to be configured with system information, paging information, resulting in large overhead. The single cell structure can avoid such system overhead with flexible frequency resource selection, in which, UE only need to monitor the anchor frequency resource for paging reception or system information monitoring, and non-anchor frequency resource can be configured with longer periodicity SSB for R18 and onwards UE to save power when needed.

-
For RRC connected state,

For UE without CA capability, fast frequency resource switching can be realized without layer 3 involvement.

For UE with CA capability, with CA framework, if Pcell changes, RRC involved handover procedure is needed. While for single cell framework, L1/L2 switching is enough, which is faster.

Answer to #7,

Then combined band range and deployment types you listed are all possible and can be further studied.

Answer to #12,

Our intention is to reduce the overhead on non-anchor frequency resources by only transmitting system information and paging message on the anchor frequency resource and at the same time the idle mode UE camping only on anchor frequency resource. On the other hand, we think the spec will not forbid broadcasting OSI, paging on non-anchor frequency resources, which may be left some flexibility for operator's configuration.

Answer to 13,

A1 to Q1: There is no intention to introduce higher requirement or capability than CA.

A2 to Q2: the aggregating bands can be either FDD or TDD band.

Answer to 14,

For current CA structure, changing PCell requires RRC reconfiguration with sync, which is L3 HO. For Approach#1, changing frequency resource is L1/L2 mobility without RRC reconfiguration, similar as BWP switching. So the L3 signaling is reduced.

6 – CATT

In our view, the frequency bands that are aggregated should be within a certain frequency range and the sync/QCL assumptions can be inferred across multiple frequency bands. SSB and SIB overhead can be reduced at least for frequency resources refarmed from LTE and the frequency resources too small for SSB and SIB transmissions, and the backward compatibility would not be impacted. In addition, the proposal has the advantage in terms of cell management, fast carrier switching/activation and less higher layer signaling overhead etc..

5.5 RIS ("Reconfigurable Intelligent Surface")

This section is targeted at identifying commonalities and interactions for RIS ("Reconfigurable Intelligent Surface").

Feedback Form 17: Questions/Comments

1 – ZTE Corporation

We have strong interest on this topic as proposed in our dedicated contribution (RWS-210465). In our view, the maturity and benefits of this technique is justified by both field measurement and simulation results as shown in our contribution.

Regarding the possible interference issue discussed in the workshop GTW session, we think the impact on adjacent channel can be alleviated by joint optimization via frequency selective materials and beamforming design/control. Without aligning the beamforming direction from RIS with adjacent channel, the RIS itself will be just like a typical scatterer in normal propagation environment. Also, frequency selective materials can be used. Possible interference management and proper UE-specific beamforming control can be further studied in the study phase.

According to the pre-workshop summary (RWS-210548) and contribution review, starting with the study phase on channel model and evaluation seems to be needed according to the feedback from many companies. More specifically, at least both outdoor and indoor cases can be prioritized for FR1 and FR2.

In addition, for the technical enhancement part, both similarities and differences between RIS and smart repeater can be considered. For example, from our side, it seems that following standardization aspects can be shared or partially shared:

1. Interface between gNB and RIS/repeater
2. Beam management (at least for far-field case)
3. Interference management

In this case, we can try to conduct the joint study once the consensus on the identified list is achieved. Based on this discussion, we have the following questions to interested companies:

-

Do you think some aspects can be studied and shared for both RIS and smart repeater?

-

Do you also identify any common/similar parts for standardization?

2 – Spark NZ Ltd

There are a number of issues with RIS:

1. Firstly for FR1, the channel is multipath rich already (supports direct paths, reflections and diffractions), so one wonders what additional benefits a reflective panel will provide. Statistically it is unlikely that it will alter alter the channel characteristics especially the channel rank.
2. Secondly for FR2 , RIS could overcome diffraction issues at mm waves. But there are commercial products available consisting of back to back passive antennas with one antenna facing the base station and the other towards the corner where coverage is required. One wonders what study is needed for these products.

Research papers and analytical simulations show that active RIS could be used to direct beams towards users in desired locations. This is possible but no study has been done on the effects of pixel failures that

will happen as the reflective surface is exposed to the weather, bird droppings, temperature gradients etc. Network elements in a 5G systems must also comply with a very high reliability objective (see ITU R M 2410 and IEEE JSAC June 2017, Table 1 page 1202). These management of these failures will require on going maintenance- an overhead on operators. Then the RIS may be used to select UEs to beam form to. This will need control signalling information to e passed between the gNB and the RIS and for inter site COMP this information may also be passed to a central point say the CU. In effect we are now adding more transport links- again an overhead on operators and it is unclear what is the data rate these transport links need to carry and the potential impact on latency.

Given all of the above and more we are not convinced of the potential gains of RIS.

3 – Futurewei Technologies

Though RIS has recently attracted a lot of attention, we are not convinced that it is mature enough yet to be commercially deployed.

4 – LG Electronics France

This is question to the proponents of RIS for a better understanding on the proposal.

What is the main impact of RIS on the specifications (other than performance part)? In the UE perspective, I expect UE may not differentiation RIS and smart repeater or not even recognize them. If main specification impact is on the interface between gNB and RIS node, is it expected that the interface between gNB and RIS should be different from that between gNB and smart repeater?

5 – Lenovo (Beijing) Ltd

We think RIS is new technology with good potential to enhance the coverage and capacity of traditional TRP. Before we start standardizing RIS in 3GPP, we need to first understand the channel model, including the device model. This includes the equivalent circuitry, electromagnetic reflection/radiation property of the RIS elements/surface, and propagation property of the TX-RIS channel and RIS-RX channel in different deployment scenarios. It is also important to understand the frequency and polarization dependency of these properties, because the RIS device is wideband and potentially polarization sensitive. In the literature we found multiple types of RIS device, including RIS based on PIN diode, liquid crystal, SPR, and phase transition materials with different frequency range, response time, phase tuning resolution and cost. There are also passive and active RIS devices with different structures. Given the plethora of the RIS devices and their unique properties, it is necessary to understand their pros and cons. We also need to decide whether to standardize based on some selected RIS types or based on generic RIS model. We are open to further discussions in this area.

6 – KT Corp.

KT believes that Release-18 is a right timing to initiate a study item on RIS/Smart Repeater. Based on our commercial 5G experience, biggest improvement is needed for indoor and O2I coverage. We also need to consider cost-effective way of extending indoor & O2I coverage where RIS can provide this. We also think that RIS should be discussed under "Additional topological improvements (IAB and smart repeaters) as RIS with reconfigurability and beam management can be considered as "smart repeater".

7 – vivo Communication Technology

If RIS is considered in Rel-18, relation between smart repeater should be clarified. Furthermore, whether new channel model is needed and what functions reside on RIS should be clarified in order to determine the work scope. Another point since reflection performance depends on material, how to specify performance requirement in RAN4 should be also be clarified.

8 – Samsung Electronics Co.

RIS is an interesting technique that enhances coverage for FR2. However, we have questions that how much gain can passive RIS provide in terms of the physical size of RIS? Because we think in the place where the size of RIS is limited, the expected gain would be low.

9 – Xiaomi Communications

Question 1: Is RIS transparent to Rel-18 UE?

Question 2: Does it need specifying interface between RIS and gNB?

10 – Guangdong OPPO Mobile Telecom.

RIS was proposed by some companies. Since it is a very new topic, some clarification is needed to better understand the whole picture and the future work. To be specifically, we have some general questions as below

Q1: There may be different motivation to introduce RIS in a NR system, e.g., coverage extension, throughput boosting. Thus, what are the typical scenarios in mind and what is our target for RIS in the study?

Q2: There are also different types of RIS, e.g., active, passive, reflective. Which type is expected to be included in the study?

Q3: We notice companies propose to discuss evaluation methodology and channel modeling. Since the physical characteristics of RIS are very different from that of any existing network component, the channel modeling or other factors may be new. Is there any proponent planning to provide some field/lab measurement results to facilitate/validate the channel model ?

Q4: Regarding the information exchange between RIS and gNB, three different approaches seem workable here. The first one is based on implementation without any spec impact. The second one is to specify some non-air-interface, e.g., the interface is carried by cable or fiber. The last one is to define some air interface between gNB and RIS (including in-band and out-of-band). Which approach is expected in the study?

11 – China Unicom

China Unicom is interested in RIS topic and it is a good time to have an individual study item of RIS for both FR1 and FR2. According to our preliminary filed test results, in general, RIS can provide more than 10dB gain on cell coverage improvements. Moreover, RIS is beneficial for outdoor to indoor, blockage and some other scenarios. For MIMO scenarios, RIS can provide additional benefits on rank and UE data rate.

As RIS is considered as a new network element and deployed by operator, it is needed to study and define the new interface between RIS and gNB if identified. Furthermore, the design of RIS functionality and other performance requirements to supporting such a new type of equipment are also need to be studied.

We also share the same view that RIS should move to "Additional topological improvements (IAB and smart repeaters)", and revised as "Additional topological improvements (IAB, smart repeaters and RIS)".

12 – MediaTek Inc.

RIS is an interesting technology for FR2 but we're not fully convinced that RIS technology is mature enough yet. For example, there are different views on how to model the composite channel of gNB-UE and gNB-RIS-UE. Before more results on channel measurement/modeling are ready, it's difficult to conclude RIS evaluation in 3GPP.

13 – KDDI Corporation

We have interest on this topic because we believe this is one of potential devices to address coverage issues especially in FR2, and think it is time to start study for RIS. Based on the discussions in this group so far, we think we need to study to align each company's understanding of RIS. For example, it seems that there are some variations in the image of the type/model of RIS device that each company has. Also, the gain and usage scenario may be different. Therefore, we think the first step for RIS is to find out from each company what kind of aspects need to be studied.

14 – China Mobile Com. Corporation

We have the same concern about the impact of RIS to the other operators' network as some company commented during the online. The RIS is controllable to provide a better propagation environment for the target cell, but for the network deployed in the same area, the propagation environment is also changed, since the effect of RIS is band agnostic or covering a much broader band. The network deployed in the same area but without the control of the RIS may be changed in an unpredictable way. We also noticed that there are some commonalities between smart repeater and RIS, so we are open to also take into account the common part between smart repeater and RIS during the study.

15 – Sony Europe B.V.

As pointed out by several companies during pre-RWS discussions, RISs can be used to enhance network coverage and capacity, e.g., by overcoming blockage. Because RISs are passive, they may be mass-produced at low cost.

In RWS-210300, presented by KDDI during the first GTW session, RISs and smart repeaters are shown side by side in each figure. In the figures, a BS, a UE, and *one* RIS/smart repeater are shown. This motivates the following more general questions:

-

Do companies foresee a single RIS being deployed per BS, or rather several, even many, RISs being deployed in one cell?

-

What about smart repeaters, i.e., how many smart repeaters per cell are expected in a typical deployment?

-

Is this different for FR2 compared to FR1?

Answering these questions can help to identify use cases and scenarios for which RISs are particularly advantageous compared to other alternatives, such as smart repeaters or IAB nodes. In our view, the above questions can be investigated in a Rel-18 SI, which we support, together with other aspects proposed in various Rel-18 WS contributions, such as channel modelling, beam management, channel state acquisition and interference management (see, e.g., RWS-210300).

We note that our questions above and several of the other aspects proposed in Rel-18 WS contributions share many commonalities with smart repeaters, and even IAB. Therefore, we encourage companies to

consider whether RIS should be included in Sec. 4 “Additional topological improvements (IAB and smart repeaters)”.

16 – Rakuten Mobile

While its true that there are number of challenges and open questions related to feasibility and need of standardization for RIS. However, at the same time we believe that it is one of the area which is open to innovation and a lot of study is needed to understand the basics such as channel models, Material properties, interference management/beam forming techniques etc.. For this very reason we would like 3GPP to initiate RIS related study item in Rel-18.

17 – Nokia France

We see some academic interest in RIS, but it is rather clear that the topic has not yet reached the level of maturity needed to justify a study in 3GPP in the Rel-18 timeframe.

18 – Ericsson LM

Ericsson also believes that RIS is an interesting research area to look into. But it is too early to start the standardization work already in Rel-18 timeframe. Corresponding research project are currently ongoing, from which many are targeting the 6G timeframe. 3GPP should wait until the use cases, the deployment scenarios, and the technology becomes mature.

Feedback Form 18: Answers/Comments

1 – LG Uplus

We are interested in RIS as a long-term study but deprioritized for commercial package since we think RIS could cause unintended interference for adjacent band.

2 – ZTE Corporation

Answer to #2 (Spark NZ)

Thanks for your feedback.

In the FR1 case, in our view, the benefits of RIS can still be observed for both throughput and coverage improvement. For example, although rich paths can be observed in some scenarios, the overall channel quality and RANK can still be significantly improved by introducing the distinguishable ray with higher power.

For the FR2 case, we understood that there are multiple implementation to improve the performance based on RIS or RIS-like technique, e.g., back to back passive antenna. I share the views that if only static application is targeted, all relevant issues can be addressed by implementation without spec impacts. However, the required efforts for network optimization is larger and unable to boost the benefits of this technique by enabling the adaptive controlling with minimum overhead on the signaling.

W.r.t the reliability of RIS-based production, it’s up to the implementation and similar as legacy network infrastructure, I do believe that the needs can be complied by the well-designed product.

Answer to #4 (LGE)

Thanks for your question.

W.r.t the required specification efforts, except for the channel model and evaluation phase, all required changes can be categorized in two parts:

1. Controlling interface between gNB and RIS to enable the adaptive behavior
2. Supplementary enhancement, e.g., beam management/RACH enhancement and interference management.

W.r.t the transparency to UE, in general, signal transmission and reception is expected to be transparent to UE. And I share the views that the UE may not recognize the RIS.

For the required interface between gNB-RIS and gNB-smart repeater, commonality is also observed in our side to enable the low layer information delivering from gNB to additional entity. We are open to strive for the unified framework and the detailed content can be further discussion, e.g., some information related to the power controlling may not be needed for RIS.

Answer to #7 (Vivo)

Thanks for your comments.

W.r.t the relationship between RIS and smart repeater, in our views, both share the similarity on usage and potential aspects for enhancement. It's also the motivation to discuss the RIS under same section with smart repeater, e.g., "Additional topological improvements".

For the channel model part, based on the preliminary study, it seems that there is need to introduce some new feature. Details can be converged within the study.

W.r.t the RAN4 part, in our view, similar as other topics, with well-defined assumption, the requirements can be consolidated. More specifically, as the passive device, the required efforts in RAN4 will also be limited.

Answer to #8 (Samsung)

Thanks for your questions.

As one passive entity, I agree that the gain of RIS is up to the design including the size and which can be adjusted according to the needs and deployment scenarios. Based on our initial field measurement, performance gain around 10 20dB can be achieved for outdoor scenario with proper size. Meanwhile, without the PA component, the improvement will be directly on the signal without impact of noise level.

Answer to #9 (Xiaomi)

Thanks for your questions.

For Q1: Yes. In general, signal transmission and reception is expected to be transparent to UE. To exploit full potential gain from RIS, potential enhancement on the BM/CSI report should also be considered. So the UE behaviour on measurement and reporting can be different from the existing scheme but the UE still may not need to be aware of the existence of RIS. This new UE behaviour may correspond to a new standardized UE feature.

For Q2: To enable the adaptive behaviour of RIS, it's preferred to design the interface between RIS and gNB. Moreover, the specified solution (e.g., via air-interface) is more beneficial for the flexible RIS deployment.

Answer to #10 (Oppo)

Thanks for your questions.

For Q1: In our views, both motivation are needed to be considered during the study phase. At least the basic part as channel model and evaluation is common for both purposes. W.r.t the specification enhancement, maybe more improvement are foreseen for throughput case.

For Q2: For this study, we can focus on the RIS with controlling from gNB. W.r.t the transmissive or reflective based RIS, in our view, all relevant studies are shared.

For Q3: For the channel model part, convergence on the modelling will be based on the groups' inputs in the similar way as before. Both field measurement results and simulation are valid and necessary for justification.

For Q4: In our view, both option-1 and option-2 are for implementation. With consideration on the flexibility for RIS deployment, the air-interface is preferred for this study.

Answer to #14 (CMCC)

Thanks for your feedback.

We also share the views on the commonality between RIS and smart repeater and prefer to take the study jointly under "Additional topological improvement".

For the impact of RIS to the other operators' network, we believe that some implementation based solution can be considered and we are also open to discuss other solutions with spec impacts in the study phase.

Answer to #15 (Sony)

Thanks for your feedback and question.

In our views, the question w.r.t the required number of RIS or smart repeater per cell will be determined by usage and target environment. More specifically, if the intention is also to improve the throughput for UE within the coverage, more entities will be needed comparing to the deployment for fixing the coverage hole.

Moreover, since the RIS is also one way to improve the network performance by changing the topology of system, we also prefer to discuss this topic under "Additional topological improvements".

Answer to #3#12#17#18 (Futurewei, Mediatek, Nokia and Ericsson)

Thanks for your feedback. W.r.t the question on maturity of this technique, in my view, it's already well developed and ready for the commercial usage in Rel-18 phase with clarification on following aspects:

1) outputs, some examples for the early research are listed below and more outputs have emerged in the last few years.

-H. Legay, B. Pinte, M. Charrier, A. Ziaei, E. Girard and R. Gillard, "A steerable reflectarray antenna with MEMS controls," *IEEE International Symposium on Phased Array Systems and Technology*, **2003**, 2003, pp. 494-499, doi: 10.1109/PAST.2003.1257031.

-S. V. Hum, M. Okoniewski and R. J. Davies, "Modeling and Design of Electronically Tunable Reflectarrays," in *IEEE Transactions on Antennas and Propagation*, vol. 55, no. 8, pp. 2200-2210, Aug. **2007**, doi: 10.1109/TAP.2007.902002.

-S. Montori *et al.*, "Wideband dual-polarization reconfigurable elementary cell for electronic steerable reflectarray at Ku-band," *Proceedings of the Fourth European Conference on Antennas and Propagation*, **2010**, pp. 1-5.

-Yang, H., Cao, X., Yang, F. et al. A programmable metasurface with dynamic polarization, scattering and focusing control. Sci Rep 6, 35692 (2016).

Based on all the research, the benefits on RIS over legacy technique have been justified on the energy efficiency, cost and deployment flexibility.

2) Industrial: The develop activity of this RIS has also been initialized including prototype and field measurement. One example is that as shown in our contribution, availability and performance are justified. Similar observation and views are also shared by other companies in the feedback.

Then, it's a right timing to initiate a study item on RIS with starting on some basic aspects, e.g., channel model. The convergence on the relevant topic can be achieved based on the inputs from all groups in the similar way as before.

Answer-to #5#6#11#13#16 (KT, CU, KDDI, Rakuten)

Thanks for your comments. Yes, we share the same views that study on the RIS should be triggered in Rel18 from basic part firstly. Convergence and prioritization on the scenarios, frequency band and potential RIS component are certainly needed during the study phase.

Moreover, since the RIS is also one way to improve the network performance by changing the topology of system, it's preferred to discuss this topic under "Additional topological improvements" with others.

3 – Sony Europe B.V.

We believe that Rel-18 is the right time to start an SI on RIS. We also believe that certain aspects can be addressed jointly for RIS and smart repeaters in this SI; see details in the answers below. Because of this, we recommend to move RIS from Rel-18 topic "14. Additional RAN1/2/3 candidate topics, Set 1" to Rel-18 topic "4. Additional topological improvements (IAB and smart repeaters)," as this seems a better fit for the type of discussions that one should expect.

#1 (ZTE.) Our view is very similar to ZTE's and we support a Rel-18 SI that jointly addresses aspects common to RIS and smart repeaters. For example, the following aspects could be part of such joint Rel-18 SI: gNB-RIS / gNB-smart repeater interface; beam management; interference management.

#2 (Spark NZ Ltd.) For FR1, RIS can be used to create reflections toward dead spots within cells; in general, creating or improving the strength of reflections can improve the condition number of the channel matrix, if not the rank. For FR2, back-to-back antennas with one side facing the BS may fall into the category of transmissive RISs; there are also reflective RISs, with only one face; the study would include both kinds of RISs. We agree that the effects of pixel failures and the amount of maintenance required are important aspects, and should be included in the SI. In our understanding, the required control signalling between gNB and RIS, and the associated overhead, is a problem common to both RIS and smart repeaters, as both types of devices would need signalling to provide spatial information; this is, indeed, one of the common aspects that have been identified during the pre-Rel-18 WS between RIS and smart repeaters. In our view, to jointly address this issue, RIS and smart repeaters should be part of the same Rel-18 topic. For example, RIS can be moved to topic 4 "Additional topological improvements (IAB and smart repeaters)."

#4 (LG Electronics.) Please, see our reply to ZTE for details on impact of RIS on the specifications. Regarding the gNB-RIS and gNB-smart repeater interfaces, our view is that these basically provide the same functions (e.g., time synchronization, TDD information, spatial information) and should therefore be based on a common design principle. However, details of the interfaces could differ, and this should be investigated in a Rel-18 SI. For example, RISs might need some form of near-field information signalling, but smart repeaters are not expected to.

#5 (Lenovo.) We agree with your view that an investigation of required improvements to channel modelling, as well as how to adequately model RIS devices for simulation purposes is needed. In our view, such an investigation should be part of a Rel-18 SI. Regarding the various technologies used to implement RISs (e.g., PIN diode, liquid crystal, SPR, ...), we believe that these will remain implementation aspects, and only certain high-level parameters, such as the reflection coefficient of the RIS material, will be visible in simulation models, thereby hiding the details of the RIS implementation.

#7 (vivo.) Yes, we also think that the relationship between RISs and smart repeaters should be clarified. In our view, this is best done by including these two in the same Rel-18 topic. For example, RIS can be moved to topic 4 “**Additional topological improvements** (IAB and smart repeaters).” Regarding material properties, please see our answer to Lenovo.

#8 (Samsung.) Available studies show that the benefits provided by RISs depend not only on the RIS size, but also on the gNB-RIS and RIS-UE distances. Moreover, RISs are passive devices that do not add noise, which also contributes to enhancing system performance. All in all, this is a complex question and should be studied in a Rel-18 SI. Regarding the availability of space, we note that, at 28 GHz, a RIS with 256 elements can be fitted into 8.5x8.5 cm², and a 1024-element RIS has a footprint of 16.5x16.5 cm². Hence, one would expect that available space should suffice to deploy RISs with a very large number of elements.

#9 (Xiaomi.) In our opinion, the interface between gNB and RIS should be specified. Furthermore, our preference is that it is specified jointly with the gNB and smart repeater interface. Regarding the question of whether RIS is transparent to Rel-18 UEs, we believe that it is still early to tell; for example, companies might raise scenarios in which awareness of RIS by Rel-18 UEs might bring performance improvements. Thus, we do not exclude it at this stage.

#10 (OPPO.) Q1: We believe a Rel-18 SI should address both indoor and outdoor scenarios. Q2: In our view, RISs are passive devices which can be further classified into reflective and transmissive. We believe a Rel-18 SI should address both reflective and transmissive devices and strive to provide a uniform simulation model for both types. Q3: Channel modelling and evaluation methodology are, of course, important aspects that should be part of a Rel-18 SI. Q4: For easy of deployment, our preference is approach three, i.e., gNB-RIS air interface.

#14 (China Mobile.) The impact of RIS from one operator into another operator’s network is certainly an important aspect that should be studied. In our view, this should be part of a Rel-18 SI; see also our reply to ZTE. We would also like to make a couple of clarifications. First, as pointed out by some RIS proponents, RIS can be made frequency selective. Hence, RISs do not need to be frequency agnostic. Second, RISs are capable of accepting signals from certain incoming directions, or certain points, and focus them toward certain other directions, or points, *only* if the RIS is programmed to do so. Without access to the RIS controller, incoming signals to a RIS are most likely to be scattered in every direction. Because of this, RISs are not expected to unintentionally focus energy (i.e., interfere) on devices connected to other operators’ networks.

4 – NEC Corporation

This is in response to #2, #3, #6, #8, #9, #10 (partially), #11, #12, #14, #15 and #17

We should highlight that there are different types of RIS worth investigation: RIS might be a simple reflectarray (working in reflection mode only) where only different phase shifts can be set: this would require a minimum energy consumption without providing a (CSI) feedback. Conversely, there might be a RIS working in receiving mode (this would require an RF-Chain on board) that might process the incoming signal and provide feedback.

Although the concept of smart repeater is quite different (a smart repeater is intended to be an intelligent amplify-and-forward device), RIS addresses a similar problem space, and should therefore be discussed in conjunction with smart repeater.

All in all, the main advantages of RIS can be summarized as the following:

- low complexity
- low energy consumption
- limited control channel
- deployment flexibility

However, while configuring an RIS it might be needed to have a direct interface between BS (eNB/gNB) and the RIS: as exhaustively demonstrated in the literature transmit beamforming pattern (at the BS) and RIS configurations might be jointly issued to reach specific areas/UEs.

Regarding maturity, there are several companies creating prototypes where small/medium RIS are deployed. Some preliminary measurement campaigns have been conducted to demonstrate the validity of the solution compared to active relay node or smart repeater. In addition, ETSI has already approved a new ISG focusing on RIS to be kicked off in September 2021.

From the UE perspective, RIS can be transparent. However, it might be needed in the future to advertise UE about potential RIS deployment to perform an ad-hoc channel estimation procedure: this would require applying different RIS configurations (for e.g. different phase shifts) while asking UEs to provide CSI feedbacks so that the BS can select the best RIS configuration. In this case, we may assume a pure reflecting RIS not able to provide feedbacks.

Finally, the RIS size matters: the larger the RIS, the higher the expected gain, the more degrees of freedom for configuring the RIS. This is under investigation as different vendors are trying to cope with Large-RIS (more than 3 by 3 meters-grid) but we would expect some commercial product ready within the next 2/3 years.

5.6 Others

This section is targeted at identifying commonalities and interactions for other topics submitted to eMBB evolution which are not categorized in any topic above.

Feedback Form 19: Questions/Comments

1 – ZTE Corporation

Comments for SDT

For SDT, we have noted that the tdocs discussing the relevant aspects are distributed in different NWM threads. So, in order to provide an overview, we are providing a summary of all these tdocs below and we are adding some comments/notes from our side. We are providing this input in all three NWM threads (so that companies need not go through other threads to get an overview of this topic).

Relevant tdocs:

- Agenda item 4: RWS-210422
- eMBB AI (4.1): RWS-210080,
- non-eMBB AI (4.2): RWS-210007, RWS-210231
- cross-function AI (4.3): RWS-210485

Summary of areas of interest for Rel-18 (extracted from the contributions):

- SDT in RRC IDLE and further enhancement to SDT over preconfigured resources
- Backhaul signalling improvements of RA-SDT (to avoid unnecessary UE context fetch failure and improve the SDT without anchor relocation)
- improved PDCCH monitoring to reduce power consumption (e.g. DRX enhancement)
- Support of MT-triggered SDT (including enhanced paging to trigger the SDT for MT use case)
- DL CG-SDT support and coexistence with UL SDT
- Left over issues from Rel-17 (possible examples: RRC-less, optimisations for cell reselection etc)
- Support of URLLC transmissions in INACTIVE state

Some comments

-

We certainly think that MT-SDT is very useful and seems very relevant for a number of use cases including positioning and to support specific verticals. The work needed to enable this is relatively simple and should be part of Rel-18 work.

-

We also note that there is lot of interest in other areas mentioned above from various companies and we acknowledge that SDT seems to be of relevance to a number of features.

-

Since the Rel-17 work is ongoing, it is a bit early to speculate on the leftovers from Rel-17 and we sense that this is the reason why some of the companies were not explicit about the left-over topics (and understandably so), however, we think these aspects will become clearer by the next RAN plenary and we should be able to zero-in on a well-defined scope for the leftovers too at this point.

Based on the above we think that further discussion on the exact scope for SDT is worth having between now and next RAN-plenary to identify topics that can be further pursued in Rel-18. We think a dedicated thread to discuss the details will be helpful.

2 – Ericsson LM

As mentioned by Vodafone and AT&T in Monday's GTW session and also by KT in their contribution (RWS-210460, RWS-210212, RWS-210361), we agree that it is important to continue to enhance DSS. LTE devices, especially NB-IoT and LTE-M devices, are likely to be around for a long time and hence it is important to ensure as efficient coexistence as possible between LTE and NR. While DSS is very efficient from an LTE perspective, there is still room for improvements of both NR PDCCH and PDSCH efficiency.

3 – LG Electronics Inc.

Agree with ZTE that SDT is worth to be considered in R18. The SDT is one of the hot topics in RAN2 in R17, and there is strong motivation to continue the work on SDT in R18. Our main focus is on DL SDT, but open for other enhancements e.g. RRC-less based SDT. We hope to open a dedicated e-mail thread to discuss the details of SDT.

4 – Samsung Electronics Co.

As shown in RWS-210182 and RWS-210450, we think that to enhance the current user plane protocols (e.g. PDCP and RLC) for very high throughput—also known as 'High Speed Packetization (HSP)' enhancements as titled in RWS-210182—would be one of the key technologies for the success of 5G-Advanced. Since more band combinations are defined for NR (especially in FR2), both UE and network would have to handle too many headers, and this would become severe bottleneck for the support of very high throughput in the near future. Hence, we think Rel-18 is indeed right time to enhance the user plane protocols considering the actual implementation of this release.

5 – Xiaomi Communications

We think IDC is an important topic to discuss in Rel-18. Different from the LTE IDC, the NR IDC discussion could include solutions to resolve the following issues:

Issue 1) Interference between 3GPP and other RATs (e.g. WiFi and blue tooth).

Issue 2) Interference between 3GPP frequencies (e.g. including the MSD issue discussed in Rel-17 RAN4).

Issue 3) UE capability sharing between 3GPP and other RATs

Issue 4) UE capability sharign between multiple SIM(s).

The candidate solution direction would include:

1) FDM: UE reporting of frequency indication to cover a large range of frequencies affected by interference.

2) TDM: UE reporting of its preference DRX or UL/DL configuration

3) Desensing reporting: UE reporting of desensing issue as discussed in the Rel-17 RAN4 MSD topic

4) Preferred radio capability: UE reporting of radio capability reduction/split

5) Indication of measurement inaccuracy: Suspension of logged/immediate MDT report; handling of other measurements affected by interference.

6 – Nokia Corporation

We also see that there is clear interest to do further work on SDT in Rel-18 and it would be beneficial to have a dedicated discussion to better facilitate the discussion of Rel-18 SDT scope.

7 – HuaWei Technologies Co.

Regarding UP enhancements especially for PDCP concatenation proposed in 0450 and 0182, there seems support in previous Q&A to reduce the processing complexity for UPIP and ciphering, and also reduce the overhead for L2 headers. Therefore we think this is worth consideration and the impacts can be under control with major changes at PDCP layer.

Regarding 0114 of IDC, we think the FDM solution for indicating the specific affected frequency range may be helpful to avoid unnecessary de-configuration of the whole bandwidth, and for TDM solution we think the DRX part from LTE can be reused, while we don't see other needs like HARQ as NR has different HARQ mechanism than LTE. Regarding inaccuracy of measurements, we'd like to first see more detailed analysis on how much it impacts the current measurement result.

8 – EURECOM

We are interested in SDT but we would like to better understand potential RAN1 implications. Rel-17 SDT is confined to RAN2 which builds on features from RAN1, e.g. 2-step RACH. However, we think that for massive sporadic random access with small packets there is still a need to improve delay and reliability of the UL data transmissions.

9 – Sony Europe B.V.

Advanced Modulation

Many companies have identified the need for increased throughput in order to support applications such as AR, FWA etc. Throughput can be increased by increasing the MIMO order. However, at higher frequencies, reception tends to be LOS for which high MIMO orders are inefficient because of channel rank deficiency. Higher order modulation can help. But with the increased phase noise at higher frequencies, careful constellation design may be needed to provide a good SINR margin.

10 – vivo Communication Technology

SDT

We are open to continue the work for SDT in Rel-18, especially for the leftover in Rel-17, e.g. RRC-Less, cell reselection enh.

IDC,

We are supportive of IDC from Rel-16.

Regarding the enh. on FDM solution, current mechanism could indicate the ARFCN list on the impacted frequencies. We would like to check is it the correct understanding that enhanced frequency indication is mainly for signaling overhead reduction?

Regarding the TDM solution, we assume LTE solution should be used as the baseline with some consideration on NR specific impact. E.g. different numerology, additional enhancements would need to be justified.

Some questions to Proponent (Xiaomi)

On Desensing reporting: Could you explain more about the motivation and the solutions?

On Preferred radio capability: It seems to overlap with the UE capability adjustment as being discussed in MUSIM thread?

On UE reporting of its preference DRX: There are some Rel-16 UE assistant information for DRX introduced, could you please explain the difference?

Feedback Form 20: Answers/Comments

1 – HuaWei Technologies Co.

For QoE enhancements in 0386/0387, as we commented in XR, we think there requires coordination on QoE and XR metric which we see some need to enhance QoE.

2 – Lenovo Information Technology

Comments on PDCP Concatenation/reponse to comments#7

we also think PDCP concatenation as proposed in 0450 and 0182 is worth to be considered in Rel-18 to reduce the processing complexity of security and reduce the L2 overhead.

3 – LG Uplus

SDT : We see of course the benefits from the improved SDT in near future where, in general, message exchanging within social media services which is one of the use cases of SDT requires UL and DL as well.
QoE : Also we want proper coordination between QoE and XR for evaluating the user experience in Rel-18.

4 – ZTE Corporation

With regards to SDT:

To answer Eurecom's question about RAN1 implications, we note the following:

-
SDT builds on existing building blocks (namely, 2-step RACH, CG type1 resources). So, in Rel-17 the work needed in RAN1 is being carried out using a light-weight mechanism of *driving the necessary work through LSs from the main WG (i.e. RAN2)*. Judging by the areas of work that we have heard so far (support mobile terminated traffic, IDLE mode support, RRC-less, improvements to backhaul signalling, DL-CG support, optimisations for cell reselection, support for URLLC etc) we think an arrangement similar to this can also work in Rel-18 and would minimise the impact to RAN1.

Then, we would like to thank LG-Uplus for their explicit support and agree with the points raised that this is beneficial in use cases that requires small infrequent data exchanges that require UL and DL support (specifically DL too which is not covered in Rel-17).

5 – NEC Corporation

Comments on SDT

Looking at comments in previous phase, e.g. #1, #3, #6 and #8, many companies showed their interests on SDT in Rel-18. We are also interested in enhancements for SDT in Rel-18, for example MT-SDT, RRC-less SDT and other Rel-17 leftovers. So we support to have one dedicated email discussion for the scope of SDT in Rel-18.

6 – Xiaomi Communications

IDC:

@vivo's Question "We would like to check is it the correct understanding that enhanced frequency indication is mainly for signaling overhead reduction? "

Answer: Indicating the specific affected frequency range may be helpful to avoid unnecessary de-configuration of the whole bandwidth. Signaling overhead reduction would also be another benefit.

@vivo's Question "On Desensing reporting: Could you explain more about the motivation and the solutions?"

Answer: The desensing issue which is known as MSD (Maximum Sensitivity Desense) is now discussed in Rel-17 RAN4. The solution is to allow the UE to report the desensing issue to the gNB. Then the gNB can try to reduce the UL transmission power of the UE, or use TDM (either DTX or DRX) for FDD band.

@vivo's Question "On Preferred radio capability: It seems to overlap with the UE capability adjustment as being discussed in MUSIM thread?"

Answer: We consider that all capability sharing issues could be discussed together to avoid duplicated/colided solutions.

@vivo's Question "On UE reporting of its preference DRX: There are some Rel-16 UE assistant information for DRX introduced, could you please explain the difference?"

Answer: The IDC TDM solution would include DRX solution (only for DL interference), UL/DL configuration (for both UL and DL interference) and UE autonomous deny. Firstly the UL/DL configuration (for both UL and DL interference) is missing. Secondly the DRX is to avoid the DL interference from other UL transmission. In NR, the UE could have more parallel/types UL transmissions (e.g. WiFi, BlueTooth, 3GPP (1st/2nd/3rd) harmonic wave or intermodulation) affecting different DL frequencies. Indicating one DRX can not reflect all the DL interferences. Thirdly, the autonomous deny solution may still be on the table depending on companies' interests.

7 – KT Corp.

We would also like to see further enhancement for SDT as some of the proposals discussed here shows potential benefits to our 5G customers. I would prefer to have a separate thread for SDT.

8 – KT Corp.

Regarding DSS, we also see strong needs for the enhancement as Rel-18 product which is likely to be available from 2H of 2024 and there is potential 3G/4G spectrum refarming for NR usage during that time. It is likely that LTE is going to last for quite a while and we don't see any other solution which can cover both LTE and NR within the same spectrum.

9 – China Unicom

Answer to #1 HuaWei Technologies Co., Ltd and to #3 LG Uplus on XR QoE

In the scope of XR, it is proposed "Application awareness at RAN and RAN awareness at application". The intention aims to improve the user experience. While **in the scope of NR QoE enhancement, RVQoE is one of the important objectives, and new service type such as XR, TSN should be supported.** For XR service, the coordination between these two SI/WI are needed. It is observed that NR QoE enhancement will provide generic mechanism for RAN awareness of service. That will bring the benefits for supporting XR service in R18.

The potential scope of NR QoE enhancement in R18 should includes:

- Leftover features which are not included in R17 normative phase should be specified in R18.
- Specify QoE measurement collection and reporting continuity in Inter-system and Inter-RAT scenario.
- Specify the QoE configuration, measurement collection and reporting in *RRCIDLE* and *RRCINACTIVE* state.
- Specify and support for QoE in MR_DC:

- Depending on the result of R17 normative work, the following features may be further specified in R18.
 - Specify per-slice QoE measurement and reporting mechanism if not complete in R17, specify the per-slice configuration and reporting mechanism, RAN-visible and radio related metrics for slice optimization.
 - Specify more RAN-visible parameters based on R-17 normative work and specify RAN-visible parameters for more service types, maybe depend on SA4, such as XR, URLLC, TSN etc.
 - Specify radio related QoE parameters and information not include in current MDT measurements for different service types, such as jitter for TSN, etc.
- Other potential enhancement can be further discussed, e.g. AI/ML for prediction of user QoE metrics/score.

10 – Sony Europe B.V.

SDT: We would also like to see continuing work on SDT based on progress and leftovers from Rel-17, and the large interest from many companies, including UL+DL, power saving aspects, subsequent data transmission, mobility aspects, RACH and CG etc.