RAN93e-R18Prep-02 - Version 0.0.6
RAN

3GPP TSG RAN#93e **RP-211652**

Electronic Meeting, September 13 - 17, 2021

Agenda Item: 9.0.1

Source: NTT DOCOMO, INC.

Title: Moderator's summary for discussion [RAN93e-R18Prep-02] UL enhancements

Document for: Information & Decision

The discussion in this thread covers the topic #2 [RWS-210659] "**Uplink enhancements**" with the following example areas:

- >4 Tx operation
- Enhanced multi-panel/multi-TRP uplink operation
- Frequency-selective precoding
- Further coverage enhancements

Deadline and NWM organization based on the guidelines provided by the RAN Chair in [RP-211639].

As per guidance [RWS-210659] of the RAN Chair the discussion in this thread should be based on the (RAN REL-18 workshop) RWS submissions.

The aim is to converge on a set of areas with a reasonable scope as a "high-level description" – where "high-level description" herein is not a "draft SID/WID" but is something like a single slide with a set of bullets. In other words, it can be viewed as a skeleton of the possible objectives with some high-level notes.

Please avoid any input like "We support / we do not support" as this is no "number counting" driven discussion, but focus on tangible commercial interests (near & longer terms).

1 Initial round

1.1 Collection of company views

1.1.1 General high level views

Feedback Form 1: General high level views

1 – China Telecommunications

From China Telecom's point of view, we think the example areas of UL enhancement can be divided into two separate WIs, e.g. UL capacity enhancement and further UL coverage enhancement. More than 4 Tx operation, enhanced multi-panel/multi-TRP uplink operation and frequency-selective precoding can be included in UL capacity enhancement. Moreover, we think UL Tx switching enhancement can be also included, potential scope can be: enable more configured UL bands than UL RF capability & UL Tx switching schemes across more than 2 bands etc.

The main reasons for two separate WIs lie in: First, coverage performance is really important for operators, although some enhancement schemes are being specified in Rel-17, the performance gaps still exist. As we have devoted great efforts in the study phase discussing the potential solutions, we think we can move forward one step and see what can be done in Rel-18 to further improve the coverage performance. Second, the corresponding scope and work load may be too huge to include all the areas under a single WI for uplink enhancement.

2 – Futurewei Technologies

Futurewei thinks R18 UL enhancements are important, especially on improving the flexibility of UL transmissions (e.g., via UL carrier switching, UL antenna switching), given more UL heavy traffic in new use cases and limited UE UL transmission capabilities. Overall, the enhancements should benefit general UE devices (such as smartphones) and not just UEs with very high capability.

3 – Apple Computer Trading Co. Ltd

In our view, there are two key categories in this area: UL capacity enhancement and UL coverage enhancement, where the first 3 examples, i.e. >4 Tx UL transmission, UL frequency selective precoding and UL multi-panel transmission, should belong to the UL capacity enhancement category. Based on past experience, it seems quite challenging to finish all the three examples within a release. Thus, we suggest we pick up up to 2 examples from UL capacity as well as 1 or 2 examples from UL coverage enhancement in Rel-18.

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5 – Intel Deutschland GmbH

We consider that it may be preferable to include all DL and UL MIMO enhancements into a single MIMO WI, but acknowledge this could result in a very large item.

6 – TELECOM ITALIA S.p.A.

We think that UL enhancements is one of the key topic in Rel 18. I tend to agree that it would be better to have "simple" Work Items rather than big containers. Adding to the previous suggestion to have two WIs (capacity enhancements and coverage enhancements), we suggest to further split the capacity enhancements in two, differentiating between smartphones (limited in e.g. size, power, ...) and high end/industrial devices, which could not have the above restrictions

7 – Qualcomm Incorporated

UL enhancements is an important topic for Rel-18.

For now, we prefer not to discuss how many UL enhancement WID there should be. As it has been discussed before, some UL enhancements, such as frequency selective precoding, or >4Tx, if agreed, may be moved to a joint DL/UL MIMO WID. At this point, we don't see the benefit of splitting the remaining items further.

8 – SHARP Corporation

In our view, Rel-18 UL enhancements are important from both the capacity and coverage perspectives, in order to support broader applications and services.

9 – ZTE Corporation

We support UL enhancements as one Rel-18 direction to satisfy the demand coming from both the operators and vertical industries. In our view, the target should include both capacity enhancements and coverage enhancements with also taking URLLC requirements for vertical use cases into account. Overall, we think this should be a RAN1 leading topic, which may also involve RAN2 works depending on the detailed enhancement aspects.

10 – CATT

NR supports a maximum of 4 layers in the UL and 8 layers in the DL. It is desirable to bring UL peak data rate on par with DL to allow a balanced spectrum usage and user experience. In our opinion, up to 8 UL layers should be supported in Rel-18.

11 – CATT

In general, we think UL enhancements is important in Rel-18. We are supportive of >4 Tx operation, enhanced multi-panel/multi-TRP uplink operation and frequency-selective precoding. We also support further coverage enhancements in general and we can further discuss the detailed channels/solutions for coverage enhancements.

12 – NTT DOCOMO INC.

From our perspective, UL throughput/capacity enhancement is more important than UL coverage enhancement for Rel.18, due to our customers demand (e.g. video uploading in stadium). For coverage enhancement, as we already enhanced bottleneck channels in Rel.17, we don't see the need to enhance it, unless there is new scenario from Rel.17 discussion. So, we should have more enhancement features for UL capacity enhancement than UL coverage enhancement in Rel.18.

13 – LG Electronics France

While we understand both enhancements to UL MIMO and enhancements to coverage enhancements may satisfies similar goal of UL coverage/capacity enhancements, we think separation of these two items may need to be considered at some point of time on the course of discussion since they may have quite different technical aspects.

14 – Guangdong OPPO Mobile Telecom.

New services keep emerging and they would require higher and higher uplink data transmission. For instance, high-definition live news coverage service would require 1080P or even 4K video transmission in

uplink. Therefore, we can observe strong motivation for improving the NR uplink transmission throughput. In order to support this type of new services, we suggest to support higher layer UL MIMO transmission.

On the other hand, as the limited UL resources for the typical TDD NR network, UL coverage is still needed to considered. During the latest release, some enhancements were introduced to improve the UL coverage. However, due to the limited time, some other enhancements were not specified so far. Thus, we think there are still room for further enhancement of UL coverage.

15 – NEC Corporation

We have three high-level comments.

1. Some objectives should be frequency range dependent. To be more specific, frequency-selective precoding and >4Tx operation are only suitable for FR1, if supported. On the other hand, enhancements on multi-panel/multi-TRP uplink operation are targeting FR2.

2. Some objectives should be defined together with DL MIMO. For example, multi-panel/multi-TRP uplink operation is closely linked to the DL MTRP/BM enhancements.

3. UL capacity enhancement and UL coverage enhancement are targeting different scenarios and may be enhanced on different target physical channel, e.g. UL capacity enhancement forces on PUSCH and UL coverage enhancement forces on PUCCH and PRACH.

16 – Nokia Corporation

We have the following general comments:

- From the Rel-18 workshop it is clear there is a strong request from operators to **focus on UL enhancements** in Rel-18, including capacity driven enhancements and multi-TRP/multi-panel aspects.
- **Multi-TRP/multi-panel aspects** are split between DL and UL threads, with the main UL aspects considered here. For future discussions we should **consider merging this topic and DL MIMO**, e.g. as "**Coverage and multi-antenna enhancements**" with focus on uplink multi-antenna aspects.
  At the very least, an eventual WID needs to combine DL and UL aspects of MIMO enhancements, where applicable. Coverage enhancements can be considered separately.
- Clear objectives needed for **RAN4** work on all topics, to be listed already when drafting the WID.

17 – CAICT

Uplink coverage and capacity enhancements are important for 5G-Advanced. In addition to the 4 listed enhancements, more enhancements could also be considered such as uplink tx switch and so on.

18 – SoftBank Corp.

UL throughput/capacity enhancement are important area in Rel-18. In addition, we think UL CA enhancement is one of the important technology we should look at in Rel-18 because UL CA is not actively used in the commercial network, which is unfortunate.

For coverage enhancement, we are supportive for this activity itself. However, it wouldn't be good to simply revive the dropped technologies in Rel-17 items.

19 – MediaTek Inc.

- Support further UL performance enhancements.
- Targeted device type would need to be discussed for some proposals.

- Multi-beam aspects (including TCI extension to multi-TRP) apply jointly for UL and DL, so may be best discussed together in future.

20 – China Mobile Com. Corporation

We think UL enhancement is an important topic, which both enhance the UL capacity and coverage. We are open to discuss the UL capacity and coverage in a single WI or turn into two separate WI. More than 4 Tx operation, enhanced multi-panel/multi-TRP uplink operation and frequency-selective precoding are promising for the UL capacity. And there are leftover issues from Rel-17 and some useful features are not included in the Rel-17 could be further specified in Rel-18, e.g. some enhancements to the FR2 band.

Besides, the UEs aggregation from our side could be used to enhance the UL performance. At least, more power from multiple UEs under UE aggregation could be used for single UL transmission, which could increase the UL transmit power. And the UL antennas could be virtualized for a single UL transmission. Not only the coverage but also the capacity could be enhanced by UE aggregation.

21 – China Unicom

We thinks R18 UL enhancement is an important topic. UL enhancements should include UL capacity enhancement and UL coverage enhancement. We support >4Tx operation, Enhanced multi-panel/multi-TRP uplink operation and Frequency-selective precoding. For UL coverage enhancement, it is propose to include further enhancement on PUSCH, PUCCH and PRACH.

22 – Huawei Tech.(UK) Co.. Ltd

The current example areas do not include uplink enhancement specifically for smartphones. UL capability of current commercial NR phones is with up to 2Tx. More Tx RF chains are difficult to implement for smartphones due to increasing complexity, size, overheating, power limitation, spurious emission and intermodulation interference. A high percentage of smartphones is expected to remain so in 2025. Other companies have also shown similar concerns for the UL capability limitations in June workshop, such as Tdocs 0369, 0449, 0143, 0183, 0165 and 0056. A proposal in that direction is provided in the ”other proposals” section. Also generally we believe uplink enhancements are a critical part of Rel-18 and deserve their own project separately from downlink.

23 – Telia Company AB

We see UL enhancements as one of the priority work items for Release 18. WIs should be clear and focused and not trying to capture all in one big WI.

24 – Asia Pacific Telecom co. Ltd

From our point of view, UL enhancements is an important topic for Rel-18. There are more and more advanced applications with more strict reliability, throughput and latency requirements, such as XR, machine vision, vision-based factory detection (e.g., 3-dimensions enabled sensor), remote medical service and live video. Increasing the uplink spectrum and the UL data rate to meet such strict requirements for the advanced applications is an important step to meet the commercial needs.

25 – LG Uplus

Our prioritized UL enhancement area is as following;

- UL coverage enhancement in throughput perspective (XDD and dynamic RF carrier switching are promising)

- SRS coverage enhancement for DL throughput enhancement in TDD (long-sequence SRS and multi-TRP UL reception is promising)
- UL power saving (Dynamic RF carrier switching is promising)
- Reliability enhancement for data channel (multi-TRP UL reception is promising)
- Reliability enhancement for control channel (multi-TRP UL reception is promising)

26 – Sony Corporation

We agree with China Telecommunications that there should be two WIs. One focusing on UL capacity enhancements (e.g. supporting UL video streaming use cases) and one focusing on coverage enhancement (continuing the CE work from Rel. 17). In fact, the mechanisms (or approaches) to achieve coverage are often not the same as for capacity enhancements.

27 – Xiaomi Communications

We think uplink enhancements is an important topic in Rel-18, both capacity and coverage need to be enhanced further on many aspects. Considering the different technical aspects discussed for UL MIMO and Coverage Enhancements, we are open to discuss if separation into two items is needed further at some point.

28 – Rakuten Mobile

It does seem logical to divide the work item into Capacity and Coverage enhancements, however, Thanks to Shannon's theorem it would be difficult to separate them in few cases like Full Duplex & CA Power aggregation, >4Tx Operation etc.

It would be better to keep it as a single Item atleast in the study phase.

Our priority Items for UL Enhancements are

1. Full Duplex (XDD)
2. Multiple UEs/Multi Panel Tx Power aggregation.
3. RACH or other remaining coverage enhancement topic's from Rel-17.
4. Enhancement in UL CA Power Aggregation.

29 – Telstra Corporation Limited

We agree with the general community here that UL enhancements are a key component of Rel-18. These should be aimed at improving both capacity & coverage in equal priority and perhaps this is an appropriate way to split the work into more manageable packages.

30 – Orange

Orange believes that UL enhancement is an important topic for Rel-18, both in terms of coverage and capacity. Specific attention should be made to optimise the UL performance with smartphones limited to 2 Tx.

31 – Samsung Electronics Co.

We support at least the followings, e.g., further coverage enhancement and enhanced multi-panel/multi-TRP uplink operation which seems definite support from plenty of companies.

1.1.2 >4 Tx operation

Feedback Form 2: >4 Tx operation

1 – VODAFONE Group Plc

Aspects to consider in a study include:

- amount of Tx diversity gain in the UL
- whether more than two-layer UL MIMO is possible (in very good radio conditions)
- limitations due to UE power (as the power would be shared across ports)
- target frequency bands / target device form factors (e.g. feasibility for a smartphone form-factor)
- impact on UE RF complexity and power consumption

2 – Futurewei Technologies

Futurewei thinks that it is difficult for general UE devices to support >4 Tx and hence the benefit and urgency of such a feature are not clear.

3 – vivo Communication Technology

It should be clarified that this is for non-handheld devices if agreed to study, specify.

4 – Apple Computer Trading Co. Ltd

In general, we are not interested in >4Tx UL transmission since it has very limited or no deployment use case. We think the target use case for this enhancement is CPE or Fixed Wireless, which should include the following aspects:

- UL codeword to layer mapping
- UL >4Tx for codebook based transmission
- UL >4Tx for non-codebook based transmission
- UL >4Tx for SRS antenna switching

5 – Apple Computer Trading Co. Ltd

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- UL codeword to layer mapping
- UL >4Tx for codebook based transmission
- UL >4Tx for non-codebook based transmission
- UL >4Tx for SRS antenna switching

6 – Intel Deutschland GmbH

We are open for such enhancement in Rel-18. In order to have more efficient discussion in RAN1, the target device type (e.g., CPE) for enhancements should be clarified. We also think that it is important to have requirement specified in RAN4 for 4Tx capable UEs before starting this work on > 4Tx UEs. The objective should consider enhancements to CB, NCB operation as well as SRS.

- Specify >4 Tx operation at the UE including support of 8 MIMO layers for PUSCH. Consider enhancements to CB and NCB operation as well as to SRS.

7 – Beijing Lenovo Software Ltd.

Considering the high demand for UL capacity, especially from CPEs and (mostly) stationary applications such as surveillance cameras which have relaxed requirement for physical size and power consumption, up to 8TX UL transmission in FR1 and FR2 need to be supported in R18. This shall be accompanied with a performance study to verify the gain for >4TX layers in single-panel as well as multi-panel UEs. Related enhancement including SRS and DMRS, UL codebook, new codeword-to-layer mapping shall also be studied.

8 – TELECOM ITALIA S.p.A.

We share the view expressed by Lenovo. >4Tx operation (and multi-TRP) is quite difficult to obtain in smartphones. But it is essential for CPEs and industrial applications where size, power consumption, SAR may not be an issue. Therefore, we suggest to clearly split the activity on UL enhancements between smartphone-like devices and other devices. >4Tx should be focused on the second category.

9 – Qualcomm Incorporated

Given that the deployment of UL MIMO is still focusing on 2Tx, the development of >4Tx for mobile devices in general seems not the highest priority. For regular UEs, e.g., smartphones, we don't see the urgency to pursue this item in Rel-18.

For >4Tx in CPEs, there are actually two options. The first option is UL transmission with increased number of layers. Based on previous study results in Rel-15, we don't see much gain with more than 4 layers. Furthermore, with relatively close to LOS channel for CPE devices, it would be rare to see that the channel rich enough to support more than 4 layers. Therefore, we don't see motivation to pursue more than 4 layer UL MIMO in Rel-18. The second option is >4Tx but with no more than 4 layers. With this, devices can benefit from larger beamforming gain associated with new precoders. If >4Tx work is included in Rel-18, we propose it to be limited to no more than 4 spatial layers.

10 – SHARP Corporation

We support study of 8Tx UL MIMO for some scenarios. We have been considering not only the handset-type devices but also other types of devices, e.g.) CPEs, vehicles, factory devices, etc. To improve the capacity for such devices would be beneficial.

11 – ZTE Corporation

Motivation:

- To enable > 4 layer UL transmission, e.g., up to 8 layer for SU-MIMO, and up to 12 layers or more for MU-MIMO and UE-aggregation.

Objective:

- For CB, high-resolution UL codebook (for both >4 layers and ≤ 4) [RAN1].
- For NCB, re-design of DCI SRI codepoint (for both >4 layers and ≤ 4) [RAN1].
- Increase of #. of DMRS ports per UE [RAN1].

SRS design for supporting 6 or 8 Tx (e.g., for CB, NCB, and antenna switching (e.g., 6T6R, 6T8R, 8T8R)) [RAN1].

12 – CATT

NR supports a maximum of 4 layers in the UL and 8 layers in the DL. It is desirable to bring UL peak data rate on par with DL to allow a balanced spectrum usage and user experience. In our opinion, up to 8 UL layers should be supported in Rel-18. To extend to 8 UL layers, extension of SRS and PUSCH transmission schemes to 8 ports should be considered, including 8 layer DMRS design and UL codebook extension to 8Tx.

13 – NTT DOCOMO INC.

We support it as we observe UL performance gain in dense deployment scenario (e.g., indoor, dense urban). At least it can be supported for CPE-like UEs. Hopefully, smartphone like UE can support it.

14 – Guangdong OPPO Mobile Telecom.

To boost the UL data throughput for highly-demanding UL data rate services/applications, we propose to support higher order SU-MIMO PUSCH transmission with up to 8 layers in Rel-18. From the perspective of implementation, it is possible for a UE with large form factor to use a larger number of Tx antennas. From the technical point of view, in order to support up to 8 layers UL transmission, we need to study and specify the aspects, e.g., 8-port transmission and association signaling, codebook design, RS enhancement and so on

15 – NEC Corporation

We think >4 Tx has some benefit for some non-handheld devices, e.g. IAB-MT. We suggest to study the potential gain firstly, especially on capacity performance on good channel conditions.

16 – Nokia Corporation

Possible objectives are as follows:

- Specify support for higher rank on UL (FR1)
- Specify frequency selective precoding for >4TX precoders (FR1)

17 – SoftBank Corp.

We think >4Tx is a good candidate technology for CPE UEs in Rel-18.

18 – MediaTek Inc.

We support the proposal to specify >4Tx operation targeting CPE/FWA type of UE.

19 – Huawei Tech.(UK) Co.. Ltd

Enhancements for high-end UEs and CPEs with more than 4 Tx antennas can be useful. We would suggest clarifying that this example area is indeed targeting high-end UEs and CPEs:

n >4 Tx operation **for high-end UEs/CPEs**

We would like to note that 3GPP specifications are still missing RAN4 RF requirements for 4Tx uplink, although 4Tx uplink is already supported by the protocols. So this should also be a target for Rel-18.

20 – Telia Company AB

>4TX preferred for Release 18 CPE-based UEs (eg FWA), not for handheld UEs due form factor limits.

21 – Deutsche Telekom AG

We think the ">" (greater) 4 Tx is a mistake based on misunderstandings in the WS. There were voices raised, incl. from Deutsche Telekom, that the optimisation work shall also consider 4 Tx (and not limited to >4 !).

If it turns out that 4 Tx is excluded, we do not see a need for any work in Rel-18, but we clearly see a need to enhance the UL for 4 Tx which would include hand-held devices ...

22 – Asia Pacific Telecom co. Ltd

We have interest in the following example areas:

Supporting of a UE which at least equipped with 4Tx to be configured with more than two UL bands and can be dynamic switched for simultaneous transmission:

- Including Capability reporting mechanism regarding on the supported number of equipped Tx and number of simultaneous transmitted carrier.
- Including a mechanism for flexible adjusting Tx to be mapped with configured bands.
- Including scenario at least to be applicable on CA and further considering DC.

23 – China Mobile Com. Corporation

We are open for the further enhancements of >4Tx operation.

But it seems the use cases only focuses on the CPE which is not the normal size and hand hold cell phones. Then the total amount of CPE could be an issue.

For the FR2, multiple panels which may obviously have more than 4Tx could be considered.

A further thinking is that, >4Tx operation could be considered with UE aggregation. Multiple UEs could virtualize a more than 4Tx for UL transmissions, which could further utilized the enhancements of this topic, but with further consideration the coherence between Tx antennas and CSI issues.

24 – KDDI Corporation

For UL capacity enhancements based on the need of UL heavy scenarios, we are supportive that UL >4Tx operation is in Rel-18 scope. We believe that further consideration should be given to the type of device such as CPE and the corresponding channel model for evaluation e.g., no mobility.

25 – Xiaomi Communications

The enhancments of >4Tx considering both UE and CPEs would bring some benefits for uplink capacity. And many aspects need to be included, eg. the CB,NCB operations, SRS,DMRS too.

26 – Ericsson LM

We are OK to study >4 Tx operation, but use cases should be clearly understood and appropriate antenna configurations and channel models should be used.

27 – Rakuten Mobile

We support >4Tx and higher number of UL MIMO layers for CPE (FWA).

28 – Telstra Corporation Limited

We agree with DT, >4Tx is an 'example' only so we would like to see 4Tx included which helps extend the benefit to more device types.

1.1.3 Enhanced multi-panel/multi-TRP uplink operation

Feedback Form 3: Enhanced multi-panel/multi-TRP uplink operation

1 – Futurewei Technologies

Futurewei suggests to include R16/17 M-TRP UL MIMO carryover into R18. R16/17 M-TRP assumes one UL timing (i.e., TA), generally causing significant UL performance degradation or limiting the use cases for M-TRP. Separate (e.g., TRP-specific) UL timings need to be supported. Other R16/17 M-TRP leftovers may also be considered.

2 – vivo Communication Technology

We support further enhancement of multi-panel/multi-TRP in UL. Items left over from Rel-17 FeMIMO can be starting point. Differenet types of devices can be consisdered. UE power consumption, complexity should be taken care of.

3 – Apple Computer Trading Co. Ltd

Currently in Rel-17, the progress for uplink panel selection is still slow. So far there has been no meaningful agreement. We think it is premature to study simultaneous uplink multi-panel transmission. Instead, Rel-18 should focus on the leftover issues from Rel-17 on uplink panel selection. Thus the following detailed enhancement can be considered:

· Remaining leftover issues on uplink panel selection based on Rel-17, e.g. panel selection for channels other than PUSCH, panel selection for CA and so on

4 – Intel Deutschland GmbH

We support objective related to enhancements to multi-panel/multi-TRP operation. In particular Rel-18 should specify support of simultaneous transmission from the UE in multi-panel/multi-TPR scenarios to improve peak data rate (eMBB) and reliability of the transmission (URLLC). The enhancement should consider both FR1 and FR2 and should focus on PUSCH/PUCCH/SRS physical channels and reference signals.

1. Specify enhancements related to support of simultaneous transmission from the UE in multi-panel/multi-TRP scenarios for both FR1 and FR2 taking into account eMBB and URLLC scenario and PUSCH/PUCCH/SRS signals.

5 – Beijing Lenovo Software Ltd.

We support simultaneous transmission from two panels to two different TRPs in FR2. This is important for enhancing the UL throughput and robustness. The total transmitted layers from both panels can be up to 8. This also includes separate TA, power control, and beam management (including default beams) for the two TRPs. This can be developed as a further extension of R17 unified TCI framework.

6 – TELECOM ITALIA S.p.A.

The activity should be focused on non-smartphone type of devices (see comment on >4Tx operation)

7 – Qualcomm Incorporated

CG support for mTRP

Rel-16/17 mTRP was optimized for dynamic grant-based use cases. SPS/CG support was not included. In Rel-18, support of mTRP should be extended to the SPS/CG use cases in both the DL and UL with more deterministic traffic while taking advantage of the mTRP benefits.

Multi-PUSCH grant for mTRP

In the current Rel-17 60GHz WI, multi-PUSCH grant for FR2-2 is introduced to reduce control overhead. However, in Rel-17, the multi-PUSCH grant was not designed for mTRP operation. To further improve the reliability of transmissions, a straight-forward enhancement can be the extension of the design to allow multiple TB transmission with each TB repeated over different TRPs.

Simultaneous UL transmission for mTRP

For mTRP for UL, the current Rel-17 mTRP, doesn't offer efficient support of simultaneous UL transmission (if UE has the capability). Introducing this feature helps to improve efficiency and delays. Different combinations of simultaneous transmission of channels/signals can be considered, such as PUSCH+PUSCH, PUCCH+PUSCH, PUCCH+SRS, etc.

One use case of simultaneous mTRP is to improve the reliability of PUSCH transmission. For example, in FR2, the same PUSCH can be transmitted to two different TRPs with different beams over the same carrier. Alternatively, UL throughput can be improved by sending two different PUSCH through different beams.

Another important use case of simultaneous transmission is transmitting two different channel/signals on the same CC by fully utilizing the Tx chains that UE is equipped with. For a UE with X ports MIMO capability, the UE has X UL Tx chains. Those Tx chains can be utilized to transmit different channel/signals simultaneously, to avoid unnecessarily channel dropping or UCI multiplexing. For example, when a PUCCH overlaps with SRS on one or more OFDM symbols on a same CC, with Rel-15/16/17, either PUCCH or SRS has to be dropped (depends on the UCI type carried in PUCCH). With simultaneous transmission, PUCCH and SRS can be transmitted using different Tx chains. Another example is avoiding problematic UCI multiplexing in mTRP with simultaneous PUCCH and PUSCH transmission on the same CC. Assuming two asynchronized TRPs where the HARQ-ACK scheduled by the 1st TRP overlaps with a PUSCH scheduled by the 2nd TRP, given the two TPRs may not know the scheduling decision between each other, if UE multiplexing the HARQ-ACK on the PUSCH, TPR 1 cannot decode the HARQ-ACK and TPR 2 may fail PUSCH decoding. This issue can be also solved by transmitting the overlapping PUCCH and PUSCH simultaneously.

8 – China Telecommunications

We think enhancement on multi-panle/TRP uplink operation is needed to achieve higher reliability as well as throughput. We think at least simultaneous uplink transmission across multi-panels can be included in the scope.

9 – SHARP Corporation

We support the following objectives for multi-panel/multi-TRP uplink operation
1. Multi-TRP operation with different TA
2. Simultaneous UL transmission with different UL panels.

10 – ZTE Corporation

Motivation:

- To further improve UL capacity (e.g., 15.7% mean UPT for STxMP) and reliability via spatial multiplexing/diversity.

- To strive for unified signaling design for TD/SD/FD-repetition/multiplexing PUSCH (being compatible for Rel-16 mTRP PUSCH), and frequency selective indication.

Objective:

- High-priority: Support simultaneous Tx cross multi panel (e.g., FDM and SDM, PUSCH vs PUCCH), and left-over issues for multi-panel UE operation from Rel-17 [RAN1]

Mid-priority: Enhancements on UL-only M-TRP operation (involving UL BM and power control) [RAN1]

11 – CATT

The current NR system does not support multi-panel joint transmission. Using multiple panels simultaneously for UL will naturally lead to better diversity and spatial multiplexing gain, both of which are inherent for improved UL throughput, coverage, and reduced beam blockage. For multi-panel transmission, the maximum power of UL transmission may increase linearly with the number of panels, which will further improve UL coverage. In our view, multi-panel enhancement should be considered, including at least multi-panel joint transmission. The relevant scenarios include both single TRP and multi-TRP transmissions. UE power consumption and inter-cell interference due to simultaneous actuation of multiple Tx panels should be taken into account.

12 – ASUSTEK COMPUTER (SHANGHAI)

We also support the enhancements on multi-panel/multi-TRP uplink operation, including simultaneous UL transmissions, different TAs, and UL-only TRP.

13 – NTT DOCOMO INC.

The discussion progress of multi-panel UE in Rel-17 is slow, which should be further discussed in Rel-18. So we support at least UE-initiated panel activation/selection, and panel status reporting to gNB, which is Rel-17 leftover.

And we also support simultaneous UL transmission with different beams, which is beneficial to utilize more than rank2 in FR2, as shown in RWS-210268.

14 – LG Electronics France

We suggest including the following in the scope

- Enhanced UL synchronization for multi-panels/TRPs
- STxMP for both reliability & capacity
- Further MPUE enhancements for vehicle DAS UE (based on input from 5GAA)

15 – Guangdong OPPO Mobile Telecom.

Rel-17 is working on the fast panel selection. A further step is to support simultaneous transmission of multiple panels. The key motivation is to better support highly-demanding UL data rate services/applications. Regarding the applicable UE type, CPE is one of them, which is usually working with power adaptor rather than battery. Considering the typical use case and implementation limitation, we can restrict the number of active panels for simultaneous transmission to be two.

16 – NEC Corporation

For multi-panel UE uplink operation, we see the need to

1. Support enhancements for UE panel management based on Rel-17 solution, for both sTRP and MTRP.
2. Specify enhancements for simultaneous transmission across multiple UE panels, for both sTRP and MTRP.

For multi-TRP uplink operation, in addition, we see the need to

3. Extend the support of MTRP within the unified TCI framework developed in Rel-17, for which there is no consensus to support in Rel-17 according to RAN1 106e agreements, due to lack of time.
4. Support asynchronous MTRP for a more realistic FR2 deployment

17 – Nokia Corporation

Possible objectives are as follows:

- **Multi-TRP operation (FR1 & FR2)**
  - Support more realistic assumptions (e.g., different TA, beam switching gap) for Multi-TRP operation
  - Support UL transmission from a multi-panel UE to two TRPs (simultaneous transmission from two UE panels) (FR2)
- **Multi-beam enhancements (FR2)**
  - Enhancements to support UE-assisted UL beam switching for MPUE
  - Fast UL beam selection for MPE handling

18 – 5GAA

5GAA, as a 3GPP Market Representation Partner, believes that the example area "Enhanced multi-panel/multi-TRP uplink operation" is related to the specific feature "Enhancements for vehicular Distributed Antenna System (DAS) UE transmission" from 5GAA's input to the 3GPP RAN Workshop (see RWS-210360) in June 2021. For the 5GAA members, this feature was ranked level 8 (lowest) out of 8 priority levels and the main motivation identified was:

- Advanced use cases operating in sidelink unicast mode and also via Uu will benefit of enhanced vehicular DAS UE transmission due to the improved signal quality
- This includes HD sensor sharing for AVs, group start, coordinated, cooperative driving manoeuvre, etc.

As potential sub-topic and enhancement, we had identified:

- Include enhancements for vehicular DAS UE. E.g. sending the SL/UL signal/channel only from the antenna panel achieving the best performance for the target receiver

5GAA would be thankful, if 3GPP could consider the above in its further discussions on SI/WIs for Rel-18.

19 – Huawei Tech.(UK) Co.. Ltd

Here multi-panel uplink and multi-TRP uplink operation are mixed as one area. In our view, multi-panel uplink operation by itself is of sufficient interest, starting with fast UL panel selection (being discussed in Rel-17 but possibly not completed in Rel-17 due to the slow progress). Combining with the fact that multi-panel uplink operation at UE is not necessarily bundled with multi-TRP uplink operation, where multiple non-back-to-back positioned panels at UE could be pointing towards the same TRP via beamforming, we suggest splitting them into separate bullets and collect feedback separately in the next round of discussions, as below.

- Enhanced multi-panel uplink operation
- Enhanced multi-TRP uplink operation

For multi-panel uplink operation, given the workload and progress in Rel-17, our assessment is the specification work on fast UL panel selection cannot be completed by Rel-17 but it is worth specifying and should be continued in Rel-18, aiming for a smooth mobility support for handheld UEs under stringent power consumption restriction.

In addition, multi-TRP uplink operation has room for improvement. An important scenario is indoor industrial production lines with many uplink video monitoring points with frequent high definition uplink activity, where uplink reception points are distributed in the factory area and each reception point has a relatively small number of antennas. In this scenario the bottleneck is the maximum number of orthogonal uplink DMRS ports (currently 12), which should be increased to e.g. 24 or 36.

20 – MediaTek Inc.

We suggest to focus on **fast UL panel switching as an extension of Rel-17 MP-UE framework**, which we see as widely applicable in terms of deployment scenarios and device types. We see this as a higher priority focus compared to techniques such as simultaneous multi-panel Tx.

For multi-TRP and multi-beam, latency reduction for intra-cell mobility is still an important issue for FR2 (even after Rel-17 enhancements), and we the following as important (*also added to the DL MIMO discussion thread*):

- UE-initiated beam operation at least including beam selection/activation, if not completed in Rel-17
- Extension of Rel-17 unified TCI framework to support M,N > 1 at least for multi-TRP, and potential use cases for single-TRP

The following could also be considered as slightly lower priority in our view:

- Enhancement to beam indication for grouped UEs for use cases e.g., HST
- Reducing activation delay of TCI states and PL-RSs involving RAN1 design and RAN4 requirement revision.

21 – China Mobile Com. Corporation

multi-panel/multi-TRP uplink operation could enhance the uplink throughput especially in FR2. If the power consumption and complexity is acceptable to UE, the multiple panels could bring additional data rate and avoid the blockage issues.

22 – Asia Pacific Telecom co. Ltd

We have interest in the following example areas:

- Multi-TRP based UL transmission scheme for intra-cell and inter-cell scenarios
- Simultaneous UL transmission with multiple UL panels for same type of traffic types (e.g., eMBB only) or different types (eMBB and URLLC)
- Dynamically switching between multi-DCI based multi-TRP scheme and single-DCI based multi-TRP scheme

23 – Sony Corporation

- Extend Rel.17 UL beam indication to Rel.18 multi-TRP/panel
  - Unified TCI states for either joint or separate UL beam indication was defined in Rel-17 for single-TRP operation. To avoid NW configuration on two parallel UL beam indication mechanisms, it would be better to extend it to multi-TRP/panel operation in Rel-18.
- Extend single TA to multiple TAs for multi-TRP/panel
  - Since there is no RAN1 consensus on supporting single TA or multiple TAs for inter-cell beam management and inter-cell TRP, we hope this issue could be addressed in Rel.18, especially for FR2-2 with shorter CP length.

24 – Ericsson LM

We are open to study multi-TA based multi-TRP uplink operation. Further discussion is needed on the exact scope of such multi-TRP based multi-TRP operation (i.e., whether this applies to only multi-DCI based multi-TRP schemes, or both multi-DCI based and single-DCI based multi-TRP schemes).

In NR Rel-17, multi-TRP PUSCH/PUCCH transmission schemes were limited to TDM based PUSCH/PUCCH transmission towards two TRPs. The TDM based PUSCH/PUCCH transmissions in FR2 are primarily targeting scenarios where the UE is not capable of simultaneously transmitting to two TRPs in the uplink. Hence, in Rel-18, we are open to consider multi-TRP PUSCH/PUCCH transmission schemes that allow simultaneous transmission from multiple panels towards two TRPs.

25 – Xiaomi Communications

we support the following enhancement objectives for the uplink operation,

1.multi-TRP operation to support simutaniously uplink transimissions,

2.multi-beam operation for fast UL panel selection considering the leftover in R17

26 – Fraunhofer IIS

We support the following objective:

- Simultaneous multi-panel UE UL transmission.

27 – Samsung Electronics Co.

We support the following issues:

•UL multi-panel/multi-TRP:

- UL dense deployment (distributed UL, centralized DL), e.g. per-TRP TA and UL PC, enhanced separate DL/UL TCI
- UL simultaneous TX across multiple panels

1.1.4 Frequency-selective precoding

Feedback Form 4: Frequency-selective precoding

1 – VODAFONE Group Plc

Study of this seems beneficial. It is anticipated to optimise UL precoding for channels that are severely frequency-selective (less loss blasting power into fades), but quantification of the typical gains needs some simulation work.

2 – Futurewei Technologies

Frequency-selective precoding has been discussed in previous releases. In order to further consider this enhancement in R18, simulation studies are needed to identify the scenarios (e.g., channel frequency selectivity, typical number of UE Tx antennas), gains, and potential standard impacts.

3 – vivo Communication Technology

We support studying frequency-selective precoding in UL, spectral efficiency as well PAPR should be considered, considering both CP and DFT waveforms. Potential codebook enhancement for 4Tx can also be studied.

4 – Apple Computer Trading Co. Ltd

In general, we are not interested in UL frequency selective precoding since it has very limited or no deployment use case. We think the target use case for this enhancement is for >= 4Tx UE with coherent transmission and the following can be considered

· For codebook based PUSCH operation: control signaling for subband TPMI indication

· For non-codebook based PUSCH operation: Uplink PRB bundling

5 – Intel Deutschland GmbH

We are open for such enhancement in Rel-18. We propose to also have study phase to better understand benefits of the proposed pre-coding considering that previous RAN1 analysis on this enhancement was not very conclusive.

- Study and if sufficient gains are shown specify frequency selective precoding for uplink transmission

6 – Beijing Lenovo Software Ltd.

From simulation, we have observed performance gain up to 40% with UL frequency selective precoding. Frequency selective precoding can be introduced in R18 as further UL capacity enhancement with proper tradeoff between DCI signaling overhead and UL precoding granularity.

DCI format 0*1/0*2 need to be enhanced with subband TPMIs.

7 – Qualcomm Incorporated

The benefit/gain of UL frequency selection precoding comes with the burden of DCI overhead to signal the precoders. The study on this topic should consider the tradeoff between DL DCI overhead and frequency selective precoding gain. Another important aspect for this topic is mitigating the impact of variable overhead (due to variable PUSCH allocated bandwidth) to signal the frequency selective precoders. Moreover, considering the impact of intermodulation, the benefit of frequency selective precoding is questionable. Besides, in Rel-15, it has been observed that frequency-selective precoding is beneficial only for >4Tx, so frequency selective precoding should be deprioritized until after >4Tx operation is introduced. Another aspect is that the benefit/gain of frequency selective precoding is observed only when comparing it to current low-resolution TPMI codebooks, however, the benefit/gain may not exist when comparing it to high resolution wideband precoding.

8 – SHARP Corporation

We support the study of frequency selective precoding to reduce the gap between DL data rate and UL data rate.

9 – ZTE Corporation

Motivation:

- To support high-performance transmission in larger UL BW. Based on our SLS results, it can be observed that there are significant gains for average & edge UPT (more efficient than only enhancing WB high-resolution codebook)

Objective:

- Flexible signaling design with tolerable increase of DCI overhead [RAN1, RAN2]

Above applies to both CB and NCB PUSCH transmission [RAN1]

10 – CATT

NR UL bandwidth is substantially wide and a single wideband precoder cannot sufficiently exploit the channel frequency-selectivity. In our opinion, frequency selective precoding should be supported to fully exploit the adaptive link adaptation gain. The relevant scenarios include near stationary applications where channel is stable within a relatively long period of time to facilitate closed-loop link adaptation, lightly-loaded cells where each user may occupy the entire system bandwidth and densely loaded cells that with frequency-selective channel. For frequency selective precoding, the balance among scheduling overhead, latency and performance should be considered.

11 – NTT DOCOMO INC.

It has low priority as we observe limited performance gain, as shown in RWS-210268.

12 – Guangdong OPPO Mobile Telecom.

In the current spec, only wide band precoding is supported for UL MIMO. For the scenarios with high frequency-selective channel, wideband precoding is not optimal and subband precoding can offer better performance. During the R15 standardization procedure, many studies and evaluations were carried out for subband precoding, which showed that the performance gain of subband precoding for 2-port/4-port PUSCH transmission is not so large. Subband precoding may achieve some performance gain for 8-port PUSCH transmission. Thus, we propose to study first and then specify, if necessary, subband precoding only for 8-port UL transmission.

13 – NEC Corporation

Frequency-selective precoding has benefit for UL capacity enhancement theoretically. On the other hand, it may increase DL signaling overhead and increase processing complexity on both UE side and network side which is the payment. We should study it firstly and find the gain and standard impact. Study should include codebook based transmission and non-codebook based transmission.

14 – Nokia Corporation

We support specifying frequency selective precoding for >4TX precoders in FR1, as gains are not expected to be meaningful in other scenarios.

15 – MediaTek Inc.

We believe that user/system performance would benefit from frequency-selective precoding, but we also believe that **codebook compression and signalling optimisations should be specified** to minimise associated overhead.

16 – Huawei Tech.(UK) Co.. Ltd

Frequency-selective precoding is missing on the uplink and could be specified with small efforts.

17 – China Mobile Com. Corporation

The frequency selective precoding could benefit the UL performance not only in capacity but also for the coverage. But signaling overhead and processing complexity should be serious considered and limited.

18 – Ericsson LM

For UL frequency-selective precoding, we should further investigate the potential gain and complexity tradeoffs in Rel-18.

In more detail, frequency-selective precoding was studied in Rel-15, however more investigation was needed, e.g. establish the tradeoffs of UL throughput vs. DL signaling overhead and the performance with realistic UE antenna configurations, especially as the number antennas increases and where directional antennas are used. We can understand the wide interest in frequency-selective precoding, especially given its support on the downlink. However, UL MIMO behavior and implementation are quite different on the uplink from the downlink, especially with respect to antenna configurations, power limitations, and the high overhead needed for frequency-selective precoding on the uplink. Overall, we think that UL frequency-selective precoding is an interesting area, but we should further investigate it to see how its potential gain and complexity tradeoffs in Rel-18 use cases, and, in particular, how it can be supported without drastic changes to DL control signaling and PDCCH.

19 – CEWiT We support the study of frequency selective precoding as part of UL enhancements
20 – Xiaomi Communications We support the enhancements on frequency selective precoding, if real benefits can be achieved considering also the tradeoff between performance gain and signaling overhead.
21 – Rakuten Mobile We support uplink frequency selective precoding.

1.1.5 Further coverage enhancements

Feedback Form 5: Further coverage enhancements

1 – China Telecommunications From China Telecom's point of view, further coverage enhancement in Rel-18 is essential and the potential scopes for further coverage enhancement can include: 1) Specification of PUSCH enhancements 1-1) Specify enhancement on PUSCH repetition type B · Actual PUSCH transmission across the slot boundary/invalid symbols · The length of actual repetition larger than 14 symbols 1-2) Specify mechanism to support sub-PRB transmission with multi-slot aggregation, e.g. 6 tones 1-3) Specify mechanism to support higher layer compression 1-4) UE transmit waveform design to reduce MPR, e.g. including tone reservation, FDSS (Frequency Domain Spectral Shaping) with spectral extension for QPSK. 2) Specification of PUCCH enhancements 2-1) Specify DMRS-less PUCCH with UCI payload up to 11 bits 3) Specification of PRACH enhancements for short formats for FR2 3-1) Multiple PRACH transmissions with the same beam 3-2) Multiple PRACH transmissions with different beams 4) Left overs of Rel-17 WI on coverage enhancement
2 – VODAFONE Group Plc Techniques such as those in RWS-210076 seem worthy of study.

3 – Futurewei Technologies

UL coverage enhancement continues to be important but remains to be very challenging. A study phase / SI may be needed for some of the new coverage enhancement proposals from the RAN R18 workshop.

4 – Apple Computer Trading Co. Ltd

We have no strong interests in further UL coverage enhancements. The following items were discussed in Rel.17 study and can be considered as potential topics in Rel-18.

- DMRS-less PUCCH
- PRACH repetition

5 – Intel Deutschland GmbH

We think further coverage enhancement can be considered in Rel-18 to address further coverage gap for uplink transmission. The potential scopes may include

1. Some left-overs from Rel-17 WI for coverage enhancement if identified.
2. Multiple PRACH transmissions with same beam for FR2.

6 – Spreadtrum Communications

We support UL coverage enhancements. Although Rel-17 studies some solutions for some bottleneck channels, such as PUSCH, PUCCH and Msg 3, there are still some gaps between the required performances, even with the solutions defined in Rel-17 WI. In addition, there are UL channels do not in the scope of Rel-17, such as PRACH formats, which also found to be bottleneck for UL. Thus, from the coverage aspect, we think further UL coverage enhancements are necessary.

7 – Beijing Lenovo Software Ltd.

We believe the UL-only node proposed by some companies needs further discussion. In our opinion, comparison with similar approaches that can improve UL coverage, e.g., smart repeaters is required in order to better assess the merit of this framework. Issues such as BM, TA, PC should be discussed, where KPIs such as throughput, complexity, reliability, latency need to be considered. Besides, we are supportive to study coverage enhancement in Rel.18 for the potential bottleneck channels identified but not further studied in Rel.17, e.g., PRACH for FR2/FR1.

8 – Qualcomm Incorporated

Dynamic power aggregation

PUSCH enhancements in the power domain are worth pursuing in Rel-18. Power domain enhancements were studied as part of Rel-17 coverage enhancements but were left out of the WI. Power is the most valuable commodity in the uplink, and enhancements targeted at unlocking additional uplink power are very useful. We think dynamic power aggregation that aims to take advantage of all the PAs that are available to a UE and drive them to their individual maximum power would be the most straightforward manner to increase uplink power by several dBs. The prime consideration is focusing on typical multi-band UEs that already have all the necessary hardware to support the higher power without RF design changes. With this, UL link budget limitation would become a motivator and trigger for turning on UL CA, and using it in the widest setting, as opposed to being a trigger to turning it off, as it is today.

Other PUSCH enhancements

Other PUSCH enhancements aren't likely to be practically essential and we don't think they are worth pursuing in Rel-18.

Sequence based (non-coherent) PUCCH

On PUCCH enhancements, we continue to believe that sequence based PUCCH offers significant gains over legacy PUCCH. Sequence based, DMRS-less PUCCH should be adopted and specified in Rel-18.

RACH repetition

RACH enhancements in the form of repetitions with or without beam sweeping were studied in Rel-17 coverage enhancement. We think this enhancement is worth pursuing in Rel-18.

Dynamic PUCCH repetition indication for other than DG

Dynamic PUCCH repetition indication is supported for HARQ ACK corresponding to DG PDSCH. But the equivalent operation is unsupported for either HARQ ACK corresponding to SPS PDSCH or for CSI. We propose closing this gap in Rel-18.

9 – SHARP Corporation

Further coverage enhancement is benefit for operators. In Rel-17, some solutions are being discussed to improve coverage performance. However, other solutions (e.g., sequence-based PUCCH) discussed in SI phase of Rel-17 are deprioritized due to TU and the performance gaps still exist. Therefore, we think further coverage enhancement is essential.

10 – ZTE Corporation

As studied in Rel-17 coverage enhancement SI, not only PUSCH but also other channels could encounter coverage issues in some scenarios. As UL MIMO enhancements are mainly targeting for PUSCH, enhancements to other channels are also desirable to match up PUSCH coverage. In our view, the following enhancements, which is supported by the majority in Rel-17, could be considered.

- Sequence based PUCCH for >2 bits UCI [RAN1]
- Multiple PRACH transmissions [RAN1, RAN2]

11 – NTT DOCOMO INC.

It has low priority as we already enhanced bottleneck channels in Rel-17. The new scenario from Rel-17 should be clarified first, if it is to be supported in Rel-18.

12 – Guangdong OPPO Mobile Telecom.

UL coverage should be continuously improved as there were some part not specified due to the limited of time. For PUCCH, the DMRS-less schemes can be then considered in Rel-18. For other channels, like PDCCH, PRACH, could also be considered under certain condition. PDCCH may taken into account of 1RX. Other enhancement can be justified by more evaluation as the UL coverage will always be helpful for the overall NW performance.

13 – CATT

In general, we support further enhance UL coverage in Rel-18. Various potential enhancements for different channels were proposed in Rel-17 CE SI and WI, but it is challenging to include all of them in Rel-18. We prefer to focus on one or two bottleneck channels and prioritize the techniques with clear benefit without significant impact on the specifications and implementations.

14 – EURECOM

We support further improvements in coverage for the critical channels identified in the Rel-17 SI. In particular, many companies showed significant gains of a DMRS-less PUCCH transmission compared to Rel-15 PUCCH Format 3. Therefore, a DMRS-less PUCCH transmission format for larger payloads (> 2bits) should be specified in Rel-18.

15 – NEC Corporation

We think PUCCH and PRACH coverage enhancement may have higher priority than PUSCH coverage enhancement since we have done some PUSCH coverage enhancement in Rel-17 and left-over issue seems have less marginal utility. Based on TR of coverage enhancement, DMRS-less PUCCH enhancement, multiple PRACH enhancement and PUSCH repetition type B enhancement could be included.

16 – Nokia Corporation

Considering the areas covered already by the Rel-17 WID on coverage enhancements, our view is that the main areas for coverage enhancements in Rel-18 are the following:

- RACH enhancements:
  - Specify multiple msg1 transmissions using same TX beam (FR1)
  - Specify multiple msg1 transmissions using different TX beams (FR2)
- Investigate and specify coverage enhancements in power domain (FR1 & FR2):
  - Focus on modulation orders beyond BPSK
  - Investigate and specify new methods to reduce PAR/MPR, especially spectrum extension
- Extend the usage of PC2 to FDD bands

17 – SoftBank Corp.

Coverage is, needless to say, very important to operators. Thus we are supportive for this activity. Regarding the detailed scope, we are not quite sure if further gain can be achieved for PUSCH on top of Rel-17 features. We can focus on other aspect, e.g. PRACH and/or DMRS-less PUCCH in Rel-18.

18 – Huawei Tech.(UK) Co.. Ltd

For the further coverage enhancement, the current R17 is focusing on lower data rate such a voice traffic. In R18 the higher data rate (e.g. 1Mbps) should be the focus for the further coverage enhancement. Power domain enhancement is a straightforward way to improve the uplink coverage. One way is to have reduced MPR for QPSK to enable the UE to transmit more power using the current power amplifier, e.g. power class 3 UE can transmit 26dBm power using QPSK if the MPR is reduced as proposed in R17 coverage enhancement SI. Another way is to increase the pi/2 BSPK spectrum efficiency for the cell edge users. Some leftovers from R17 coverage enhancement SI e.g. PRACH and PUCCH enhancement could be considered, but the PUSCH enhancements should be prioritized.

19 – China Mobile Com. Corporation

We are not sure the PUSCH repetition type B should be further enhanced for the coverage, considering the specification complexity and the using scenario of type B should be more focused on the URLLC traffic.

We are open for the further enhancements for the FR2 operations.

For the UL coverage, more resource should be inputted for the UL transmission, e.g. more transmit power or more antennas to utilize beamforming or TxD gains. The work in Rel-17 is more limited by the transmit power and UL time domain resources. Then, the UE aggregation could be an candidate to enhance the UL coverage, which more transmit power from multiple UEs and more antennas. Besides that, a lower frequency for UL transmission could be also considered.

20 – MediaTek Inc.

For radio link focused coverage enhancements (i.e. not considering repeaters or relays), the agreed essential improvements should already be specified in Rel-17, so we hope that this has addressed the main operator concerns. So any consideration/discussion on additional techniques should take the Rel-17 SI and WI outcomes as baseline, and consider incremental gain vs complexity.

21 – LG Uplus

In our analysis, SRS coverage in FR2 is bottle neck to provide sufficient DL throughput. We need to investigate SRS enhancement such as long-sequence SRS.

22 – Sony Corporation

The Rel 17 CE SI/WI focus on joint channel estimation (JCE) and related repetition schemes for bottleneck physical channels. A further area to study would be repetition feedback. Based on the assumption that the DL is typically much better than the UL, schemes where ”error free” feedback is used to enhance the UL should be investigated.

23 – KDDI Corporation

In Rel-17 study, we have identified bottlenecks and have been working on the specification of effective methods for the channels to be addressed. In Rel-18, priority should be given to the channels that have not been addressed in Rel-17 e.g., PRACH.

24 – BBC

The BBC supports measures to enhance cell coverage in order to improve the delivery of media services over 5G networks, especially in rural areas.

25 – Ericsson LM

We expect that the low hanging fruit for what we can do in coverage enhancement in RAN1 has been addressed by the Rel-17 study & work item. There seem to be more potential gains from a RAN4 perspective, e.g. for MPR reduction, where we use existing physical channels and waveforms. Approaches that we do consider should be substantial enough such that they achieve real gains in practice, that is, they will not be lost in in MPR, test tolerances, or other uncertainties in RAN4. Therefore, we think that coverage enhancement aspects could be driven by RAN4, with RAN1 as a secondary WG.

The RAN1 study also identified VoNR signaling (i.e. SIP Invites) as a potential coverage limitation. The UDC work item may allow higher layer compression of VoNR/SIP content, but does not address use cases where encryption is used. Protocols such as SigComp can support encrypted content as the compression is done prior to encryption or using IPSec, and so we think that higher layer compression (SigComP) should be considered as a mechanism for coverage enhancement. However, such work should probably be addressed by working groups outside of RAN, e.g. CT1 and SA4. RAN working group should trigger an LS towards the SA and CT working group.

26 – Telstra Corporation Limited

We strongly agree with Qulacomm's comments, particularly on dynamic power aggregation.

27 – Xiaomi Communications

we support to continue the further coverage enhancements in Rel-18. The topics can be discussed further ,

-PDSCH type B transmission

-DMRS-Less-PUCCH

-PRACH transmission

28 – Rakuten Mobile

We support Continuing UL Coverage enhancement WI in REL-18. We are especially interested in RACH and Lower modulations.

1.1.6 Other proposals

Feedback Form 6: Other proposals

1 – Futurewei Technologies

Futurewei suggests to consider the following proposals to improve the flexibility of UL transmissions for UEs with limited UL transmission capabilities (such as for regular mobile phones), especially given more UL heavy traffic in newer use cases:

- UL carrier switching
- UE Tx antenna switching enhancements for UL transmissions

2 – vivo Communication Technology

support flexible switching of waveforms and rank >1 for DFT waveform.

study, if needed specify, impact of hardware impairments on UL performance.

3 – Intel Deutschland GmbH

1. We think that key / higher priority uplink enhancements are still missing. In particular it would be important to address UL issues in Rel-18 by using more advanced deployment scenarios such as HetNet (TRPs with different Tx power) or Rx only capable TRPs. The corresponding enhancements can be used for further densification of the NW in cost efficient manner. The detailed objective for this enhancement is provided below.

- Identify and specify enhancements to support deployment scenarios such as TRPs with different Tx power / number of antennas or TRPs with Rx only capability

2. We think that Rel-18 should also support SRS enhancements to facilitate better channel prediction in high mobility scenarios. The detailed objective for this enhancement is provided below.

- Specify SRS enhancements to more efficient DL and UL transmission in high mobility scenario

3. We think that support of additional orthogonal DM-RS ports can be considered by introducing additional CS for uplink DM-RS. The detailed objective for this enhancement is provided below.

- Specify additional CS for DM-RS Type I for overhead reduction and support of larger number of orthogonal DM-RS ports.

4 – Beijing Lenovo Software Ltd.

Dynamic switching between CP-OFDM and DFT-s-OFDM transmission modes shall be supported to enhance cell-edge UE.

5 – TELECOM ITALIA S.p.A.

One of the key limitations in UL performance is the fixed TDD frame structure imposed by regulators (at least in Europe). Hopefully this topic is covered in the flexible frame format discussion, otherwise it should be considered under this topic.

A clear distinction between smartphones and non-smartphone devices need to be done, otherwise the progress will be strongly impaired by the limitations imposed by smartphone-like devices. Therefore two Work Items should be at least approved to differentiate among form factors/UE capabilities.

Performance enhancements for smartphone-like UEs should be identified (study phase?)

6 – Qualcomm Incorporated

Uplink multi-layer DFT-S-OFDM waveform is a feature that LTE supports. To bring the NR cell edge UE's UL peak spectrum efficiency to at least similar level as LTE, this feature can be introduced in NR. Much of the LTE design can be reused to minimize the impact to specification and UE implementation. Some features from NR single layer DFT, such as Pi/2-BPSK DM-RS, can be reused to preserve the NR enhancement introduced to DFT-S-OFDM waveforms.

7 – ZTE Corporation

Firstly, we suggest to consider UL codeword (CW) mapping enhancement, targeting both FR1 and FR2. The issue was observed from real tests, and the UL CW mapping enhancement for ≤ 4 layers was supported by many operators based on RAN1 Rel-17 TEI discussion. Specifically, to support 2 CWs for >=2 layers in UL with the following objectives

- CW mapping, signaling design (e.g., per-CW MCS/NDI/RV indication) [RAN1]
- UCI multiplexing, e.g., in one out of 2 codewords [RAN1]

Depending on the overall scope about the enhancements in Section 1.1.1 1.1.5, we are also fine to consider to include UL CA enhancements (as flexible spectrum integration to be discussed in additional candidate topics-set 1) and UE aggregation (to be discussed in additional candidate topics-set 3) in UL enhancements.

8 – NTT DOCOMO INC.

We think UL dense deployment with Rx only is important for both UL capacity and UL coverage enhancement. As shown in RWS-210268, large performance gain can be observed with additional RX points deployment (610% cell average and 740% cell edge gain). The potential enhancements for UL dense deployment include UL TPC, TA, UL BM, etc.

We also support dynamic waveform switching b/w CP-OFDM and SFT-S-OFDM for UL, which is beneficial for our NW operation because RRC re-configuration between the two waveforms can be avoided.

9 – China Telecommunications

We think UL Tx switching enhancement can be also included in UL enhancement, potential scope can be: enable more configured UL bands than UL RF capability & UL Tx switching schemes across more than 2 bands etc.

10 – Nokia Corporation

In addition to the enhancements above, the following should be considered for UL-MIMO (not limited to >4TX only):

- Specify support multi layer PUSCH transmission with DFT-S-OFDM

11 – DENSO CORPORATION

Dynamic waveform switching should also be considered as one of the candidate topics.

12 – China Mobile Com. Corporation

In our opinion, the UEs aggregation could be used to enhance the UL performance. At least, more power from multiple UEs under UE aggregation could be used for single UL transmission, which could increase the UL transmit power. And the UL antennas could be virtualized for a single UL transmission. Not only the coverage but also the capacity could be enhanced by UE aggregation.

13 – Huawei Tech.(UK) Co.. Ltd

The current example areas do not include uplink enhancement specifically for smartphones. UL capability of current commercial NR phones is with up to 2Tx. More Tx RF chains are difficult to implement for smartphones due to increasing complexity, size, overheating, power limitation, spurious emission and intermodulation interference. A high percentage of smartphones is expected to remain so in 2025. Other companies have also shown similar concerns for the UL capability limitations in June workshop, such as Tdocs 0369, 0449, 0143, 0183, 0165 and 0056.

However, UE UL capabilities such as band configuration, activation and concurrent transmission, are strictly coupled in the protocol designs of Rel-15 17. Thus, smartphones cannot be configured with more than 2 bands if they are equipped with up to 2Tx.

Many operators have deployed or plan to deploy NR on more than two frequency bands with different bandwidths, TDD/FDD duplex and DL/UL configurations. Statically configuring a UE with 2 bands (e.g. one FDD band + one TDD band) limits the amount of UL resources available to that UE, for example during DL slots of the TDD band, whereas another TDD band may provide UL in the same slot with larger bandwidth than in the FDD band. Such restrictions also limit trunking efficiency, load balancing.

In order to boost the uplink throughput and capacity for widely-applicable scenarios, it is necessary to efficiently utilize all uplink resources in multi-carrier scenarios (>2 bands) for smartphones with a limited number of Tx antennas (e.g. 2Tx). Dynamically selecting carriers with UL Tx switching based on the data traffic, TDD DL/UL configuration, bandwidths and channel conditions of each band, instead of RRC-based cell(s) reconfiguration, will lead to higher UL data data, spectrum utilization and UL capacity. This was also proposed by companies at the June workshop, such as Tdocs 36, 56, 122, 199.

Thus we have the following proposal.

Include "Enhanced multi-carrier (> 2 bands) uplink operation for devices with 2Tx" as an additional area for Rel-18 uplink enhancement.

- ***Specify the mechanisms to allow a UE (e.g., 2TX UE) to be configured with more UL bands than its simultaneous transmission capability and specify mechanisms for dynamic carrier selection as well as TX switching between n (n>=2) configured bands.***

With currently listed areas under unlink enhancements, it is unclear where to put UL beam management enhancements that does not relate to multi-panel or multi-TRP uplink operation. For example, to support asymmetric Rx (wide) and Tx (narrow) beamforming from the same UE panel/array (details in Section 4.1.2 of RWS-210438), enhancements to UL beam training procedure are needed. We propose to add an area to cover these interests as below.

Include "Enhanced UL beam management" as an additional area for Rel-18 uplink enhancement.

14 – SoftBank Corp.

We support the following items proposed by other companies:

- multi layer PUSCH transmission with DFT-S-OFDM.
- 2 CWs for >=2 layers in UL

In addition, we think the Scell dropping (currently discussed in RAN4) is real issue which prevent from aggressive use of UL CA. If no solution is introduced in Rel-17, it should be tacked in Rel-18.

15 – MediaTek Inc.

Another useful enhancement to improve UL MIMO performance that we think should be considered is **Parameterized higher resolution precoding matched/tailored to UE antenna architecture.**

We proposed this in the June workshop in our submission (RWS-210093) so it is not newly proposed, and was discussed in the corresponding email thread.

16 – Asia Pacific Telecom co. Ltd

We have interest in the following example areas:

Coverage enhances for PRACH transmission both in FR1 and FR2:

- Multi-Msg1 transmission with different Tx beam and corresponding SSB measurement procedure and resource selection functionality.
- Contention resolution procedure among multiple transmitted Msg1.

17 – Ericsson LM

Assuming they are not supported in Rel-17, we think that a) fast switching between DFT-S-OFDM and CP-OFDM and b) rank 2 and higher DFT-S-OFDM should be supported. Both should have modest spec impact (DFT-S-OFDM is already supported for multilayer UL MIMO in LTE), but allow better PA efficiency and/or coverage, as discussed in RWS-210307.

We also think that UL capacity could be limited by PUSCH DMRS, and therefore we should also specify DMRS capacity enhancements for Type 1 DMRS to at least double the number of orthogonal DMRS ports in one OFDM symbol.

18 – SoftBank Corp.

let me update our comment #14 because it is not completed

We support the following items proposed by other companies:

- multi layer PUSCH transmission with DFT-S-OFDM.
- 2 CWs for >=2 layers in UL

In addition, we think the Scell dropping (currently discussed in RAN4) is real issue which prevent from aggressive use of UL CA. If no solution is introduced in Rel-17, it should be tacked in Rel-18. We can find some proposals from other companies related to UL CA (e.g. from Huawei), and we want to further investigate if they can be used to address this issue.

19 – China Mobile Com. Corporation

Currently most operators have multiple bands, e.g. above 3 bands, for further deployments. How to utilize the multiple bands is one issue. And the enhancement of multiple carrier >2 bands could kind of solve this issue. When needed, UE could switch to lower frequency band to achieve a better coverage. And UEs could also switch to band with larger bandwidth to achieve a higher data rate. we support to further enhance the multi-carrier beyond 2 bands for uplink operation for devices with 2Tx in Rel-18.

20 – Telstra Corporation Limited

Broad UL performance improvements will form a key part of Rel-18 scope so we support Huawei's proposal to enhance >2 band MC UL for devices with 2Tx

21 – Rakuten Mobile

We also support, Dynamic Carrier Selection for Uplink CA and UL CA Power increase over 26dBm for short duty cycle.

22 – vivo Communication Technology

Currently the handheld devices are only capable of two simultenous Tx chain, and 3Tx is infeasible due to the complexity, overheating, power consumption, self-interferecne concerns.

Based on such implementation limitations and considering the desire to boost UL capacity, there maybe beneficial to consider the more advanced UL Tx switching, e.g. across more than 2 UL bands, while the simultaneous transmisison is no more than 2Tx.

1.2 Moderator Summary and recommendation for further discussion

General

Thank you very much for valuable inputs from many companies. Everyone could observe that "UL enhancement" can be considered as one of the key topics for Rel-18 because of real demands in the market. Also, it could be observed that both UL capacity/throughput enhancement and UL coverage enhancement are proposed/requested by many companies based on the real demands. Because of such a very high interest from many companies on UL enhancement, some companies concern potential too large scope for the UL enhancement and hence propose to split this topic into e.g., UL capacity enhancement and UL coverage enhancement, and/or enhancements targeting hand-held devices and enhancements targeting non-hand-held devices, etc. However, it is clearly stated in RAN chair guidance [RP-211639] that "*The goal of the email*

discussion is to potentially further refine the areas for each of the topics using the set of topics endorsed in RWS-210659, with NO intention to update the set and the organization of the topics as endorsed in RWS-210659", and hence **we don't need to further discuss potential separation of some item, potential merging with some item discussed in other email discussion thread (e.g., enhancements of mTRP for both DL/UL) and also some item clearly captured as example area or candidate item for other topic (e.g., XDD, UE aggregation, Flexible spectrum integration, etc.) in this email discussion** although it can/should be definitely discussed later.

There are many valuable feedbacks on current example areas for UL enhancement and several other proposals shown in Rel-18 WS contributions related to UL enhancement. It should be noted that RAN chair guidance [RP-211639] described that "*Any refinement of the areas for each topic from the email discussion require strong motivation/justification and the bar is very high! Critical to keep all items under rigorous check; important to avoid "number counting" driven discussion, but focus on tangible commercial interests (near & longer terms)*". Therefore, the moderator will not count number of supports for any item, but will focus on reasonable arguments from companies for some high-level aspects as RAN chair guidance also indicated that "*Aim for converged high-level description of the topics. "high-level description" herein is not a "draft SID/WID" but is something like a single slide with a set of bullets. In other words, it can be viewed as a skeleton of the possible objectives with some high-level notes*".

>4 Tx operation

Following observations on high-level aspects could be made based on initial round inputs.

- Although many companies argued that supporting >4 Tx operation at UE is beneficial to boost the UL throughput, it is also argued by majority companies that feasibility of supporting >4 Tx operation for handheld devices is questionable and hence it should be clarified that the target device type of this enhancement is limited to non-handheld device (e.g., CPE).
- Some companies pointed that RAN4 requirements on 4 Tx UL is still missing and hence necessary work for 4 Tx should also be included (or should be done before working on >4 Tx).
- Many companies seem to consider that the study phase is required for this item, e.g., as some companies concern the gain for >4 layers.

Based on above observations, the moderator recommendation for intermediate round email discussion is to check companies' views on above observations and possible refinement of this example area based on above (i.e., clarification/limitation of target device type, inclusion of RAN4 work on 4 Tx RF requirement, necessity and target of study on this item, etc.).

Enhanced multi-panel/multi-TRP uplink operation

Following observations on high-level aspects could be made based on initial round inputs.

- It seems that strong motivation to support simultaneous multi-panel UL transmission at least for multi-TRPs is provided by many companies.

- Many companies argued that some leftover items from Rel-17 FeMIMO should be covered in Rel-18 to extend the benefit and use-cases of multi-panel/multi-TRP uplink operation. For example, separate UL timings for multiple TRPs and fast UL panel selection are mentioned by multiple companies.
- It is pointed that multi-panel UL operation and multi-TRP UL operation are mixed in this example area, but it can be separated actually.
- Some companies proposed to clarify target device type and frequency range for each item.

Based on above observations, the moderator recommendation for intermediate round email discussion is to check companies' views on above observations and possible refinement of this example area based on above (i.e., capturing some particular items such as simultaneous multi-panel UL transmission [at least for multi-TRPs], separate UL timings for multiple TRPs and fast UL panel selection, separated views on multi-panel UL operation and on multiple TRP UL operation, clarification of target device type and frequency range for items, etc.).

Frequency selective precoding

Following observations on high-level aspects could be made based on initial round inputs.

- Although many companies argued that supporting frequency selective precoding for UL is beneficial to enhance UL capacity/throughput, it is pointed by some companies that Rel-15 study on this item observed that this item is beneficial only for >4 Tx case.
- Many companies seem to consider that the study phase is required for this item. In particular, the trade-off between performance gain and overhead/complexity increase would need to be evaluated.

Based on above observations, the moderator recommendation for intermediate round email discussion is to check companies' views on above observations and possible refinement of this example area based on above (i.e., clarification/limitation of applicable UL Tx configuration, necessity and target of study on this item, etc.)

Further coverage enhancements

Following observations on high-level aspects could be made based on initial round inputs.

- Many companies argued that there would be still some coverage gap for some UL channel/signal even considering on-going Rel-17 CovEnh WI, while some other companies concerned potential marginal gain on top of Rel-17 CovEnh solutions. Many companies supporting further coverage enhancement in Rel-18 mentioned that PUCCH coverage enhancement (e.g., DMRS-less PUCCH) and PRACH coverage enhancement (e.g., multiple PRACH with same or different beams) are beneficial and would provide sufficient coverage improvement from Rel-17 based on Rel-17 CovEnh study outcome.
- It is also mentioned by multiple companies that power domain enhancement for UL is beneficial for both UL coverage enhancement and UL capacity/throughput enhancement and relatively large gain can be expected. For example, reducing MPR and dynamic power aggregation for UL CA are mentioned by multiple companies.

Based on above observations, the moderator recommendation for intermediate round email discussion is to check companies' views on above observations and possible refinement of this example area based on above (i.e., capturing some particular items such as PUCCH/PRACH enhancements and power domain enhancements, etc.)

Other proposals

Following observations on high-level aspects could be made based on initial round inputs.

- There are number of other proposals for UL enhancement. For example, interests and motivations from multiple companies are shown on following items.
  - Enhancement for multi-carrier UL operation e.g., UL carrier switching, targeting devices with 2Tx (e.g., smartphone), since some of current example areas may target non-handheld device
  - Enhancement for DFTS-OFDM e.g., dynamic waveform switching and/or >1 rank support for DFTS-OFDM as in LTE
  - Enhancement for UL dense deployment (UL Rx only point) e.g., power control, beam management aspects, to enhance both UL capacity and coverage
  - Enhancement for UL CW mapping e.g., 2 CWs for >= 2 layers

Based on above observations, the moderator recommendation for intermediate round email discussion is to check companies' views on above items (possibly including some clarifications for high level target for each item) and potentially others if strong motivation/justification could be provided.

2 Intermediate round

2.1 Collection of company views

2.1.1 General high level views

Feedback Form 7: General high level views

1 – InterDigital France R&D We beleive that the scope should be divided to two separate WIs, - UL capacity enhancement (under MIMO) - UL coverage enhancement
2 – Futurewei Technologies We thank the moderator for providing an excellent summary of the initial round inputs.
3 – AT&T We didn't have a chance to comment in the first round due to technical issues. AT&T strongly supports

- UL TPMI enhancements incl. sub-band precoding
- Higher order SU-MIMO (>4 layers) in UL
- Simultaneous UL transmissions (mTRP/mPanel enhancements)
- Further enhancements on top of Rel. 17 coverage enhancements focusing on power domain enhancements

The main focus is to increase parity between UL and DL in capabilities and features especially for stationary devices with a large number of antennas (CPE/FWA/...).

4 – Samsung Research America

It would be good to combine UL/DL multi-TRP and multi-beam under one WI given the unified TCI framework developed in Rel-17 applies to UL and DL channels.

5 – Apple Computer Trading Co. Ltd

We agree with moderator that there are two categories in general for this topic:

- Cat1: UL capacity enhancement (UL MIMO)
- Cat2: UL coverage enhancement

For Cat1, it seems currently the use cases are still unclear: CPE/FWA or phone. We suggest we clearly identify the target use case for each potential enhancement.

6 – Huawei Tech.(UK) Co.. Ltd

We would also like to propose that under each category (capacity, coverage) this discussion aims to identify which proposed enhancements are applicable and beneficial for handheld UEs (including smartphones) or for high-end UEs (e.g. CPEs), so that we later have the choice to have a balanced scope addressing all important needs for uplink enhancements.

7 – SoftBank Corp.

Agree with moderator's observation.

8 – Qualcomm Incorporated

Thanks for the excellent summary. For now, we prefer to have a self-contained discussion on all uplink enhancements in this thread, while leaving the SI/WI discussions to a later point in time.

9 – ZTE Corporation

We agree this topic includes both UL capacity enhancement and UL coverage enhancement, while it seems no clear motivation to do categorization explicitly for each potential area. For any UL MIMO enhancement which does not involve DL clearly, they should be included in UL topic, e.g., >4Tx operation, UL frequency-selective precoding, etc.. For some issues which involves DL as well, e.g., UL MTRP or Multi-panel, as long as the detailed description is clear, it should be no issue for further progress in the UL WI in WG level. Hence we support to include these aspects in UL topic as well.

According to RAN chair guidance, we need also to have the first discussion/identification regarding the leading WG for the respective topics. For UL enhancements, it seems a common understanding that this should be a RAN1 leading topic.

10 – Nokia Corporation We generally support the moderator's views on these aspects, even if we were on the companies indicating the current structure is not optimal for discussion on some of the topics. However, we hope there is room for optimization of structure at a later stage of the process (not this week).
11 – NTT DOCOMO INC. Thank you, moderator for the nice summary. We agree with moderator's observation.
12 – LG Uplus In general, we can agree with moderator's view. However, we need to discuss further terminology and definition through finer tuning period. In our analysis, - In FR1, coverage bottleneck is PUSCH with a sufficient throughput to enable TCP service. - In FR2, coverage bottleneck is PUCCH/SRS as assuming CA/DC and PUSCH for standalone mode. - That is, coverage is partially tangled with capacity.
13 – CEWiT We agree with moderator's summary.
14 – Ericsson LM We appreciate Moderator's efforts for providing an excellent summary.

2.1.2 >4 Tx operation

In addition to moderator's recommendation on this item described in Section 1.2, companies are encouraged to provide views on leading WG/secondary WG for this item and potential SA/CT impact for this item if any.

Feedback Form 8: >4 Tx operation

1 – InterDigital France R&D We are open to discuss >4 TX operation, however the scope needs to be clarified from the beginning as whether it is intended for all UEs or just CPEs.
2 – Futurewei Technologies We support the moderator's assessment. No further action is needed until RAN4 first completes 4 Tx UL work.
3 – Spreadtrum Communications We are interested in this enhancement. And we support to have a study phase to reach consensus on the use case including UE types and identify how much the spec impact would be. Regarding the situation of RAN4 requirements, we believe RAN4 can finish the work on time. The feature design doesn't have to wait for RAN4's progress.

4 – AT&T

AT&T strongly supports higher order SU-MIMO (>4 layers) in UL. It's okay to clarify this targets stationary devices with large number of antennas (CPE/FWA)

5 – Apple Computer Trading Co. Ltd

Our view is as follows:

· We agree that this is only for non-handheld device

· We do not think we need to involve RAN4's work on 4Tx, which seems to be a separate issue. But we agree that >4Tx is not urgent.

· We agree that some study is needed to investigate the performance.

6 – Verizon UK Ltd

Agree with ATT. Important. This is for CPE and other large form factor data device. >=4 tx, 4/2 layers. Hard to do it for smartphone.

7 – Samsung R&D Institute UK

Our view:

- We support 8Tx, potential scope could include both codebook-based and non-codebook based transmission, and RS design. The target device type can be non-handheld device (e.g. CPE) with higher priority

- Note that >4Tx has been studied and discussed in Rel.15, and good gains had been shown with reasonable overhead especially using dual-stage codebook

- Re RAN4 work for 4Tx, it's a separate issue, and can be discussed separately

8 – Intel Deutschland GmbH

We agree with observations provided by moderator. If the enhancement targets CPE only devices, we think this objective should not be the highest priority for UL enhancements.

9 – Guangdong OPPO Mobile Telecom.

We support this feature. We also think it is likely to used for non-handheld devices (e.g., CPE), rather than smart phone.

Regarding RAN4 work, it is fine to include 4Tx. As usual, other WGs (e.g., RAN1, RAN2) may introduce new features in advance, and RAN4 will do the corresponding work at a later stage. Thus, the current RAN4 status of 4Tx should not preclude the further enhancement to support of > 4Rx

10 – SoftBank Corp.

Agree with moderator's observation.

11 – LG Electronics Inc.

We are open for >4Tx enhancement. This feature could be applicable for vehicle UE as well as CPE-type UE.

12 – Qualcomm Incorporated

In general, we agree with the moderator's observations. For >4 Tx, we think the meaningful use case is for non-handheld devices such as CPE. We don't see a use case for it for handheld devices. For >4 layers, based on Rel-15 study results, it was already clear there is no gain or at most marginal gain, we don't see the need to repeat the study rather than concluding to focus on <=4 layers for >4 Tx for CPE.

13 – vivo Communication Technology

above observations are fine in general, we still emphasize to limit the scope, if agreed, for non-handheld device. Also agree with second observation, otherwise it becomes paper product only.

14 – Telia Company AB

We support >4TX enhancements for CPE-type UEs (non-handheld) as stated in the initial round comments.

15 – TELECOM ITALIA S.p.A.

This is high priority and important not only for CPE/FWA but also for industrial applications. We support the specification of >4Tx (i.e. a Work Item, not a SI) focusing on non-handheld.

Uplink optimizations for handhelds are certainly important, but due to complexity could be part of a separate study.

16 – KDDI Corporation

>4Tx opeartion should be focused on non-handheld devices. And other aspects including Codebook, non-codebook operations, etc., needed to be considered.

17 – SHARP Corporation

We are supportive to this enhancement. For the device type, we are fine to clarify that the design target is non-handheld devices. As for RAN4's work on 4Tx, it should be a separate work. We do not see the need to put it in the scope.

18 – MediaTek Inc.

Agree that this should be ONLY for non-handheld devices (e.g. CPE/FWA).

We think there can be gains in relevant scenarios (not necessarily focused on LOS), and would be fine to evaluate the number of useful layers further.

19 – ZTE Corporation

First of all, we support this work. In our views, this feature is essential for enabling Industrial IOT case.

For the first bullet, we don't think it is needed to differentiate handheld and non-handheld device from specification perspective. We prefer to avoid too many UE types to fragmentize the market and gNB implementation. UE types should be further discussed in UE capability session after the features are ready in RAN1.

- For instance, if considering UE aggregation, we may have more than 4 Tx for a group of smart phones; then, for FR2, there may be more than 4 Tx ports (e.g., 6 ports from three individual panels in a phone) for transmission.

For the second bullet, we think the main motivation here is to support >4 Tx which is led by RAN1. The performance gain is clear as shown in our previous contribution. As for 4Tx work in RAN4, it doesn't collide with >4Tx as they are handled by different working groups. Usually, RAN4's work is based on RAN1's outcome, of course should be later than RAN1. We believe that RAN4 can complete 4 Tx RF requirement on time.

For the last bullet on >4 layers, we would like to highlight our position that higher order SU-MIMO (>4 layers) in UL is really needed for UPT. In our SLS results for indoor hotspot, we have identify that more than 20% UE can achieve >4 layer transmission.

20 – VODAFONE Group Plc

For operation from 6-7 GHz, smartphone form factors might be practical, so we are interested in not restricting this work to just CPE.

21 – China Mobile Com. Corporation

For the >4Tx operation, it should be more focused on the CPE type. It is difficult to implement 4Tx in a hand-held devices.

And for the 4Tx RF requirement, which belongs to the RAN4 scope, could be solved in the last RAN4 specific thread.

22 – CATT

Enhancements with up to 8 layers for both FR1 and FR2 should be studied to bridge the gap between DL and UL spectral efficiency. The target device types include at least IAB, CPE, RSU etc.

To support up to 8 UL layers, UL codebook design for up to 8 Tx is needed for CB based PUSCH, and the extension of SRS are required for both CB based PUSCH and non-CB based PUSCH. DL DMRS design and codeword-to-layers mapping may be reused for UL. We are open on whether SRS for antenna switching is enhanced for up to 8Tx or not.

23 – Nokia Corporation

We support the moderator observations for this topic.

Leading WG: RAN1/4

24 – NTT DOCOMO INC.

We observe UL performance gain of supporting >4 layers, in dense deployment scenario (e.g., indoor, dense urban) in RWS-210268. We are fine to focusing on non-handheld devices such as CPE.

25 – Huawei Tech.(UK) Co.. Ltd

Yes, enhancements targeting >4Tx are not for handheld devices, we support clarifying this in the corresponding high-level description.

RAN4 work to complete requirements for 4Tx UL may be done in parallel, but we don't think it would be reasonable to spend RAN time to define e.g. codebooks for 8Tx UL if RAN4 has no task to define requirements for 4Tx UL MIMO. If companies have doubts on the benefits of 8Tx UL for CPEs and thus if a study is needed, then this could be considered in a general study on enhancements for CPE/FWA (as it seems in the DL MIMO discussion there may be also be a need to study potential solutions for CPEs before being able to pick one).

26 – Rakuten Mobile

We agree with Huawei's opinion, enhancements related to >4Tx can be clarified in high-level description.

27 – LG Uplus

We generally support the moderator observations for this topic.

28 – CEWiT

We support >4Tx antennas, but want to restrict the feature only for CPEs. And regarding RAN4 impact, we believe that need not restrict the decision we make now.

29 – Ericsson LM

We share the moderator's observation that a large number of companies (we think the vast majority) think the work should be focused on devices other than smartphones, with a large number mentioning CPEs. We also agree with the observation that many companies would like a study phase. Therefore, our suggestion would be to first define use cases and antenna configurations for >4 Tx, identifying corresponding scenarios and channel models, where we target higher capability devices than smartphones. Then we should evaluate the performance of enhancements vs. Rel-17 baselines and decide based on these evaluations if enhancements will be specified.

We agree that it does make sense to specify requirements for 4 Tx in RAN4 before expending too much work on specifying more than 4 Tx in RAN1.

Regarding the supporting WGs, we think RAN1 can be the lead WG for this study.

30 – NTT DOCOMO INC.

Late input from Lenovo and Motorola Mobility

- We are OK to include Tx=4 optimization to the proposal as proposed by Deutsche Telecom

- Regarding comments from some companies on supporting >4 Tx but limiting Rank to ≤4, we believe this can be part of the study for single panel UE, i.e., studying whether Tx>4 is supported, and, if supported, whether Rank>4 is also supported. For multi-panel UE in FR2, we see no reason to limit the total transmission rank to 4.

- We agree that the main use case for >4 Tx can be for CPE, however the specification should remain transparent to device type (UE capabilities/categories are defined instead). Differences in device type, e.g., CPE or hand-held UE can be captured in the study in terms of the antenna configuration, given the larger CPE size which can handle a variety of configurations.

2.1.3 Enhanced multi-panel/multi-TRP uplink operation

In addition to moderator's recommendation on this item described in Section 1.2, companies are encouraged to provide views on leading WG/secondary WG for this item and potential SA/CT impact for this item if any.

Feedback Form 9: Enhanced multi-panel/multi-TRP uplink operation

1 – InterDigital France R&D

We support to continue the work on leftover items from R16/17, e.g.; Panel activation/selection for PUSCH, and also simultaneous UL transmission that covers aspects such as Multi-TA, power control, as well as beam aspects.

2 – Futurewei Technologies

Support the moderator's assessment. Possible refinement of this example should prioritize carryovers from R16/17 that are necessary to support multi-TRP uplink, especially the following:

- Separate UL timings and associated PRACH enhancement.

3 – Spreadtrum Communications

Fast UL panel selection needs to be further discussed in R18. For simultaneous UL multi-panel transmission, we are OK to support for both single-TRP and multi-TRP scenario since it has clear benefit. The beam indication mechanism can be based on R17 TCI framework.

4 – AT&T

AT&T supports the proposal by the moderator, in particular, simultaneous UL transmission and leftovers from Rel. 17 related to fast UL panel selection

5 – Apple Computer Trading Co. Ltd

Our view is as follows

· It is premature to consider simultaneous multi-panel transmission, given the situation that panel selection has not been supported. So far Rel-17 has not agreed to support anything.

· We agree that the leftover issues on panel selection should be covered by Rel-18. But it is premature to consider separate UL timings for multiple TRPs, in general, we do not think we need to consider enhancement for asynchronous multi-TRP deployment at this stage.

· We failed to see the necessity to separate UL multi-panel and UL TRP.

· We think this is for non-handheld device and FR2

6 – Verizon UK Ltd

Agree with ATT again.

7 – Samsung R&D Institute UK

Our view:

- Conditioned on some positive assessment outcome on potential benefit (e.g. reusing the Rel-17 EVM), we support identifying and specifying features to support simultaneous multi-panel UL tx. This could be beneficial for CPE type UEs

- Agree that leftover items from Rel-17 should be covered, for instance, identify and specify features to support M>1 and N>1, where M is the number of indicated DL TCI states and N is number of UL indicated

TCI states, including support of multiple TA values and UL power control enhancements. However, this should be done in DL enhancement as a part of Multi-beam (thread 1)

- We prefer both multi-panel and multi-TRP UL discussed together in DL enhancement (thread 1)

8 – Intel Deutschland GmbH

We agree with observations provided by moderator. In addition, we have the following comments:

1. We propose to add clarification that the above enhancements are targeting eMBB and URLLC scenarios for both FR1 and FR2.

2. We are not sure whether fast panel selection needs to be mentioned as part of this objective due to still ongoing Rel-17 work on this issue.

9 – Guangdong OPPO Mobile Telecom.

We support this work.

Regarding the Rel-17 leftovers, we should clarify which part or which specific issue. For some issue, the motivation and use cases should be clarified first. For example, the work/discussion on "fast panel selection" started from R16. But there is very limited progress if there are any. One reason is that the motivation and use case are not clear. Thus, R17 leftover should not be included in R18 automatically, and their benefit/use case be justified as the first step

From our view, this feature is applicable to the non-handhold UE (e.g., CPE). As the first step and keep the solution simple, we prefer to consider only two active panels for simultaneous transmission in R18.

For Separate UL timings, it should be clarified whether it only focus on FR2 with high SCS.

10 – LG Electronics Inc.

We think that there are three major areas for enhancements. We think that all these are important and could be captured in the exemplary areas.

- Simultaneous multi-panel UL transmission
- Separate UL timings for different panel/TRP
- Features for fast panel selection (including leftovers from Rel-17 FeMIMO)

11 – Qualcomm Incorporated

Generally agreeing with the moderator's observations.

Allowing larger timing difference between two simultaneous UL transmissions should be supported and it can apply to both FR1 and FR2.

For simultaneous UL transmission, we believe it also applies to both FR1 and FR2. This includes transmission two PUSCHs simultaneously and transmitting different channels or signals from different panels.

We have no strong view on how to organize multi-panel vs. multi-TRP.

12 – vivo Communication Technology

above observations are fine in general, fast panel selection and simultaneous multi panel transmission can be considered for specific device types. Rel-18 multi-panel/multi TRP operation should consider extended Rel-17 TCI framework to support multi TRP uplink operation. Inter-cell multi TRP support of UL transmission can be considered.

13 – NEC Corporation

Thanks for the summary and we also agree with moderator's observation. In addition, we would like to clarify/support that

- simultaneous multi-panel UL transmission is for both single TRP and multi-TRPs.
- objective for fast UL panel selection should be extended to include UL beam selection.
- Rel-17 unified TCI framework (not spatial relation in Rel-15/16) should be the base for further improvement.

14 – Sony Corporation

Thanks for the nice summary and we agree with the observations from moderator.

In Rel.17, UL transmission (e.g. PUCCH/PUSCH) to multi-TRP are commonly based on TDM fashion, which somehow reduces UE complexity in handling UL transmissions at the same time. In Rel.18, we think it could be worthy to further step forward on evaluating and supporting (if needed) the simultaneous multi-panel UL Tx, in order to boost UL capacity.

In addition, supporting of multiple TA with respect to multi-TRP could be even more valuable, since the same TA may not be coverd by the CP length when SCS goes larger, e.g. at FR2-2.

For multi-panel operation, we think that generally refers to antenna panels at UE side, whereas for multi-TRP operation, those TRPs are deployed by NW. If that's the case, we hope we don't mix the discussion of multi-panel/multi-TRP to avoid unnecessary misunderstandings.

15 – MediaTek Inc.

Multi-panel UL

We agree with some others that we should focus the scope on specification of **UL panel switching** and not on simultaneous UL Tx if this is intended for handheld devices, as this type of operation will lead to increased power consumption by the UE.

UL panel switching seems to be more widely applicable than simultaneous UL Tx in terms of device operation, deployment scenario (higher power per beam), and offers service robustness by enabling diversity, so is really the first step in our view.

We would like further clarification proponents what type of device they have in mind for "simultaneous" multi-panel UL Tx.

Multi-beam & multi-TRP (Rel-17 leftovers applicable to both)

- We propose UE-initiated beam operation at least including beam selection & activation, if not completed in Rel-17, as we think this can reduce latency for FR2.

Multi-TRP:

- We support extension of Rel-17 unified TCI framework to support M,N > 1 at least for multi-TRP, and potential use cases for single-TRP, to lower latency for mobility in FR2
- We would also be fine with some level of UL timing difference (should of course be restricted to the relevant scenario when UE is able to efficiently communicate to more than 1 TRP)

16 – Fraunhofer IIS

We are fine with the proposal and support in particular simultaneous multi-panel UL transmissions.

17 – SHARP Corporation

We support the moderator's assessment.

18 – KDDI Corporation

We agree with the moderator's observation and support this feature. In particular, simultaneous UL transmission using different beam for multi-TRP is beneficial to enhance capacity and reliability.

19 – ZTE Corporation

First of all, we support this work.

Then we can explicitly capture some items for progress, and after reviewing companies input, we think the following bullet seem to be stable.

- Simultaneous multi-panel UL transmission [at least for multi-TRPs]

After that, we are open to have separate UL timings for multiple TRPs, but 'fast UL panel selection' should be captured into a special case for 'Simultaneous multi-panel UL transmission', rather than an individual one.

- In our views, 'fast UL panel selection' has been discussed in two releases, but may be down-scoped twice. The technical reason is that the motivation or necessity of only enhancing this panel selection is unclear if panel selection is purely up to UE side, and we shall preclude repeating those discussion again and again.

- In short, let's focus on 'simultaneous multi-panel UL transmission' firstly, and then we can further consider whether we need to have simplified solution for fast UE panel selection.

Finally, we also think this feature is mainly applicable to the non-handhold UE (e.g., CPE), but we do not need to limit this case only due to the same reason as we mentioned for >4Tx.

20 – CATT

In our opinion, enhancement on simultaneous multi-panel UL transmission for both single TRP and multi-TRP scenarios in FR2 can be with higher priority.

For multi-TRP enhancement, besides simultaneous multi-panel UL transmission, we are open to study separate UL timings for multiple TRPs and TRP-specific scheduling for multiple TRPs.

21 – Nokia Corporation

We agree with the moderator's observations in general. Since this discussion week is targeting a better definition of the scope of each area, we believe it is beneficial to explicitly list the items that are assumed to be part of the initial scope of this discussion. Naturally these will need to be discussed for further prioritization later, but that is perhaps a future step.

It is indeed beneficial to list Multi-TRP and multi-panel/beam separately as they are somewhat distinct areas. Moreover, classification of frequency range for the different items is helpful too, as it has an impact on the expected workload. We added such considerations in our proposals to initial round above. We are not so sure about the relevance of indicating target device type for all cases, though it may be relevant for some enhancements.

One topic that is apparently missing from the list is MPE handling, which is a potential leftover from Rel-17. It is true that it is difficult to define the precise scope at the moment, but given the relevance of the topic for real-world scenarios, we think it is important that we do not miss it.

Leading WG: RAN1

Secondary WGs: RAN2/RAN4

22 – NTT DOCOMO INC.

We support both panel activation/selection (Rel-17 leftovers), and simultaneous multi-panel transmission. For simultaneous multi-panel transmission from UE, it can be supported for both S-TRP reception and M-TRP reception at gNB.

23 – Huawei Tech.(UK) Co.. Ltd

We agree with Apple and Mediatek that it is premature to consider simultaneous multi-panel transmission, given the situation that panel selection has not yet been supported and although it is an objective of Rel-17 it is likely that this objective will not conclude in Rel-17 due to lack of time. Panel selection is simpler and should provide benefits for more types of devices.

We don't think that UL multi-panel and UL mTRP should be merged. There are clearly use cases for UL mTRP where UEs don't have to be equipped with multiple panels (obviously in FR1) and for which UL mTRP enhancements are needed. So we would prefer to continue discussing UL multi-panel and UL mTRP separately, without precluding cases where both may apply in the same deployment.

We have quoted the factory environment as an example requiring more orthogonal UL DMRS ports with mTRP uplink reception when many video monitoring points on a production like upload high definition video almost constantly.

24 – China Mobile Com. Corporation

multi-panel/multi-TRP uplink operation could focus on FR2 first. And hand-held devices should be prioritized. Only in FR2, the multiple panels could be implemented on the smart phones.

We are open to deal with the leftovers from Rel-17. And the timing and TA issues could be also considered.

25 – LG Uplus

M-TRP reception at gNB and multi-panel selection are prioritized.

26 – Ericsson LM

Simultaneous multi-panel UL transmission to multiple TRPs with separate timing advance can be captured, focusing first on multi-DCI based multiple TRP operation where we can assume each TRP has its own scheduler.

Simultaneous multi-panel transmission at least for multiple TRPs can also be captured. Given that simultaneous UL transmission to multiple TRPs is also possible in FR1 (for instance, for reliability purposes). Then, using the 'simultaneous UL transmission at least for multi-TRP' may be better wording that would cover both FR1 and FR2 instead of 'simultaneous multi-panel transmission'.

We are OK to discuss multi-TRP and multi-panel separately.

Overall, having a common understanding of the type of devices and frequency range to be supported by specifications would be helpful.

RAN1 can be the lead WG for this work.

27 – CEWiT

We are fine with the moderator's summary and support in particular simultaneous multi-panel UL transmissions and different TAs across TRPs.

28 – NTT DOCOMO INC.

Late input from Lenovo and Motorola Mobility

- We agree that leftovers from UL M-TRP enhancements should be taken care of in Rel. 18, e.g., fast UL panel switching and separate TA

- We agree with Huawei that UL transmission with multi-panel UE and UL transmission to M-TRP are different issues and shall be treated separately. However, regarding the support for UL simultaneous multi-panel UE transmission, we believe this should be studied for UL multi-TRP setup only, i.e., two UE panels transmitting to two TRPs.

- Regarding UL simultaneous multi-panel UE transmission, we support studying for FR2.

2.1.4 Frequency-selective precoding

In addition to moderator's recommendation on this item described in Section 1.2, companies are encouraged to provide views on leading WG/secondary WG for this item and potential SA/CT impact for this item if any.

Feedback Form 10: Frequency-selective precoding

1 – InterDigital France R&D

We support frequency-selective precoding, however we believe the focus should be on signaling of existing TPMIs for subband precoding rather than designing/optimizing new codebook.

2 – Futurewei Technologies

We support the moderator's assessment. No further action is needed until RAN4 first completes 4 Tx UL work. At that point, a study would still be needed first.

3 – Spreadtrum Communications

We support to have a study phase to reach consensus on the achievable gain for both <=4 Tx and >4 Tx.

4 – AT&T

AT&T supports UL TPMI enhancements incl. sub-band precoding. Okay to limit to stationary devices with large number of antennas (CPE/FWA) if that helps. Feature parity between UL and DL in capabilities is main driver.

5 – Apple Computer Trading Co. Ltd

Our view is as follows

- We agree that it is only benefitial for >=4Tx. In addition, it is only benefitial for coherent transmission.
- We agree that some study is needed to identify the case with performance gain

6 – Verizon UK Ltd

Agree with ATT again.

7 – Samsung R&D Institute UK

Our view:

- In our view, UL FS precoding can be beneficial for >=4Tx, there is no gain for 2Tx.
- Re the work scope, before deciding to specify, we propose to study/assert the benefit considering the DL control overhead (i.e. performance-overhead trade-off). We observe some gain in 8Tx and/or dual-stage codebook especially in cell-edge user TP. At the same time, this could impose large DL control overhead unless two-part DCI design is used. The feasibility of such solution needs to be investigated.

8 – Intel Deutschland GmbH

We agree with observations provided by moderator. If the enhancement targets CPE only devices, we think this objective should not be the highest priority for UL enhancements.

9 – Guangdong OPPO Mobile Telecom.

We are fine to study the performance gain firstly and prefer to restrict this study only for 8Tx transmission.

10 – LG Electronics Inc.

Frequency-selective precoding was investigated in Rel-15 and the conclusion was that it's gain is not significant considering DCI overhead and UL channel estimation error. We are open for this enhancement in Rel-18 but this needs to be a low priority item compared to others.

11 – Qualcomm Incorporated

We generally agree with moderator's observations. In the Rel-15 study, the gain of frequency-selective precoding was observed only with >4 Tx. There is no gain with it for <=4 Tx. If there is a study of UL frequency-selective precoding in Rel-18, the following four aspects should be considered. The third aspect is related to both RAN1 and RAN4. We raised this issue in first round of comment, which seems to have been missed in the moderator's observation.

- Tradeoff between DL DCI overhead and frequency selective precoding gain.
- Impact of variable overhead (due to variable PUSCH allocated bandwidth) in DCI to signal the frequency selective precoders.
- Increased MPR (max power reduction) of frequency selective precoding due to variable (per antenna port) PSD.
- Wideband precoding enhancement can be considered a necessary baseline as it has no inter-Mod issue and similar or less overhead compared to frequency selective precoding.

A very simple example for the PSD/MPR issue with frequency selective precoding is the following. For a 2-Tx UE, if the precoder is oscillating between [1,0]^T and [0,1]^T, the PSD on each single Tx has on/off pattern which would create inter-modulation and would require larger MPR to meet RAN4 requirements.

12 – vivo Communication Technology

above observations are fine in general, further evaluate with enhanced codebook for 4 Tx and >4Tx (if agreed to include), if needed, specify including control signaling enhancement.

13 – MediaTek Inc.

Further evaluation would be ok for this, bearing in mind some of the comments raised. However, regarding the 1st round comments from Qualcomm regarding frequency selective precoding gains disappearing if high resolution precoding is used, we would therefore propose to include **high resolution precoding enhancement** into the scope as an alternative option (which we proposed in Other Proposals in round 1).

We also think that techniques to reduce overhead and optimise signalling would need consideration as part of the evaluation.

14 – SHARP Corporation

We support the moderator's assessment. Also agree to have study first.

15 – ZTE Corporation

We support this feature as we observed the performance gain from 4Tx case. We are open to further study and evaluate, but we don't think it is appropriate to preclude 4Tx case at this stage. Instead, the SLS/LLS evaluation and condition, if any, for initializing frequency-selective precoding should be made in RAN1 in Rel-18, if the feature is captured in WID fortunately.

As for the trade-off between performance gain and overhead/complexity, we think it is a good point to study whether some enhancements are needed to address the issues, e.g. two-step DCI, MAC-CE + DCI, etc.

Finally, we think this feature should be applied to both CB and NCB UL transmission.

16 – VODAFONE Group Plc

We support some Rel 18 study on this topic.

17 – CATT

Some companies' simulation results showed that frequency selective precoding provides substantial performance improvements than wideband precoding at least for 4Tx, therefore frequency selective preccoding is helpful to accommodate wider system bandwidth in FR1/FR2 at least for 4Tx. For frequency selective precoding, the indication of subband TPMI/SRI should be carefully studied to have a good balance on the overhead consumption and performance improvement.

18 – China Mobile Com. Corporation

According to the feedback from last round and the observation from the moderator, the frequency selective precoding is more beneficial for >4Tx case. We are open for further study and evaluation of the benefits, providing a clear view to the group and facilitating the decision.

This item could be merged under the >4Tx operations and more focused on the CPE type devices.

19 – Nokia Corporation

We agree with the moderator's summary for this topic in general. Indeed we have observed relevant gains only for some limited scenarios, in particular >4TX antennas. We also see this more applicable to FR1.

Leading WG: RAN1

Secondary WGs: RAN4

20 – NTT DOCOMO INC.

We agree moderator that we should study which scenario we can observe gain of frequency-selective precoding.

21 – CEWiT

We agree with the moderator's assessment to have a study on frequency selective precoding first.

22 – Ericsson LM

We agree that the benefit of frequency selective (FS) precoding should first be studied. In particular, we think that the study should assume that DCI carrying FS precoding information fits in Rel-15 PDCCH, since FS precoding is not likely to bring sufficient gain to warrant drastic change to control structures. The study should also address realistic UE antenna configurations and how to support low PAPR operation.

RAN1 can be the lead WG for this work.

23 – NTT DOCOMO INC.

Late input from Lenovo and Motorola Mobility

- Our simulations show significant gains for UL frequency-selective precoding, even for ≤4 Tx. With higher resolution codebook coming with >4Tx, more gain can be expected from frequency selective precoding. In our opinion, further study should be pursued in Rel. 18 taking into account different tradeoff points between performance, complexity, and DCI overhead.

- We are OK to study, and, if possible, specify UL frequency selective precoding enhancements, in order to identify antenna configuration/channel model assumptions, as well agree on common performance/overhead tradeoff points. Both CB-based and non-CB-based PUSCH transmission, as well as CP-OFDM and DFT-s-OFDM can be included in the study.

2.1.5 Further coverage enhancements

In addition to moderator's recommendation on this item described in Section 1.2, companies are encouraged to provide views on leading WG/secondary WG for this item and potential SA/CT impact for this item if any.

Feedback Form 11: Further coverage enhancements

1 – InterDigital France R&D

We acknowledge and support that more work needed for further covergae enhancements, e.g.,

- Work on PRACH which was not in the scope of R17
- Sequence-based PUCCH

Also, we believe that power domain PUSCH enhancement by power aggregation of different PAs of different band can be very effective in enhancing UL performance.

2 – Futurewei Technologies

We support the moderator's assessment. We think PUCCH/PRACH enhancements could have only very marginal gains on top of R17 CE work. Power domain enhancements require further study, in either a SI or a study phase of a WI.

3 – China Telecommunications

Thanks for the moderator's summary. Additional considerations on further coverage enhancement are as follows:

Regarding PUSCH enhancement:

· **Enhancement on PUSCH repetition type B** [RAN1]

We think it is beneficial for PUSCH coverage, where special slot can be used. Companies' simulation results summarized in TR 38.830 also shows that performance gain can be obtained by PUSCH repetition type B enhancement. We think both "actual PUSCH transmission across the slot boundary/invalid symbols" and "the length of actual repetition larger than 14 symbols" can be the potential scope of PUSCH repetition type B enhancement.

· **UE transmit waveform design to reduce MPR** [RAN1][RAN4]

We think enhancement on power domain is a straightforward way to enhance coverage and can be included in the scope. As commented by some companies that power domain enhancements require further study, we think a study phase can be added in corresponding WI if necessary.

Regarding PUCCH enhancement:

· **DMRS-less PUCCH with UCI payload up to 11 bits** [RAN1][RAN4]

During Rel-17 SI on coverage enhancement, DMRS-less PUCCH is widely and deeply studied & discussed, many companies show significant gains of DMRS-less PUCCH. DMRS-less PUCCH can outperform legacy coherent PUCCH especially in low SINR range which is the typical condition for coverage limited UEs. Thus, we think DMRS-less PUCCH is beneficial for coverage and can be included in the scope.

Regarding PRACH enhancement:

· **Multiple PRACH transmissions** [RAN1][RAN2]

We think multiple PRACH transmission w/ the same/different beam(s) is beneficial for PRACH coverage for both FR1 and FR2. Moreover, PRACH B4 is identified as the potential bottleneck channel for both FR1 and FR2. Thus, we think multiple PRACH transmissions can be included in the scope.

Regarding Left overs of Rel-17 WI on coverage enhancement

If there is some left overs, we think it can be also included in the scope, this depends on the progress of Rel-17 coverage enhancement.

4 – AT&T

AT&T would like Rel. 18 to focus on power domain enhancements. There were many proposals during the Rel. 18 workshop that are worth exploring including those mentioned my the moderator in the summary

5 – Samsung Research America

PRACH was identified as a bottleneck channel and it is the channel that was not enhanced in Rel-17. We would support PRACH coverage enhancements, particularly for FR2, to be included in a general WI for UL enhancements. In our opinion, there is no need for other coverage enhancements.

6 – Apple Computer Trading Co. Ltd

Our view is as follows

· We agree that potential marginal gain on top of Rel-17 coverage enhancement is not quite clear. If needed, DMRS-less PUCCH and PRACH repetition can be the potential enhancement to improve the coverage for PUCCH and PRACH.

· We think power domain enhancement needs some further study, the potential gain and the standard impacts are not clear. And it seems to be better to handle CA related enhancement under Email thread 14, e.g. dynamic power aggregation for CA.

7 – Intel Deutschland GmbH

· We agree with FL's observations that multiple PRACH transmissions are beneficial to meet the coverage enhancement target, which is critical for cell edge UEs during initial access.

· For PUCCH coverage enhancement, during Rel-17 NR coverage enhancement SI, some companies showed that sequence based DMRS-less PUCCH scheme did not provide additional benefit in term of link budget and coverage compared to the existing PUCCH format 3.

· We think if there are some left-overs for Rel-17 NR coverage enhancement WI, we can further consider those as part of Rel-18 objectives for further coverage enhancement.

· For dynamic power aggregation, it can be beneficial for uplink coverage enhancement, but it can be considered as part of UL CA HPUE enhancements in thread 17.

· For MPR improvement, there is an ongoing RAN4 SI in Rel-17 to study MPR for pi/2 BPSK for HPUEs including 26dBm and 29dBm. It would be good to clarify the exact proposal for MPR improvement.

8 – Guangdong OPPO Mobile Telecom.

We support the moderator's recommendation of PUCCH and PRACH enhancement. Regarding the detail scope, we see the DMRS-less PUCCH and other candidates can be considered for the PUCCH. PRACH should consider to support repetition transmission with same of different beams.

In addition, we should also include the coverage recovery of PDCCH for 1RX. This topic did not cover by both Rel-17 WI of CE and RedCap. But it is concluded beneficial in study phase. And it would be good to done in Rel-18

9 – Qualcomm Incorporated

Power domain enhancements for uplink, specifically dynamic power aggregation focused on more efficient usage of all the PAs available to a UE across different bands would be a valuable direction to pursue. UL CA has so far not been widely deployed, and we believe this enhancement would likely pave the way for more widespread adoption of UL CA.

On PUCCH enhancements, we continue to believe that sequence based PUCCH offers significant gains over legacy PUCCH. Sequence based, DMRS-less PUCCH should be adopted and specified in Rel-18.

Besides this, as mentioned in the first round of discussion, we think PRACH enhancements in the form of repetitions with or without beam sweeping is worth pursuing in Rel-18 for FR2. Also, dynamic PUCCH repetition indication for either HARQ ACK corresponding to SPS PDSCH or for CSI is good to be added

in Rel-18, because for example the reliability of L1 report is very important for beam management and overall performance of the system (especially in FR2).

10 – SoftBank Corp.

We agree with moderator's view on PRACH and PUCCH enhancements.

In addition, we are interested in Power domain enhancements for uplink (specifically dynamic power aggregation) because it can potentially enable aggressive use of UL CA. We have no strong preference on the categorization of this technology, but it should be further considered.

11 – Spreadtrum Communications

We support the moderator's view on PRACH and PUCCH enhancement. Besides, we also open to other UL channels, such as PUSCH, some leftovers from Rel-17. These can be also a part of UL coverage enhancement.

According to power domain enhancements, we do not think it is as mature as other UL coverage enhancements. The potential gain and standard impacts need more clarifications.

12 – VODAFONE Group Plc

Enhancements of PUSCH repetion type B should be evaluated, similarly as it is being done for type A in Rel-17, as well as leftovers that may have been discarded from downselections from this release. The main focus on the Rel-17 was PUSCH, having PRACH and PUCCH as a 2nd Priority, thus a further study on enhancements on these channels should be included on the Rel-18 work (also aiming for RedCap UEs)

13 – SHARP Corporation

In our view, at least coverage improvements for PRACH and PUCCH should be included in Rel-18 work. As many companies mentioned already, PRACH was identified as a potential bottleneck in Rel-17 study but no enhancement is made in Rel-17. As for PUCCH, the enhancement of short PUCCH is important for the operations with beam sweeping.

14 – ZTE Corporation

We support moderator's recommendation about PUCCH and PRACH enhancements. The high-level description for each area and the leading/secondary WG are suggested as follows.

-Sequence based PUCCH for >2 bits UCI [RAN1]

-Multiple PRACH transmissions [RAN1, RAN2]

We agree power control enhancement could be beneficial for UL performance. But we would like to clarify whether it should be discussed/included under this topic or other topics (e.g., CA/DC) for some of the enhancements, e.g., dynamic power aggregation for UL CA.

15 – MediaTek Inc.

If we are to consider further coverage enhancements effort, RAN1 should first review whether we met the Rel-17 targets first with the Rel-17 specification, and identify what is still not achieved from there. However, we understand that PRACH was one area that was not covered that could have benefited from some improvement.

For dynamic power aggregation for UL CA, RAN4 is already discussing PC2 for inter-band NR-CA, so it would be good to understand what extra is proposed - just a Tx duty cycle configuration?

16 – CATT

In Rel-18, we would like to at least prioritize PRACH coverage enhancements for FR2 which has not been covered in Rel-17 CE WI.

For power domain enhancements, we also think that some study is needed and dynamic power aggregation for UL CA can be discussed under CA/DC enhancements.

17 – Nokia Corporation

We agree with the moderator's proposals for this topic in general. We believe it is beneficial to explicitly capture the areas listed by the moderator, i.e. PRACH/PUCCH enhancements and power-domain enhancements. Some examples can be found in our input to initial phase, including applicable FR for each enhancement. Regarding the leading WGs, RAN1 should be the leading WG for PRACH/PUCCH, and RAN4 for power-domain enhancements.

18 – NTT DOCOMO INC.

Although we think coverage enhancement is low priority, if Rel.18 includes it, we prefer power domain enhancement (e.g. dynamic power aggregation), because it can improve both UL performance and coverage.

Also, we believe UL dense deployment (UL Rx only point) can improve both UL performance and coverage.

19 – Huawei Tech.(UK) Co.. Ltd

Although there seems to be good interest in further coverage enhancements, it is not clear which area to focus on given the diverse views from companies. Power domain enhancements for PUSCH should be prioritized in our view.

20 – China Mobile Com. Corporation

Share a similar view as Moderator.

For the enhancement of PRACH, if supported, it is preferred to focusing on FR2. But still there are many mechanisms to enhance the FR2 operations. In FR1, we do not believe a UE would fail in the 1st step of initial access.

Power domain enhancements seems more attractive. Coverage enhancements due to higher transmit power is obvious and straightforward.

21 – Rakuten Mobile

We support PRACH/PUCCH enhancements and power-domain enhancements.

22 – Ericsson LM

We share the view with companies that specifying solutions not agreed for Rel-17 CovEnh is not likely to be the best way to get real coverage enhancement. In particular:

- We agree that reduced MPR is a promising area. Since this is in RAN4's area of expertise, the study should begin there. Therefore, we think that RAN4 can be the leading WG for coverage enhancement aspects, with RAN1 being a secondary WG as needed.

- Regarding DMRS-less PUCCH, companies using advanced receivers as baselines generally did not find gains over existing PUCCH. Moreover, in our view, introducing a new PUCCH format should be considered after enhancements using existing PUCCH structures.

23 – NTT DOCOMO INC.

Late input from Lenovo and Motorola Mobility

- Considering UL coverage enhancement has been carried out in R17, we shall limit R18 to the channels identified but not studied in R18. We support PRACH coverage enhancements using same or different TX beams

2.1.6 Other proposals

In addition to moderator's recommendation on this item described in Section 1.2, companies are encouraged to provide views on leading WG/secondary WG for each proposed item and potential SA/CT impact for each proposed item if any.

Feedback Form 12: Other proposals

1 – InterDigital France R&D

From other proposal, we see some clear benefits from UL TX switching across more than 2 bands, however we think RF hardware considerations need to be carefully examined.

2 – Futurewei Technologies

We support the moderator's assessment. Given the interest from multiple companies on the first item (multi-carrier UL operation, especially for handheld devices), this item may be promoted as a separate new area and dedicated discussions on this area should be provided by companies. UL dense deployment can also be studied. We do not see the needs for other 2 proposals.

3 – Samsung Research America

For UL carrier switching, it would be good to clarify the main use case and key differences respect to Rel-16/17.

In our view, UL dense deployment can be considered since the use case is clear, and has the potential to improve UL performance.

Re enhancements for DFTS-OFDM, we are not sure about the need/benefits since 1) DFT-sOFDM is for low PAPR (coverage limited), implying rank>1 is unlikely, 2) gNB complexity of DFT-sOFDM MIMO (link adaptation, MIMO RX), and we can use rank=1 CP-OFDM and 3) rank>1 CP-OFDM.

4 – Apple Computer Trading Co. Ltd

Our view is as follows

· We think enhancement for UL multi-carrier is better to be discussed under CA/DC (Email thread 14)

· For DFT-s-OFDM related enhancement, we think one enhancement should be enough. Rank>1 transmission seems to be more benefitial compared to dynamic waveform selection.

· Currently separate UL/DL beam management is supported, we failed to see what to be enhanced for UL Rx only point.

5 – Intel Deutschland GmbH

1. We support enhancements for UL dense deployment. From our perspective this should be one of high priority objective in Rel-18 for UL enhancement. However, in addition to UL Rx only point we propose to consider Rx points with lower Tx power to enhance both UL capacity and coverage, i.e., the following modification is proposed:

Enhancement for UL dense deployment (UL Rx only point, TRP with lower Tx power) e.g., power control, beam management aspects, to enhance both UL capacity and coverage

2. We respectfully ask moderator to capture the following enhancements proposed by Intel in the first round of discussion:

- Specify SRS enhancements to more efficient DL and UL transmission in high mobility scenario

- Specify additional CS for DM-RS Type I for overhead reduction and support of larger number of orthogonal DM-RS ports for uplink MU-MIMO.

6 – Guangdong OPPO Mobile Telecom.

From these proposals, we think the enhancement of UL CW mapping and be considered. Some study/evaluation is needed to justify the performance gain.

7 – Huawei Tech.(UK) Co.. Ltd

Considering that the majorities of companies argue that ">4Tx operations" should mainly target for high-end UEs or CPEs, the area of uplink enhancements for smartphones is kind of missing in the current example areas. As many companies have interest in multi-carrier enhancements for smartphones (e.g., 2Tx), we think

"• Enhanced multi-carrier (>2 bands) uplink operation with 2Tx" should be a new area for Rel-18 uplink enhancements.

Especially, we observed 2Tx switching among more than 2 bands can lead to higher UL data rate, higher system spectrum utilization and higher UL capacity for latency-bounded traffic thanks to efficient utilization of TDD UL slots, better adaptation to channel conditions and higher trunking efficiency, TTI-level load balancing.

To answer Samsung's question, in R16/R17, UL Tx switching can only be performed across 2 configured bands for devices with up to 2Tx. The proposal is to extend to more than 2 UL bands, which is to allow configuring more than 2 UL bands and supporting two concurrent ULs at most.

To answer InterDigital's question, while Tx switching requires some hardware, the comparison should be with 3Tx or 4Tx devices, i.e. devices supporting simultaneous transmission of 3UL or 4UL. The RF for these devices is much more complex than 2Tx with Tx switching. The main difference comes from the required number of power supplies (just 2 power supplies needed for 2 simultaneous uplinks).

8 – Orange

Amongst the possible UL enhancements, we believe that enhancing TxDiversity would be of interest, following discussion held in Rel17 on the matter.

TxD is a transparent feature from Rel. 15, however its performance may vary significantly with implementation choices, notably, with the selected cyclic delay in case of S-CDD . Additionnally, there is a need to establish some common knowledge between the UE and the gNB for efficient Link Adaptation.

We propose this topic to be treated in RAN4 , and, possibly also in RAN1 if the transparent hypothesis is deemed necessary to be revisited

9 – vivo Communication Technology

the first bullet is acceptable for us in order to boost UL performance. Enhancement related to DFT waveform is important in order to exploit full capacity of UE hardware. Study on impact of hardware impairment on UL performance is another important topic should be considered in Rel-18, it is well known that cross-talk among Tx chains in handheld devices is prevalent, which real world issue.

10 – Qualcomm Incorporated

As other companies have remarked, ensuring easier and wider access to DFT-S-OFDM waveforms would be a rather straightforward uplink enhancements that's certain to bring benefits to coverage and capacity. We are interested in pursuing this.

Other enhancements listed here would not be top priority for us, although we did note the interest by other companies in UL Tx switching enhancements.

11 – SoftBank Corp.

- **Enhancement for multi-carrier UL operation e.g., UL carrier switching, targeting devices with 2Tx (e.g., smartphone), since some of current example areas may target non-handheld device**

Due to Scell dropping issue (more specifically UL power limitation), UL CA is not aggressively used in the current network. This technology can allow UEs to dynamically choose more appropriate UL cell, which does not require higher Tx power power per PRB.

- **Enhancement for DFTS-OFDM e.g., dynamic waveform switching and/or >1 rank support for DFTS-OFDM as in LTE**

Our motivation is to benefit from single carrier waveform under MIMO applicable conditions. We think only one option is necessary, and the final decision can be left to WI phase.

- **Enhancement for UL CW mapping e.g., 2 CWs for >= 2 layers**

In our understanding, the motivation and field test result have already been provided in RAN1 TEI. We think this enhancement brings clear benefit.

12 – China Telecommunications

We think there are some limitations for Rel 16/17 uplink Tx switching:
• 2TX UE can be configured with at most 2 UL bands, which only can be changed by RRC reconfiguration.

• UL Tx switching can be only performed between 2 UL bands for 2Tx UE.
Thus, we think UL Tx switching enhancement can be considered in Rel-18, potential scopes can be as follows:

• Enable more configured UL bands than UL RF capability, e.g. Max num. of configured bands >= Max num. of activated bands >= Max num. of Simultaneously transmission bands.

• UL Tx switching schemes across more than 2 bands, e.g. 4 UL bands can be configured, and dynamic switching can be performed across the 4 bands.

13 – VODAFONE Group Plc

As mentioned by some companies, UL enhancements for handheld devices should be discussed further, as the >4 TX may not be suitable for a smartphone form-factor.

The support of multilayer DFT-S-OFDM such as in LTE seems interesting and not conveying a lot of specification work. It is quite likely that in a coverage limited scenario (e.g deep indoor) indeed you operate with single layer on uplink, but it is also possible that part of the coverage limited scenario before getting limited could benefit from more than 1 layer when using DFT-S-OFDM waveform, if possible/feasible and without losing too much on PAPR characteristics.

14 – TELECOM ITALIA S.p.A.

Since it appears from multiple comments that most of the indicated features outside ”other proposals” apply to non-haldeld UE, improvements must be found also for handheld UE.

We think that areas of interest are (not necessarily in priority order)

- UL Tx switching over multiple band
- Enhanced multi-carrier (>2 bands) uplink operation with 2Tx (could be merged with UL Tx switching?)
- multilayer DFT-S-OFDM (see Vodafone comment)

15 – China Mobile Com. Corporation

Support to upgrade the 1st bullet (Enhancement for multi-carrier UL operation to cover more than 2 bands) into a separated area for Rel-18 UL enhancement, if it got a majority support. Given current enhancement under this thread are more related to CPE (>4Tx, frequency selective precoding) and FR2 (m-Panel/m-TRP), it is possible to give a balance to enhance the hand-held cell phones. And multiple bands (>2) could facilitate the flexible use of multiple bands for operator.

For the hardware issue, from our understanding, if the UE could access the bands (>2), most important parts of the RF should already be inside the cell phone.

16 – ZTE Corporation

We support enhancement for UL CW mapping. The issue was observed from real tests, and was supported by many operators based on RAN1 Rel-17 TEI discussion.

We share similar view as other companies that UL multi-carrier is better to be discussed under other topics, e.g., CA/DC.

17 – vivo Communication Technology

We are supportive of ”Enhanced multi-carrier (>2 bands) uplink operation with 2Tx”, as we see it as one solution for UL boosting without requiring the devices to implement simultanous 3Tx (which is not feasible for handheld devices currently).

18 – MediaTek Inc.

Regarding Enhancement for UL CW mapping e.g., 2 CWs for >= 2 layers, the gains are not very clear to us beyond what is possible with the existing spec, so would probably need more time for analysis in the first instance.

19 – Nokia Corporation

Please find below our comments to each of the proposed enhancements in this section:

- Enhancement for multi-carrier UL operation e.g., UL carrier switching, targeting devices with 2Tx (e.g., smartphone), since some of current example areas may target non-handheld device
  - Nokia: we do not see a need for further enhancements on UL carrier switching. The potential gain mechanisms are very limited given the practical implications of switching to real-world devices.
- Enhancement for DFTS-OFDM e.g., dynamic waveform switching and/or >1 rank support for DFTS-OFDM as in LTE
  - Nokia: Support
- Enhancement for UL dense deployment (UL Rx only point) e.g., power control, beam management aspects, to enhance both UL capacity and coverage
  - Nokia: The target FR needs to be clarified before further consideration. If targeting FR1 then it is not clear how dense deployments are expected. On the other hand if considering FR2, then it is unclear how to manage beams efficiently without DL signals that UE could use for beam correspondence with the "UL Rx only points"
- Enhancement for UL CW mapping e.g., 2 CWs for >= 2 layers
  - Nokia: support

20 – NTT DOCOMO INC.

We support UL dense deployment (UL Rx only point) because the use-case and the benefit is clear for us.

Also, we support dynamic waveform switching, because we think it is useful to avoid RRC-reconfiguration to switch the waveform. If Rel.18 specifies the dynamic waveform switching, we think we don't need to additionally support ">1 rank support for DFTS-OFDM".

21 – Rakuten Mobile

We support Enhanced multi-carrier (>2 bands) uplink operation with 2Tx , and it seems Huawei have explained the issue of Carrier configuration; We also agree with Softbank's on more dynamic Power switching.

22 – LG Uplus

UL carrier switching is interested.

23 – Ericsson LM

We think that fast CP-OFDM to DFT-S-OFDM switching and rank 2+ DFT-S-OFDM are straightforward to support and allow better PA efficiency and/or coverage. These can be handled by RAN1.

For MU-MIMO, we think that increasing the number of orthogonal DMRS ports without increasing overhead (i.e., higher DMRS port density) is a highly important for Rel-18 enhancements. Configuring double-symbol DMRS creates too large DMRS overhead (4 out of 14 symbols in the slot is DMRS) and reduces

the throughput compared to a single-symbol DMRS. Therefore, we should also specify DMRS capacity enhancements to at least double the number of orthogonal DMRS ports in one OFDM symbol.

CA based enhancements and multi-carrier UL operation enhancements seem to be in a substantially different category from the MIMO and coverage enhancement solutions generally under consideration for UL enhancements, and should be discussed elsewhere, perhaps under thread '14 Additional RAN1/2/3 candidate topics, Set 1'.

Regarding enhanced UL CW mapping, this seems related to UL M-TRP, and might be better to discuss there. One question that we have for the proponents is that what is the benefit of introducing multiple codewords for multi-TRP over multi-DCI based multi-TRP PUSCH? Note that with multi-DCI based multi-TRP, it is possible to schedule two PUSCHs with different PDCCHs which naturally supports two codewords (where each PUSCH is associated to one codewords). Also, do the proponents intend to increase the total number of layers beyond 4? It seems further justification of the benefits of introducing enhanced UL CW mapping (over multi-DCI based multi-TRP) is needed.

24 – NTT DOCOMO INC.

Late input from Lenovo and Motorola Mobility

- We support dynamic switching between CP-OFDM and DFT-s-OFDM. We are also open to higher rank transmission with DFT-s-OFDM.

- We believe the UL Rx only node proposal needs further discussion. In our opinion, comparison with similar approaches that can improve UL coverage, e.g., smart repeaters is required in order to better assess the merit of this framework. Issues such as BM, TA, PC should be discussed, where KPIs such as throughput, complexity, reliability, latency need to be considered.

- We believe CW to layer mapping for ≤4 layers should be a lower priority

2.2 Moderator Summary and recommendation for further discussion

General

Thank you very much again for valuable inputs from many companies. Based on the RAN chair guidance, it should be noted again that some comments like "xxx should be discussed under other email thread XX" and "xxx should be discussed together with yyy in other email thread YY" are not within the scope of this email discussion, but those can be taken into account later (maybe in the RAN#93e meeting). So, the moderator continues treating all the UL enhancement items in this email discussion unless it is clearly captured under other topic in RP-210659.

The aim of this email discussion is to develop "high-level description" such as *a single slide with a set of bullets which can be viewed as a skeleton of the possible objectives with some high-level notes*. Therefore, based on the inputs from companies, the moderator tried to develop the draft high-level description for UL enhancement for companies' checking in final round discussion. Note that as described in the RAN chair guidance, the summary will be inputs to RAN#93e, and hence it can be further discussed even after this email discussion.

>4 Tx operation

Following observations on high-level aspects could be made based on intermediate round inputs.

- Majority considers this item is only for non-handheld devices such as CPE/FWA/vehicle/industrial devices, while some companies mentioned that there is no need to differentiate handheld and non-handheld device types from specification perspective or prefer to keep handheld device for study. So, it would be reasonable to describe "mainly targeting non-handheld devices" as a high level note for now, but it can be further discussed in the next phase discussion (i.e., in RAN#93e meeting).
- Although several companies mentioned that RAN4 work for 4Tx requirements can be done separately, some other companies argued that it does not make sense to work on >4 Tx in RAN1 if RAN4 is not tasked to work on 4 Tx requirements. Whether the RAN4 work is separated or not can be discussed later (as well as other topic organization aspects), and hence it would be reasonable to capture RAN4 as secondary WG for this item at this moment.
- Regarding the performance gain of >4 Tx UL operation, there seems to be different views/results among companies based on past evaluation. Therefore, to support this item, study phase would be necessary.
- It seems obvious for companies that leading WG is RAN1, and there is no SA/CT impact.

Based on the above observations, the moderator's proposal for the refinement of this example area description is shown as below.

- **Study and if necessary specify >4 Tx UL operation, mainly targeting non-handheld devices e.g., CPE/FWA/vehicle/Industrial devices [leading WG: RAN1, secondary WG: RAN4]**

Enhanced multi-panel/multi-TRP uplink operation

Following observations on high-level aspects could be made based on intermediate round inputs.

- All companies providing inputs basically support this example area for UL enhancement in Rel-18, but for each of the potential items the moderator mentioned in initial round observation, there is at least one company requesting more discussion on motivation and justification. On the other hand, to clarify the potential scope of this example area, it would be worthwhile to list up items multiple companies provided motivation and justification as just potential scope (i.e., examples) for now.
- Enhancement for multi-panel UL operation and enhancement for multi-TRP UL operation can be separated although some proposed items are in the overlapped region. So, it can be described as "enhanced multi-panel uplink operation and/or enhanced multi-TRP uplink operation".
- Regarding target device type and frequency range, it seems further discussion is necessary and it would be difficult to describe them at this moment.
- It seems obvious for companies that leading WG is RAN1, and secondary WG would be RAN2/4. There is no comment regarding SA/CT impact.

Based on the above observations, the moderator's proposal for the refinement of this example area description is shown as below.

- **Specify enhanced multi-panel uplink operation and/or enhanced multi-TRP uplink operation, potentially including fast UL panel selection, separate UL timings for different panel/TRP and/or simultaneous multi-panel UL transmission [leading WG; RAN1, secondary WG: RAN2/4]**

Frequency selective precoding

Following observations on high-level aspects could be made based on intermediate round inputs.

- Almost all companies agreed that the study is necessary for this item.
- Many companies agreed that potential use case of this item is limited to devices with large number of antennas such as >=4 Tx, and hence it would be reasonable to clarify that this item targets devices with >= 4 Tx.
- As this item targets >=4 Tx devices, RAN4 work on 4 Tx requirement would be required same as >4 Tx operation. In that sense, RAN4 can be captured as secondary WG at this moment.
- For both >4 Tx operation and frequency selective precoding, as these items targets >=4 Tx devices that may be mainly non-handheld devices, some companies argued that these items should not be high priority items as main commercial interest is more on handheld devices (i.e., smartphones). This argument is also considered for other proposals targeting handheld devices.
- It seems obvious for companies that leading WG is RAN1, and there is no SA/CT impact.

Based on the above observations, the moderator's proposal for the refinement of this example area description is shown as below.

  - **Study and if necessary specify frequency-selective precoding, targeting devices with >=4 Tx [leading WG: RAN1, secondary WG: RAN4]**

Further coverage enhancements

Following observations on high-level aspects could be made based on intermediate round inputs.

- All companies providing inputs basically support this example area for UL enhancement in Rel-18, and many companies agreed to capture listed items in the initial phase observation, i.e., PUCCH/PRACH enhancements and power domain enhancements.
- On the other hand, some companies argued that the study is necessary for power domain enhancements while many other companies argued that power domain enhancements should be prioritized. Also, some companies argued that PUCCH/PRACH enhancements may have marginal gain while many other companies argued that PUCCH/PRACH enhancements could provide benefits. Therefore, to clarify the potential scope of this example area, it would be worthwhile to list up items multiple companies provided motivation and justification as just potential scope (i.e., examples) for now.
- The leading WG may be different for different items, e,g,, PUCCH enhancement is led by RAN1 (secondary RAN4), PRACH enhancement is led by RAN1 (secondary RAN2), power domain enhancement is led by RAN1 and/or RAN4. There is no comment regarding SA/CT impact.

Based on the above observations, the moderator's proposal for the refinement of this example area description is shown as below.

- **Specify further coverage enhancements, potentially including PUCCH enhancement, PRACH enhancement and/or power domain enhancement [leading WG: RAN1 and/or RAN4, secondary WG: RAN2/4]**

Other proposals

Following observations on high-level aspects could be made based on intermediate round inputs.

- Many companies argued that enhancement for multi-carrier UL operation (e.g., UL carrier switching) targeting devices with 2 Tx is beneficial and enhancements for handheld devices is more important than enhancements targeting non-handheld devices (such as >4 Tx operation and frequency selective precoding). Considering this argument, one possible modification of example area description is to merge >4 Tx operation and frequency selective precoding so that it can be described as e.g., enhancements targeting devices with >=4 Tx potentially including features enabling >4 Tx operation and frequency selective precoding. And then we can have another new example area e.g., enhancements targeting devices with 2 Tx potentially including enhancement for multi-carrier UL operation. Since the guidance said that "*Any refinement of the areas for each topic from the email discussion require strong motivation/justification and the bar is very high*", the moderator would like to ask companies' feedback although the moderator thinks strong motivation/justification have been provided by multiple companies.
- For other items such as enhancement for UL dense deployment, enhancement for DFTS-OFDM and enhancement for UL CW mapping, it seems further discussion is necessary based on the guidance requiring strong motivation/justification for refinement of example areas.

Based on the above observations, the moderator's proposal for the alternative refinement of whole example area description is shown as below.

Alternative:

- **Uplink enhancements, with the following skeleton of the possible objectives:**
  - **Specify enhanced multi-panel uplink operation and/or enhanced multi-TRP uplink operation, potentially including fast UL panel selection, separate UL timings for different panel/TRP and/or simultaneous multi-panel UL transmission [leading WG; RAN1, secondary WG: RAN2/4]**
  - **Specify enhancements targeting devices with 2 Tx, potentially including enhancements for multi-carrier UL operation [leading WG: RAN1, secondary WG: RAN4]**
  - **Study and if necessary specify enhancements targeting devices with >=4 Tx, potentially including features enabling >4 Tx operation mainly targeting non-handheld devices e.g., CPE/FWA/vehicle/industrial devices and/or frequency selective precoding [leading WG: RAN1, secondary WG: RAN4]**
  - **Specify further coverage enhancements, potentially including PUCCH enhancement, PRACH enhancement and/or power domain enhancement [leading WG: RAN1 and/or RAN4, secondary WG: RAN2/4]**

Moderator's proposed refinement of example area descriptions

Based on the above, moderator would like to ask companies' feedback on proposed refinement of each example area and alternative modification in the final round email discussion.

Starting point of high level description (from RP-210659):

- **Uplink enhancements, with the following example areas:**
  - **>4 Tx operation**
  - **Enhanced multi-panel/multi-TRP uplink operation**
  - **Frequency-selective precoding**
  - **Further coverage enhancements**

Proposed high level description based on the email discussion:

Alt.1:

- **Uplink enhancements, with the following skeleton of the possible objectives:**
  - **Study and if necessary specify >4 Tx UL operation, mainly targeting non-handheld devices e.g., CPE/FWA/vehicle/Industrial devices [leading WG: RAN1, secondary WG: RAN4]**
  - **Specify enhanced multi-panel uplink operation and/or enhanced multi-TRP uplink operation, potentially including fast UL panel selection, separate UL timings for different panel/TRP and/or simultaneous multi-panel UL transmission [leading WG; RAN1, secondary WG: RAN2/4]**
  - **Study and if necessary specify frequency-selective precoding, targeting devices with >=4 Tx [leading WG: RAN1, secondary WG: RAN4]**
  - **Specify further coverage enhancements, potentially including PUCCH enhancement, PRACH enhancement and/or power domain enhancement [leading WG: RAN1 and/or RAN4, secondary WG: RAN2/4]**

Alt.2:

- **Uplink enhancements, with the following skeleton of the possible objectives:**
  - **Specify enhanced multi-panel uplink operation and/or enhanced multi-TRP uplink operation, potentially including fast UL panel selection, separate UL timings for different panel/TRP and/or simultaneous multi-panel UL transmission [leading WG; RAN1, secondary WG: RAN2/4]**
  - **Specify enhancements targeting devices with 2 Tx, potentially including enhancements for multi-carrier UL operation [leading WG: RAN1, secondary WG: RAN4]**

- **Study and if necessary specify enhancements targeting devices with >=4 Tx, potentially including features enabling >4 Tx operation mainly targeting non-handheld devices e.g., CPE/FWA/vehicle/industrial devices and/or frequency selective precoding [leading WG: RAN1, secondary WG: RAN4]**
- **Specify further coverage enhancements, potentially including PUCCH enhancement, PRACH enhancement and/or power domain enhancement [leading WG: RAN1 and/or RAN4, secondary WG: RAN2/4]**

3 Final round

3.1 Collection of company views

3.1.1 General high level views

Based on the moderator summary in 2.2, companies are encouraged to provide views on high-level direction of moderator's proposed refinement of example area descriptions for UL enhancement, including preference between Alt.1 and Alt.2.

Feedback Form 13: General high level views

1 – Futurewei Technologies We thank the moderator for providing the very nice summary. Alternative 2 captures the key observations from the email discussion better than Alternative 1. Thus we prefer Alternative 2. For the further coverage enhancement bullet in Alt. 2, we suggest changing "Specify …" to "Study and if necessary specify…" since some companies including Futurewei think the gain from PUCCH/PRACH enhancement would be marginal, and the power domain enhancement requires new study.
2 – Lenovo (Beijing) Ltd We would like to thank the moderator for the excellent work on summarizing the companies' proposals, as well as his efforts to capture the views of different companies.
3 – vivo Communication Technology We would like to thank moderator for hard effort and proposes alternatives. We would like to emphasize the importance of enhancement for DFT waveform in UL, which directly related to efficiency of UE hardware. It was proposed as Rel-17 TEI in RAN1#106-e, most of the companies involved in Rel-17 TEI discussion were fine to handle in Rel-17 and few companies proposed to handle in Rel-18. In our view, it should be either specified in Rel-17 TEI or in Rel-18. It should be clarified that if not included in Rel-18, this is to be handled by Rel-17 TEI.
4 – China Telecommunications Thanks for the nice summary! We prefer Alt 2.
5 – Apple Computer Trading Co. Ltd Thank you moderator for the nice summary. In general, we suggest we clearly identify the target use case, e.g. handheld or non-handheld, as well as the target frequency range for all UL capacity related enhancement, and we prefer to start from Alt1, which is aligned with example sets endorsed previously.

6 – LG Electronics Inc.

Thanks moderator for the good summary. We prefer Alt1 with possible merge of 1st and 3rd bullets. Regarding Alt2, the work scope of the second bullet is unclear and too broad.

7 – NTT DOCOMO INC.

Thanks for the very good summary. We're fine with either Alt.

And we'd like to emphasize that UL dense deployment and dynamic UL waveform switching are important for our NW operation.

8 – SoftBank Corp.

Thank you very much for the good summary. Our preference is alt 2.

9 – Huawei Tech.(UK) Co.. Ltd

We support Alt2, which better capture the status of the discussion. We suggest clarifying the second bullet for 2Tx UEs with "multi-carrier UL operation *(>2 bands)*". If this bullet needs to be more specific (to address LGE's comment) we would suggest adding as example "UL Tx switching enhancements". We agree with the suggestion that "study and specify if beneficial" would be more appropriate for the bullet on coverage enhancements, which we support.

10 – Guangdong OPPO Mobile Telecom.

Thanks for the nice summary.

No matter alternative 1 or alternative 2, the scope is too large and scope clarity is needed before the down-selection. Please find more detailed comments for each individual part

11 – Qualcomm Incorporated

We prefer to go with Alt.1 due to the following detail: It is not clear to us why precoding enhancements and > 4 Tx operation should be bundled at this rather early stage. We prefer to keep them separate for now, and revisit at a future time to see if bundling them makes sense.

We prefer changing "frequency selective precoding" to "enhanced uplink precoding". Precoding enhancement requires additional overhead in DCI, this additional overhead can be used to enhance frequency resolution but can be also used to enhance the precoding resolution. As commented in previous rounds, frequency selective precoding has a problem with intermodulation, while this problem does not exist in wideband precoding enhancement. So, wideband precoding enhancement can be also considered as a meaningful candidate/baseline instead of limiting the solution frequency selective precoding. We suggest the following change:

- **Study and if necessary specify ~~frequency-selective~~ enhanced uplink precoding, targeting devices with >=4 Tx [leading WG: RAN1, secondary WG: RAN4]**

In addition, we think DFT-S-OFDM-related enhancement would be a low hanging fruit that we should strive to take care of in Rel-18. Given clear precedence in LTE, we don't see this being controversial. Therefore, we suggest adding the following to Alt1:

- **Specify mechanisms to enable DFT-S-OFDM waveform for transmissions with more than one layer and mechanisms for fast switching between DFT-S-OFDM and CP-OFDM.**

12 – TELECOM ITALIA S.p.A.

This activity is key in Rel 18.

However we have concern regarding the proposal to group >4Tx operation with frequency pre-coding. The two topics have quite a different level of maturity and complexity of implementation.

We propose to start immediately the normative work for >4Tx operation (no need for a study phase)

13 – Nokia Corporation

We would like to thank the moderator for the good work in managing the discussion. One aspect we would like to raise still is that in RP-211639 it is clearly stated the following:

The example areas under each topic serve as a starting point and are subject to further update/removal during the subsequent email discussion

Hence, we do not agree with the moderator's statement that the bar would need to be very high to include topics such as "enhancement for DFTS-OFDM" and "enhancement for UL CW mapping", as those have been proposed in the Rel-18 WS and are definitely in scope of the discussion thread. Our understanding is that the statement on the bar being very high relates to the organization of the threads themselves, not the example areas, which by definition are only examples and not final decisions. Those topics have been supported by quite a few companies, and in our understanding they should be listed as part of the scope of this thread. They do not need to be mapped to existing example areas at all.

14 – MediaTek Inc.

Thanks to the moderator for looking at this from different perspectives. We are actually ok with alt-1 or alt-2 approach but would like some concerns highlighted in the detailed sections below to be covered most importantly.

15 – CEWiT

We are fine with Alt2 , but still share the same concern of other companies over second bullet directly mentioning "Specify". We prefer "Study and if necessary specify" instead of "Specify"

16 – VODAFONE Group Plc

Thank you for the summary.

Overall Alt.1 does not focus on techniques aimed for handheld devices (2RX) in the same way Alt.2 does explicitly, so our preference is more towards Alt. 2.

DFT-S-OFDM enhancements such as dynamic waveform switching and multilayer transmission should be added to any of the two alternatives (for example in the last sub-bullet of each)

17 – China Unicom

Thanks for the good summary, we support Alt.2.

18 – ZTE Corporation

Thanks moderator for the great efforts on providing the summary. We prefer Alt 1.

As we commented, UE types should be further discussed in UE capability session after the features are ready in RAN1. We don't see any reasoning to do categorization at this moment as we only target for very high level description and current categorization would cause unnecessary market fragmentation.

For new added bullet for multi-carrier UL operation, it's not very clear for us what's the benefits compared to current fast cell activation/de-activation + Rel-17 Tx switching, which can already support fast change of the number of activated cells for transmissions and switching among up to 3 carriers with 2 Tx. If the intention is to additionally support switching among >=4 carriers, the additional switching gain could be marginal and it would also mainly apply to high-end UEs. In addition, the recommended areas for coverage enhancements are applicable for 2 Tx UEs and the scope of Alt 1 is balanced enough for different types of UEs. The last but not least, we still believe this should be discussed under other topics, e.g., flexible spectrum integration, where similar enhancements are proposed and already under discussion there.

19 – Samsung R&D Institute UK

Between Alt1 vs Alt2, we prefer Alt1 since >4Tx operation and frequency selective precoding are two separate topics, merging them into one topic (as proposed in Alt2) can make the scope a bit blurry and decision making more complex

20 – Xiaomi Communications

Thanks the moderator for the good summary. For the scope of the two alternatives, we are fine to with either alt and suggest to start wit h Alt.1.

21 – CAICT

Thanks for the good summary and we support Alt.2.

22 – China Mobile Com. Corporation

Thanks Moderator's great effort for the summary and proposals. The Alt 2 is preferred. And as commented in the below, we think the **Enhancement for UL CW mapping** should also be included which provide a solution to balance the performance and implementation.

23 – vivo Communication Technology

We support Alt.2

24 – Ericsson LM

We prefer Alt 1, assuming our refinements discussed in the corresponding sections that follow are acceptable. We think Alt 1 is more reasonable in terms of workload and more cohesive in terms of the topics covered than Alt 2.

Merging >4 Tx UL operation with UL frequency selective precoding results in quite a large study. 4 Tx operation will require new codebook designs, one for each of the new ranks supported, taking into account UE PAPR, different UE antenna configurations, possible enhancements to non-codebook based operation, etc. Frequency selective precoding is also a non-trivial exercise, since as we have seen in Rel-15 the amount of overhead tends to be quite large, which (unless it is precluded in the study) could result in the need for new control channel designs. Codebooks may also need customization for the frequency selective case to control overhead. And non-codebook operation may also need to be considered. Therefore, we do not think the bullets for >4 Tx and frequency selective precoding should be merged.

We think that multi-carrier UL operation with 2 Tx needs to be clarified. We understand this is not UL CA, but rather UL Tx switching of 2 Tx to more than 2 carriers. Assuming that this is correct, we prefer to prioritize other UL enhancements over this, as discussed further in section 3.1.6.

3.1.2 >4 Tx operation

Based on the moderator summary in 2.2, companies are encouraged to provide feedback on the moderator's proposed refinement for >4 Tx operation as below.

- **Study and if necessary specify >4 Tx UL operation, mainly targeting non-handheld devices e.g., CPE/FWA/vehicle/Industrial devices [leading WG: RAN1, secondary WG: RAN4]**

Feedback Form 14: >4 Tx operation

1 – Futurewei Technologies We are fine to study this at some point in time, preferably after R18.
2 – Lenovo (Beijing) Ltd The study shall be for both single-panel in FR1 or FR2, and multi-panel UE in FR2. We suggest to add this to the proposed text.
3 – vivo Communication Technology We are fine with the study, if included in Rel-18 scope, assupmtions on deployment scenario, antenna structure/coherence etc should be clarified.
4 – Apple Computer Trading Co. Ltd We suggest we remove "vehicles/Industrial devices", since currently even 4Tx is not supported in slidlink and some industrial devices are low power devices, which is not feasible to support >4Tx. In addition, in our understanding this is for FR1 only.
5 – NTT DOCOMO INC. Fine with the summary.
6 – LG Electronics Inc. Support the proposal
7 – Intel Deutschland GmbH We suggest removing RAN4 from secondary WG at this moment. RAN4 involvement can be discussed separately together with concrete objectives (e.g., whether new RF requirement should be defined or not).
8 – SoftBank Corp. We support this proposal

9 – Huawei Tech.(UK) Co.. Ltd

We are fine with the proposed direction

10 – Guangdong OPPO Mobile Telecom.

We are supportive of this proposal

11 – Qualcomm Incorporated

We are in general fine with the proposal for >4 Tx. Given that the majority of companies support >4 Tx only for non-handheld devices, we think the proposal should provide more clarity regarding this with the following modification:

- **Study and if necessary specify >4 Tx UL operation~~, mainly~~ targeting non-handheld devices e.g., CPE/FWA/vehicle/Industrial devices [leading WG: RAN1, secondary WG: RAN4]**

12 – TELECOM ITALIA S.p.A.

Strong concern vs Futurwei statement to move the activity outside Rel 18.

This is a clear market requirement.

In our opinion there is no need for a study phase. The normative activity could start immediately. Therefore we propose the following modification:

specify >4 Tx UL operation, mainly targeting non-handheld devices e.g., CPE/FWA/vehicle/Industrial devices [leading WG: RAN1, secondary WG: RAN4]

P.S. to Apple: of course there are different kind of industrial devices, but one of the target applications for this activity is industrial applications

13 – Nokia Corporation

We agree with the moderator's summary in this topic.

14 – SHARP Corporation

We support the moderator's proposal.

15 – CEWiT

We are fine with the moderator's proposal

16 – VODAFONE Group Plc

As said in the previous round we are fine with studying >4 TX operation, however from 6-7 GHz, smartphone form factors might be practical and thus the restriction to CPE/non handheld devices may be removed

17 – CATT

We support the proposal.

18 – ZTE Corporation

We support the proposal in principle. But, we still slightly prefer to make the scope of targeted devices more general, like:

− Study and if necessary specify >4 Tx UL operation~~, **mainly targeting non-handheld devices**~~ **e.g., for** CPE/FWA/vehicle/Industrial devices [leading WG: RAN1, secondary WG: RAN4]

19 – Samsung R&D Institute UK

We support this study and suggest to be specific, e.g. include the following within scope of this study: CB-based, non-CB-based, RS enhancements

Based on the above, the proposal can be modified as shown as underlined text.

Proposal:

- **Study and if necessary specify >4 Tx UL operation, mainly targeting non-handheld devices e.g., CPE/FWA/vehicle/Industrial devices, and including enhancements, e.g. CB-based, non-CB-based, RS [leading WG: RAN1, secondary WG: RAN4]**

20 – Xiaomi Communications

We support the proposal in priciple. better clarify if this is for either FR1 or FR2 or both.

21 – China Mobile Com. Corporation

Fine with current version. And preferred the Alt 2 from Moderator.

If this item is included for further study, the assumption of the terminals (clearly a non-handheld devices) and using scenarios should be clarified. As we commented, the total amount is not large for the non-handheld devices.

22 – Ericsson LM

We are OK with the study in principle. We'd suggest that the list of devices be square bracketed (**i.e.** "[CPE/FWA/vehicle/Industrial devices]"), since not all of these devices may be targeted in the study. The devices can be selected either when the WI/SI is agreed or as part of the study.

Identifying use cases / scenarios with realistic antenna configurations and proper channel models will be key to such a study. While this can be addressed later in the more detailed discussion stage, these aspects need to be called out in objectives if a WI/SI including >4 Tx is approved

3.1.3 Enhanced multi-panel/multi-TRP uplink operation

Based on the moderator summary in 2.2, companies are encouraged to provide feedback on the moderator's proposed refinement for enhanced multi-panel/multi-TRP uplink operation as below.

- **Specify enhanced multi-panel uplink operation and/or enhanced multi-TRP uplink operation, potentially including fast UL panel selection, separate UL timings for different panel/TRP and/or simultaneous multi-panel UL transmission [leading WG; RAN1, secondary WG: RAN2/4]**

Feedback Form 15: Enhanced multi-panel/multi-TRP uplink operation

1 – Futurewei Technologies

Support.

2 – Lenovo (Beijing) Ltd

We second Samsung's comment that UL multi-panel/multi-TRP shall be specified together with DL multi-panel/multi-beam enhancement. We understand it is out of scope for this discussion and is probably a topic for the RAN1#93e meeting.

Additionally, power control is important for multi-TRP transmission. We propose to add it to the proposal:

Specify enhanced multi-panel uplink operation and/or enhanced multi-TRP uplink operation, potentially including fast UL panel selection, separate UL timings and power control for different panel/TRP and/or simultaneous multi-panel UL transmission [leading WG; RAN1, secondary WG: RAN2/4]

3 – vivo Communication Technology

we would like to add clarification for "**separate UL timings for different panel/TRP** " is for **inter-cell multi TRP operation**.

4 – Apple Computer Trading Co. Ltd

We think simultaneous multi-panel UL transmission should depend on the work on fast UL panel selection, and it should only be for non-handheld UE. In addition, we think several aspects could be panel specific and we do not know why we mentioned separate UL timings. In addition, we think this is only for FR2. So we suggest the following change.

- **Specify enhanced multi-panel uplink operation and/or multi-TRP uplink operation for fast UL panel selection for FR2 [leading WG: RAN1, secondary WG: RAN2/4]**
- **Study, if needed, specify simultaneous multi-panel UL transmission for non-handheld UEs, e.g. CPE/FWA for FR2**

5 – NTT DOCOMO INC.

It is better to clarify the scenario of multi-panel (Tx) and multi-TRP (Rx) for UL.

For multi-panel UL transmission (with reception at single-TRP or multi-TRP), such as fast UL panel selection or simultaneous multi-panel UL transmission, it is for FR2.

While for multi-TRP reception (with transmission from single-panel UE or multi-panel UE), it can be FR1 or FR2. And for multi-TRP operation, we think it can include both intra-cell multi-TRP and inter-cell multi-TRP.

6 – LG Electronics Inc.

Support

7 – Intel Deutschland GmbH

1. "**Simultaneous multi-panel UL transmission**" should be captured in the beginning of the objective (not after potentially) since it is the main feature of the Rel-18 enhancement. We are still not sure what kind of enhancements are required for fast panel selection given that all panels should be active. The revised objective according to the comments above is provided below:

Specify enhanced multi-panel uplink operation and/or enhanced multi-TRP uplink operation with simultaneous multi-panel UL transmission, potentially including ~~fast UL panel selection~~, separate UL timings for different panel/TRP and/or [leading WG; RAN1, secondary WG: RAN2/4]

2. We are not sure what kind of objectives are planned for RAN2/RAN4 as secondary WG. If it is conventional tasks, i.e., RRC signalling, performance requirements perhaps we don't need to capture this?

8 – Huawei Tech.(UK) Co.. Ltd

With the understanding that "and/or" means that we will need further discussion to select exactly what enhancements to finally target, we are fine to move forward with this summary. But we would not agree to this summary as a WI objective directly because the scope needs further discussion. In particular we still don't see the need to consider simultaneous multi-panel UL transmission, at least not with the same priority as the other potential objectives.

9 – Guangdong OPPO Mobile Telecom.

We suggest to revise the proposal as below

Specify enhanced multi-panel uplink operation ~~and/or enhanced multi-TRP uplink operation~~, potentially including ~~fast UL panel selection, separate UL timings for different panel/TRP and/or~~ simultaneous multi-panel UL transmission [leading WG; RAN1, secondary WG: RAN2/4]

The rationale behind the modification is as below

- The scope of this proposal is too large
- "fast UL panel selection" was studied in Rel-16 and Rel-17. If 3GPP cannot finish the corresponding work in Rel-17, we don't think there is any benefits/motivation to further work on it.
- "Separate UL timing" is the next level of details for the multi-panel UL transmission. Other similar issues are e.g., power control, coexistence of signals/channels. Thus, it should not be captured in the same level as multi-panel UL transmission.
- The scope of "enhanced multi-TRP uplink operation" is not clear. Some clarification on the scope is needed before we can agree it.

10 – NEC Corporation

Support in general. Also we support to include UL power control for different panel/TRP.

We prefer to add a note for clarification that enhancements are based on Rel-17 unified TCI framework.

11 – Qualcomm Incorporated

We have a comment on simultaneous UL transmission. We think it should cover both FR1 and FR2. The current wording "**simultaneous multi-panel UL transmission**" seems to be only covering FR2. Specification-wise, we don't see extra effort to specify simultaneous UL transmission for FR1, on top of FR2. Therefore, we don't see the reason that FR1 should be left out from simultaneous UL transmission. Therefore, we propose the following update:

- **Specify enhanced multi-panel uplink operation and/or enhanced multi-TRP uplink operation, potentially including fast UL panel selection, separate UL timings for different panel/TRP and/or simultaneous multi-panel/multi-antenna UL transmission [leading WG; RAN1, secondary WG: RAN2/4]**

12 – MediaTek Inc.

In general we can accept this as a starting point and thank the moderator for the effort. However, we do have some concerns/comments still, and would expect that further refinement is required towards December:

- Fast UL panel switching should be the priority over simultaneous multi-panel.
- Simultaneous multi-panel UL in our view is a low priority, and would need some study on the benefits vs device impact before any specification work. As a maximum, it would be limited to "non-handheld" devices in our view, for the reasons stated in the previous round. We asked in the previous round for the proponents to clarify which device type this is for - so feedback appreciated.
- Separate UL timing: Our view was that this was to allow flexibility of different timing advance in the multi-TRP scenario. This does not depend necessarily on simultaneous multi-panel in our view. But we are neutral on this if other companies don't see it as urgent.
- We understand the multi-beam related enhancements are discussed in the DL MIMO thread and not here. Otherwise we would like them to be included. Hopefully moderator can clarify.

13 – Nokia Corporation

We agree with the moderator's summary in this topic.

14 – SHARP Corporation

We support the moderator's proposal.

15 – CEWiT

We are fine with the moderator's proposal

16 – Sony Corporation

Thanks for the summary. We support the Moderator's proposal.

17 – CATT

We support the proposal.

18 – ZTE Corporation

We support the proposal in principle. Many companies have highlighted that separate UL power control for different panel/TRP is needed. So we prefer to have the following minor update:

− Specify enhanced multi-panel uplink operation and/or enhanced multi-TRP uplink operation, potentially including fast UL panel selection, separate UL timings/**UL power control** for different panel/TRP and/or simultaneous multi-panel UL transmission [leading WG; RAN1, secondary WG: RAN2/4]

19 – Samsung R&D Institute UK

Comments:

· Since this enhancement will be based on the unified TCI framework being developed in release-17; it should be clarified by adding "based on the Rel.17 unified TCI framework",

· UL power control aspects are also important area to look into

· Finally, as commented previously, we still prefer some of these should be done in DL enhancement as a part of Multi-beam (thread 1)

Based on the above, the proposal can be modified as shown as underlined text.

Proposal:

- **<u>Based on the Rel.17 unified TCI framework,</u> Specify enhanced multi-panel uplink operation and/or enhanced multi-TRP uplink operation, potentially including fast UL panel selection, separate UL timings/<u>power control</u> for different panel/TRP and/or simultaneous multi-panel UL transmission-[leading WG; RAN1, secondary WG: RAN2/4]**

20 – Fraunhofer IIS

We support in principle. Like other companies, we agree that further discussion is needed on the exact scope and some kind of down-selection of the listed topics is needed. Otherwise, the scope is too large.

21 – Xiaomi Communications

we support this proposal in principle, and same view with QC that FR1 should be coverd too.

22 – KDDI Corporation

We support the proposal.

23 – China Mobile Com. Corporation

We are fine with current version and moving forward with further detailed discussion.

24 – Ericsson LM

We are mostly fine with Moderators's proposed refinement except for one issue. It is still unclear what enhancements are needed for fast UL panel selection, since the R17 framework facilitates switching based on DCI. Some of the comments are related to UE-initiated reporting, but that is hardly fast UL panel

selection. Hence, we suggest to either replace 'fast UL panel selection' with 'UE initiated reporting', or require further clarification on what additional enhancements are needed for 'fast UL panel selection' on top of what is agreed in Rel-17.

3.1.4 Frequency-selective precoding

Based on the moderator summary in 2.2, companies are encouraged to provide feedback on the moderator's proposed refinement for frequency-selective precoding as below.

- **Study and if necessary specify frequency-selective precoding, targeting devices with >=4 Tx [leading WG: RAN1, secondary WG: RAN4]**

Feedback Form 16: Frequency-selective precoding

1 – Futurewei Technologies We are fine to study this at some point in time, preferably after R18 when >4 Tx study picks up.
2 – Lenovo (Beijing) Ltd We support moderator's proposal.
3 – vivo Communication Technology this should also include potential codebook enhancement for 4Tx
4 – Apple Computer Trading Co. Ltd We suggest we clarify that this is for FR1 only and non-handheld UE.
5 – NTT DOCOMO INC. Fine with the summary.
6 – LG Electronics Inc. We are fine with study
7 – Intel Deutschland GmbH We suggest removing RAN4 from secondary WG at this moment. RAN4 involvement can be discussed separately together with concrete objectives (e.g., whether new RF requirement should be defined or not).
8 – Huawei Tech.(UK) Co.. Ltd We are fine with the proposed direction
9 – Guangdong OPPO Mobile Telecom. We are generally fine with the proposal. But we prefer to restrict this study only for > 4Tx since frequency-selective precoding was discussed in Rel-15 and no consensus on the benefit.

10 – Qualcomm Incorporated

We prefer Alt 1. It's not fully clear to us whether precoding enhancements and > 4 tx operation must be bundled at this rather early stage. We prefer to keep them separate for now, and revisit at a future time to see if bundling them makes sense.

For the objective detail, repeating our previous comment: We prefer changing "frequency selective precoding" to "enhanced uplink precoding". Precoding enhancement requires additional overhead in DCI, this additional overhead can be used to enhance frequency resolution but can be also used to enhance the precoding resolution. As commented in previous rounds, frequency selective precoding has a problem with intermodulation, while this problem does not exist in wideband precoding enhancement. So, wideband precoding enhancement can be also considered as a meaningful candidate/baseline instead of limiting the solution frequency selective precoding. We suggest the following change:

- **Study and if necessary specify ~~frequency-selective~~ enhanced uplink precoding, targeting devices with >=4 Tx [leading WG: RAN1, secondary WG: RAN4]**

11 – TELECOM ITALIA S.p.A.

We do not agree with the rapporteur's proposal to group this item with >4Tx operation

12 – Nokia Corporation

We agree with the moderator's summary in this topic.

13 – MediaTek Inc.

- We agree with others (Qualcomm at least) that **"wideband precoding enhancement"** should also be evaluated here (this is what we called "high resolution precoding" in the previous rounds) as a baseline or alternative when doing the evaluation.
- We think it would be good not to rule out consideration of 4Tx and lower than 4Tx antennas if evidence is further demonstrated e.g. by October. We also would like to see overhead reduction/signalling optimisation to be included in scope - as this is important here.

14 – SHARP Corporation

We are fine with the moderator's proposal.

15 – CATT

We support the proposal.

16 – ZTE Corporation

We support the proposal in principle. We are open to further study and evaluate, but we don't think it is appropriate to preclude 2Tx case at this stage.

- Study and if necessary specify frequency-selective precoding, **potentially** targeting devices with >=4 Tx [leading WG: RAN1, secondary WG: RAN4]

17 – Samsung R&D Institute UK

Comments:

· We support this proposal

· We think the objective of the study should be clearly stated, e.g. study the benefit considering the DL control overhead (i.e. performance-overhead trade-off), including codebook enhancements. This implies that some design on DL control signaling is also within the scope.

Based on the above, the proposal can be modified as shown as underlined text.

Proposal:

- **Study and if necessary specify frequency-selective precoding, targeting devices with >=4 Tx, <u>based on performance vs DL control overhead tradeoff, and including codebook enhancements and DL control signaling design</u> [leading WG: RAN1, secondary WG: RAN4]**

18 – Xiaomi Communications

we are fine with the proposal

19 – CEWiT

We support this proposal.

20 – China Mobile Com. Corporation

Fine with Moderator's proposal. Alternative 2 is preferred.

21 – Ericsson LM

We are OK with the study in principle. As in the >4 Tx case, identifying use cases / scenarios with realistic antenna configurations and proper channel models will be key to such a study. Also, as commented by many companies, overhead is a key concern with UL frequency selective precoding, and therefore we think the study should be constrained to assume that DCI carrying FS precoding information fits in Rel-15 PDCCH. While they can be addressed late in the more detailed discussion stage, these aspects need to be called out in objectives if a WI/SI including frequency selective precoding is approved.

3.1.5 Further coverage enhancements

Based on the moderator summary in 2.2, companies are encouraged to provide feedback on the moderator's proposed refinement for further coverage enhancements as below.

- **Specify further coverage enhancements, potentially including PUCCH enhancement, PRACH enhancement and/or power domain enhancement [leading WG: RAN1 and/or RAN4, secondary WG: RAN2/4]**

Feedback Form 17: Further coverage enhancements

1 – Futurewei Technologies

We suggest changing "Specify …" to "Study and if necessary specify…" since some companies including Futurewei think the gain from PUCCH/PRACH enhancement would be marginal, and the power domain enhancement requires new study.

2 – Lenovo (Beijing) Ltd

We support moderator's proposal on PRACH and PUCCH. We think the merit of power domain enhancement needs study and can be made a separate SI or a study phase of the WI.

3 – China Telecommunications

We support moderator's proposal to specify further coverage enhancements, including PUCCH enhancement, PRACH enhancement and power domain enhancement for PUSCH.

For PUCCH and PRACH enhancement, actually we have done extensively study during Rel-17 SI on coverage enhancement, thus we don't think additional study phase is needed.

Regarding power domain enhancement for PUSCH, we think a study phase can be added in the WI if necessary.

4 – Apple Computer Trading Co. Ltd

We have concern for this proposal. Current proposal is too broad and no specific objectives are specified.

In our view, the DMRS-less PUCCH can be considered for PUCCH enhancement. PRACH repetition can be considered to improve the PRACH coverage, and the enhancement should focus on PRACH format B4 which is identified as the bottleneck channel in FR2 during Rel.17 study.

In addition, we think power domain enhancement needs more study and the benefit is unclear. Does the study of power domain enhancement include MPR reduction and dynamic power aggregation only?

5 – NTT DOCOMO INC.

We can revise it as "Study and if necessary specify…" at the beginning.

6 – Samsung Research America

We have essentially the same comment as from the intermediate round. The only channel requiring coverage enhancement, particularly in FR2, is the PRACH.

That can be handled in a general WI for UL enhancements. There is no need for a continuation of the coverage enhancements WI in Rel-18 and it should be deprioritized.

7 – Intel Deutschland GmbH

We are fine to include PRACH enhancement for further coverage enhancement. However, for PUCCH enhancement, it is not clear to us whether it needs to be included in the scope. As mentioned in the intermediate round, DMRS-less PUCCH scheme does not improve the performance compared to existing PUCCH format if advanced receiver algorithm is applied.

For power domain enhancement, the leading WG should be RAN4, not RAN1.

8 – Huawei Tech.(UK) Co.. Ltd

We think that the bullet should be formulated as "study and specify if beneficial". Perhaps this is the meaning of "and/or"? If so we suggest making it clearer.

9 – SoftBank Corp.

We support the inclusion of power domain enhancements. If companies want to introduce study phase, that's OK. However, it looks to us that the benefit is very clear.

As for coverage enhancements, we are OK with PRACH and PUCCH enhancements. We share the similar view as China telecom that we have already finished the study phase, and it is not necessary to re-open the discussion on candidate solutions.

10 – Guangdong OPPO Mobile Telecom.

We are supportive of this proposal.

In addition, we should also include the coverage recovery of PDCCH for 1RX. This topic did not cover by both Rel-17 WI of CE and RedCap. But it is concluded beneficial in study phase. And it would be good to done in Rel-18

11 – EURECOM

We support this proposal. PUCCH coverage enhancements are essential and, as reported in the SI, there are still significant gains to be achieved.

12 – NEC Corporation

Support the proposal. We think coverage enhancement in Rel-18 should include those which are identified benefit in coverage enhancement SI but has not been done in Rel-17 due to down-selection of scope in WI.

13 – Spreadtrum Communications

We support the PUCCH and PRACH part for UL coverage enhancements.

Regarding power domain enhancement, study phase is needed, because it is not clear for us, including use cases, specification impacts, etc.

14 – Qualcomm Incorporated

We are okay with the refinement, but prefer to list some candidate solutions

- **Specify further coverage enhancements, potentially including PUCCH enhancement, PRACH enhancement (e.g. repetitions) and~~/or~~ power domain enhancement (e.g. dynamic power aggregation) [leading WG: RAN1 and/or RAN4, secondary WG: RAN2/4]**

15 – Nokia Corporation

We agree with the moderator's summary in general, but we would remove "or" from "...and/or power domain...". We don't see a need to list further examples inside the topics, like proposed by Qualcomm above.

16 – SHARP Corporation

We support the moderator's proposal.

17 – MediaTek Inc.

- Reiterating for the 3rd time, before we agree to specify anything we would like to review where we have actually ended up in Rel-17 vs targets, and whether it makes sense to continue with further work. We completely understand that coverage is an important issue, but any improvements have to provide value, and we would not like 3GPP to just pick and choose enhancements that we didn't consider essential before based on a majority polling but with no further technical analysis, as that is not guaranteed to lead to something useful for operators. **So as a minimum some sort of structured study/Rel-17 review phase is required before anything else.**
- For the power-domain enhancements, repeating our 2nd round comment, that this really needs some studies also by RAN4 first, so that we understand the practical benefits vs drawbacks as well as elaboration of the exact proposals.
- For the dynamic power aggregation for UL CA, we would like feedback from proponents on what they feel is needed beyond what RAN4 is already doing.

18 – VODAFONE Group Plc

We are supportive of this proposal as in Rel-17 PUCCH and PRACH were 2nd priority. Other improvements from Rel-17 leftovers and applied to RedCap should be evaluated too.

19 – CATT

We support the proposal in general and agree with the comments above to change "Specify …" to "Study and if necessary specify…".

20 – ZTE Corporation

We support moderator's proposal on PRACH and PUCCH. We are ok to include power domain enhancements if it could be more specific. Currently, it is too broad.

We would like to highlight that there is clear performance gain for DMRS-less PUCCH and multiple PRACH enhancements based on the study in Rel-17 CE in TR 38.830. Basically, DMRS-less PUCCH can provide about 2.5dB SNR gain and about 3 dB PAPR gain by averaging the evaluation results provided by all sources. PRACH enhancements can provide 1.7 5.2 dB gain by enabling 2 or 4 PRACH transmissions.

21 – Xiaomi Communications

We support moderator's proposal to specify further coverage enhancements, including PUCCH enhancement, PRACH enhancement and power domain enhancement for PUSCH.

22 – China Mobile Com. Corporation

Support the power domain enhancement and prioritized. If the benefits is not clear to the group, a study item is also acceptable to us.

And sorry for repeat ourselves again. In our understanding, the PRACH enhancement should focus on FR2.

23 – Ericsson LM

We can agree to this proposal if PUCCH enhancement is removed.

The scope of these coverage enhancements is quite broad, including what is likely to be an entirely new PUCCH format, MPR reduction and/or potentially new waveforms, as well as PRACH repetition. Specifying all of these will require a lot of time units, and the benefit from some of them is not clear.

Given that PUCCH already has Rel-17 coverage enhancements in PUCCH repetition as well as joint channel estimation, and since there was not consensus on the benefit of DMRS-less PUCCH in the CovEnh study, we do not agree to PUCCH enhancements being listed in this coverage enhancement work at this time.

For PRACH, we did not see a need in Rel-17 study if tight missed detection targets were not used. However, we recognize other companies' interest and expect that multiple PRACH transmissions with the same beam using existing short PRACH formats would not require excessive specification effort, and so we can be OK to have that as part of the coverage enhancement work.

3.1.6 Other proposals

Based on the moderator summary in 2.2, companies are encouraged to provide feedback on the moderator's proposed alternative refinement as below.

- **Specify enhancements targeting devices with 2 Tx, potentially including enhancements for multi-carrier UL operation [leading WG: RAN1, secondary WG: RAN4]**
- **Study and if necessary specify enhancements targeting devices with >=4 Tx, potentially including features enabling >4 Tx operation mainly targeting non-handheld devices e.g., CPE/FWA/vehicle/industrial devices and/or frequency selective precoding [leading WG: RAN1, secondary WG: RAN4]**

Feedback Form 18: Other proposals

1 – Futurewei Technologies

Support.

2 – Lenovo (Beijing) Ltd

We prefer the structure of Alt1. For 4Tx, only frequency-selective precoding will be specified; for >4Tx, both frequency-selective and non-frequency-selective precoding precodings will be specified. This is better reflected in Alt 1. We think the frequency-selective precoding shall be based on non-frequency selective precoding, and the same or similar design can be applied to both 4Tx and >4Tx.

3 – vivo Communication Technology

As commented in general section above, enhancement for DFT waveform in UL, it should be clarified that if not included in Rel-18, this is to be handled by Rel-17 TEI.

4 – Apple Computer Trading Co. Ltd

We failed to see the necessity and benefit for enhancements for multi-carrier UL operation, and the scope seems to be too broad.

5 – NTT DOCOMO INC.

As commented in general section, UL dense deployment and dynamic UL waveform switching are important for our NW operation.

6 – LG Electronics Inc.

The scope of the first bullet is unclear and too broad. Second bullet is fine to us.

7 – Intel Deutschland GmbH

It seems current objectives only consider UE-based enhancements and only feasible for certain devices, e.g., CPE. We should also consider NW based solutions as well to make the UL enhancements valid for all device types including handheld devices. From this perspective we again strongly propose to add enhancements for UL dense deployments, which is supported by several companies based on our reading of feedback. The wording for proposed objective is provided below:

Specify enhancements targeting dense deployment scenario (e.g. TRP with UL Rx capability, TRP with different Tx powers) [leading WG: RAN1]

8 – Huawei Tech.(UK) Co.. Ltd

Please see our comments to the general section. The benefits of extending UL Tx switching for 2Tx UEs to more than 2 bands are explained in our Tdoc RWS-210436, as well as summarized in earlier rounds. UL multi-carrier operation for 2Tx UEs is limited to 2 bands per the current CA framework, which is inefficient from system perspective when more than 2 bands are avaiable, especially multiple TDD bands with different SCS or DL/UL configurations. With minor increase in UE complexity (compared to 3 band UL CA and 4 band UL CA), 2Tx UEs UL performance can be improved by allowing such UE to dynamically access more than 2 bands, leading to a more efficiency utilization of all UL resources available at the network. This is the target of the first bullet.

9 – vivo Communication Technology

Revision

As commented in general section above, enhancement for DFT waveform in UL, it should be clarified that if not included in Rel-18, this is to be handled by Rel-17 TEI.

Support of 2 CWs for >=2 layers in UL can also be considered in Rel-18, which was also proposed in Rel-17 TEI.

10 – ZTE Corporation

Thank you so much for Moderator's great efforts. Now, to be honest, we are not quite sure what's the criterion of judging 'strong motivation/justification for refinement of example areas'. For UL CW mapping, it is from real tests, and was already supported by many operators even in RAN1 Rel-17 TEI discussion, please refers to the tdoc R1-2106562.

Specifically, in the real test of some NR deployments for UL transmission with 2 non-coherent UE antennas, the peak date rate is restricted because of much different channel conditions of two antennas which

correspond to two layers of rank 2 transmission. That is because receiving power and demodulation constellation mapping are quite different for two layers which is configured with the same MCS for NR UEs. To make sure the TB is decoded correctly, high MCS values may not be selected because of the layer with lowest receiving power/SINR. That is, if the receiving power/SINR gap between two layers are much, higher MCS value cannot be indicated.

Therefore, we still believe UL CW mapping (with two MCS for two layers) should be specified in Rel-18 to meet the demands from real deployment.

- **Enhancement for UL CW mapping e.g., 2 CWs for >= 2 layers**

11 – Guangdong OPPO Mobile Telecom.

We think enhancement for UL CW mapping may be beneficial for some use cases and support to study it.

12 – SoftBank Corp.

Support for these two bullets.

Also, we still prefer to consider the following two topics:

- Enhancement for DFTS-OFDM e.g., dynamic waveform switching and/or >1 rank support for DFTS-OFDM as in LTE
- Enhancement for UL CW mapping e.g., 2 CWs for >= 2 layers

13 – Qualcomm Incorporated

Real world benefit to operators from the use of DFT-S-OFDM waveforms are likely more tangible and immediate than the other enhancements listed here. It seems premature to deprioritize this right now.

For companies asking for motivation of > 1 layer DFT-S-OFDM, FR2 has two distinct polarizations and rank-2 channels are observed more frequently than they are for FR1. We think anyone concerned about FR2 uplink would be interested in this line of enhancements.

Since no negative remarks were recorded on this besides enquiries on prevalence of rank 2 scenarios, we suggest adding the following:

- **Specify mechanisms to enable DFT-S-OFDM waveform for transmissions with more than one layer and mechanisms for fast switching between DFT-S-OFDM and CP-OFDM.**

We prefer to address this rather straightforward enhancement in Rel-18 and not postpone it any further.

14 – TELECOM ITALIA S.p.A.

As already stated, we do not agree to group together >4 TX operation with frequency selective precoding. the two topics have different level of maturity.

The activity on >4 Tx operation should be normative, not a study

15 – Nokia Corporation

Please see the comment to the general section. We understand there is no problem in listing topics that do not fit the initial example areas, which are just examples, as long as they are within the general scope of the email thread itself (UL enhancements). Hence, we believe “enhancement for DFTS-OFDM” and

"enhancement for UL CW mapping" should be listed in the summary, as those have been proposed in the Rel-18 WS, they are supported by a few companies, and are definitely in scope of the discussion thread.

On the enhancements for DFT-S-OFDM we should still separate support for more than one layer and fast switching between DFT-S-OFDM and CP-OFDM, as the motivation for the latter is less clear and more discussion is needed in our view.

As for the moderator's proposal for this section, we think the first bullet is too general, as basically it invites for any enhancements on 2TX devices, potentially even beyond what has been discussed so far. As for the second one, it is not clear what is the real difference compared to other proposals above.

16 – China Telecommunications

We support Tx switching enhancements for more than 2 bands. In addition, if finally **enhancement for UL CW mapping** is not supported in Rel-17, we think it should be included in Rel-18 scope.

17 – MediaTek Inc.

For the following **Enhancement for UL CW mapping e.g., 2 CWs for >= 2 layers**, we would like to see some further structured analysis of the gains of such a feature before we agree to specify it.

18 – CEWiT

As mentioned in the general views section, we prefer "Study and if necessary specify" over "Specify " in first bullet.

19 – VODAFONE Group Plc

We support the proposal, and the enhancements on DFT-S-OFDM (multilayer and waveform switching) and UL CW mapping seem reasonable to be included

20 – CATT

We do see the issue of imbalanced UL received power in real field. Current NR codeword mapping has limitations when there is large receiving SINR gap between different layers. Supporting 2 CWs for >=2 layers would bring obvious performance gain. So we support 2 CWs for >= 2 layers.

21 – ZTE Corporation

As commented above, we don't see the need to include the first bullet for multi-carrier UL operation.

22 – NTT DOCOMO INC.

In addition to UL dense deployment and dynamic UL waveform switching (commented above), we think "UL CW mapping (e.g., 2 CWs for >= 2 layers)" is useful. If we consider current practical scenario of 2Tx cross pol. antenna, and when there is large SNR difference across two antenna ports, it is beneficial to allow different CW for different antenna ports, to improve UL performance. We note that this can improve UL performance even for 2 Tx UEs.

23 – Huawei Tech.(UK) Co.. Ltd

In response to ZTE, current support of UL Tx switching is limited to 2 bands (even though it supports switching over 3 carriers). Switching over more than 2 bands requires cell activation/deactivation (for a

2Tx UE), which does not allow switching at the slot level to exploit the available UL slots that may change slot by slot across TDD bands.

We support the comments to make the first bullet more focused (as we suggested in an earlier comment) and if companies need 3GPP to assess the gains of UL Tx switching across more than 2 bands before specifying then this objective can start with evaluations of the gains. By the way, this seems to be broadly the case for all potential enhancements being discussed under this topic.

24 – China Mobile Com. Corporation

general fine with moderator's proposal.

Besides, we think the **Enhancement for UL CW mapping e.g., 2 CWs for >= 2 layers** should be also supported. It was also proposed in the TEI proposal in Rel-17. But it seems we do not have enough time to solve it. Then we propose to solve it in Rel-18. One of reason to raise this issue is due to different antenna gains and insert losses between the two transmit chains and mainly dependent on the implementations. The mechanism could be one solution to balance the implementation of UE side and the performance of the network and uses.

25 – Samsung R&D Institute UK

Multi-panel transmission may be handled by a MIMO-related WI.

For Tx antennas sharing a same PA, there is no material benefit from additional diversity, either Tx diversity or carrier diversity (if UEs support CA), on top of the gNB Rx diversity and the FH diversity from transmissions with repetitions. If anything, such schemes will generally result to worse performance due to degraded channel estimation.

26 – KDDI Corporation

Generally, we support the proposals. In addition to them, we prefer DFT-S-OFDM waveform for transmissions with more than one layer and mechanisms for fast switching between DFT-S-OFDM and CP-OFDM are to be included.

27 – China Mobile Com. Corporation

Thanks Moderator's great effort for the summary and proposals. The Alt 2 is preferred. And as commented in the below, we think the **Enhancement for UL CW mapping** should also be included which provide a solution to balance the performance and implementation.

28 – ZTE Corporation

Besides, we also identify benefits of introducing UL dense deployment for UL enhancement with a good tradeoff between NW deployment cost and improvements for UL throughput and reliability. So, we can also support it for Rel-18 UL enhancement.

29 – Ericsson LM

Regarding multi-carrier UL, if the intention of proposal is to support UL Tx switching with more than two carriers with UL (as suggested by some companies) this should be explicitly clarified in the proposal. If proposal intends to also enhance 2Tx with 2 carriers case, then it is preferable to capture the intended for that case separately.

On Tx switching with more than 2 carriers with UL, similar to Nokia's comment, the benefit of UL switching with more than two carriers compared to two carrier case is not clear considering potential switching

gaps, DL interruptions etc. Our preference is to prioritize other UL enhancements over this. It is also unclear why RAN1 is proposed as the leading WG for this instead of RAN4. We also expect significant RAN2 impact for this.

Regarding fast CP-OFDM / DFT-S-OFDM switching and/or multi-layer DFT-S-OFDM, these seem to be the topics with the second most interest. Companies have also commented that the specification effort should be small, which we expect is in contrast with UL Tx switching with more than two carriers, especially if the carriers are not RRC configured.

3.2 Moderator Summary and recommendation for further discussion

General

Thank you very much again for valuable inputs and discussions from many companies in all rounds. Following is the moderator's general observation based on all rounds discussions.

- All companies would agree that "UL enhancement" can be considered as one of the key topics for Rel-18. However, there is a concern on potential too large scope for the UL enhancement. Although it could be beneficial to capture a few more example areas based on this email discussion as requested by multiple companies, further discussion on prioritization among example areas would be necessary as well as narrowing down the scope of each example area.
- Although we could have a good discussion to clarify the scope of each example area and other potential example areas, it seems companies can converge only on very high level scope with just potential several scopes as examples (that can be "non-controversial" part of the final summary). Suggested further clarifications/discussion points for the scope can be captured in the summary, but as "controversial".
- Regarding Alt.1 vs Alt.2, I see that there are several companies objecting to merge ">4 Tx operation" and "frequency-selective precoding" while companies supporting Alt.2 prefer to add the new example area for "enhancement targeting devices with 2 Tx" rather than merging above two existing example areas. So, as above 1st observation from moderator, we can add a few example areas while keeping the current example areas without merging, assuming further discussion on prioritization among example areas and reorganization with other topics would be anyway necessary.

>4 Tx operation

Following observations could be made based on final round inputs.

- Generally, companies would be able to accept the moderator's proposed refinement based on the discussion.
- Regarding the clarification on target device type, although majority supports the moderator's proposed refinement "mainly targeting non-handheld devices e.g., CPE/FWA/vehicle/Industrial devices", there are some companies prefer to discuss further on the targe device later. So whether only some of listed example device types are targeted or even other device types (including handheld device in specific frequency band/range) are also targeted can be captured as "controversial" note.

- Target frequency range should also be clarified as commented by multiple companies, but it has not been converged and hence it can also be captured as "controversial" note.
- More specific scope for this example area, e.g., enhancements for codebook based UL MIMO, non-codebook based UL MIMO, RS, should be further discussed in next phase discussion.
- Also, identifying deployment scenario, antenna configurations and so on should be further discussed later.
- Whether RAN4 is secondary WG for this item is also moved to "controversial" note.

Based on the above observations, the moderator's final summary for this example area is shown as below.

[non-controversial]

- **Study and if necessary specify >4 Tx UL operation, e.g., for CPE/FWA/vehicle/Industrial devices [leading WG: RAN1]**

[controversial]

- **FFS: whether only some listed example device types are targeted or even other device types are also targeted**
- **FFS: target frequency range**
- **FFS: RAN4 as secondary WG**

Enhanced multi-panel/multi-TRP uplink operation

Following observations could be made based on final round inputs.

- Generally, companies would be able to accept the moderator's proposed refinement of separating multi-panel enhancement and multi-TRP enhancement.
- "and/or" means that we can further discuss either one of them or both will be the part of the scope for this example area. Since there are some companies supporting only one of them, "and/or" should be kept so that it can be "non-controversial".
- Regarding the listed potential scopes for this example area, it should be just examples for now based on the feedbacks. We can add a note in "controversial part" that clarification and narrowing down the scope can be further discussed based on examples as starting point.
- Although some companies commented that clarifying enhancements are based on Rel-17 unified TCI framework is necessary, it has not sufficiently discussed yet. It can also be "controversial" part.
- Target frequency range should also be clarified as commented by multiple companies, but it has not been converged and hence it can also be captured as "controversial" note.
- Whether RAN2/4 are secondary WG for this item is also moved to "controversial" note.

Based on the above observations, the moderator's final summary for this example area is shown as below.

[non-controversial]

- **Specify enhanced multi-panel uplink operation and/or enhanced multi-TRP uplink operation, potentially including fast UL panel selection, separate UL timings/power controls for different panel/TRP and/or simultaneous multi-panel UL transmission [leading WG; RAN1]**

[controversial]

- **FFS: further clarification and narrowing down of the scope for this example area based on listed example scopes as starting point**
- **FFS: enhancements are based on Rel-17 unified TCI framework**
- **FFS: target frequency range**
- **FFS: RAN2/4 as secondary WG**

Frequency-selective precoding

Following observations could be made based on final round inputs.

- Generally, companies would be able to accept the moderator's proposed refinement based on the discussion.
- Suggested clarification on the target frequency range and device types (i.e., whether we can also target <4 Tx) should be a part of "controversial" part for further discussion in next phase.
- Suggested generalization of this example area (i.e., "enhanced uplink precoding" to cover wideband precoding enhancement) should also be a part of "controversial" part for further discussion.
- More specific scope for this example area, e.g., codebook enhancements and DL control signaling design, should be further discussed in next phase discussion.
- Whether RAN4 is secondary WG for this item is also moved to "controversial" note.

Based on the above observations, the moderator's final summary for this example area is shown as below.

[non-controversial]

- **Study and if necessary specify frequency-selective precoding, mainly targeting devices with >=4 Tx [leading WG: RAN1]**

[controversial]

- **FFS: whether this example area can be generalized to enhanced uplink precoding**
- **FFS: target frequency range and target devices**
- **FFS: RAN4 as secondary WG**

Further coverage enhancement

Following observations could be made based on final round inputs.

- Based on the feedbacks, it seems better to split this into two sub-example areas, further coverage enhancement for PRACH in FR2 and power domain enhancement for UL. First one would not require study phase and led by RAN1, while second one would require study phase and maybe led by RAN4 or RAN1.
- Since we have observed and discussed on some specific scope for above two sub-example areas, i.e., PRACH repetition with same or different beams for FR2 and dynamic power aggregation, it can be captured as example scope as starting point for further discussion. We should have a note in controversial part for further clarification and narrowing down the scope,
- Regarding PUCCH enhancements (specifically DMRS-less PUCCH), it seems controversial at this moment. Based on the discussion, DMRS-less PUCCH received larger interests/supports with motivation/justification compared with other non-listed potential coverage enhancement scopes, and hence it can be captured in the controversial part.

Based on the above observations, the moderator's final summary for this example area is shown as below.

[non-controversial]

- **Specify further coverage enhancements including PRACH enhancement for FR2 e.g., PRACH repetition with same or different beams [leading WG: RAN1]**
- **Study and if necessary specify power domain enhancements e.g., dynamic power aggregation [leading WG: RAN4 or RAN1]**

[controversial]

- **FFS: further clarification and narrowing down of the scope for this example area based on listed example scopes as starting point**
- **FFS: other coverage enhancement e.g., DMRS-less PUCCH**

Other proposals

Following observations could be made based on final round inputs.

- Based on the feedbacks, not only enhancements for multi-carrier UL operation, but also enhancements for DFTS-OFDM and enhancements for UL CW mapping are supported by large number of companies with providing motivation/justification that have been shown/discussed also in RAN1 Rel-17 TEI discussion.
- Therefore, it would be ok for companies to capture above enhancements as examples for an additional example area for UL enhancement as non-controversial part. But considering too large scope, we should have a note in controversial part for further clarification and narrowing down the scope,
- Some other enhancement e.g., enhancement for UL dense, can be captured as controversial part.

Based on the above observations, the moderator's final summary for this example area is shown as below.

[non-controversial]

- **Potentially specify other UL enhancements e.g., enhancement for multi-carrier UL operation, enhancements for DFTS-OFDM, enhancement for UL CW mapping [leading WG: RAN1]**

[controversial]

  - **FFS: further clarification and narrowing down of the scope for this example area based on listed example scopes as starting point**
  - **FFS: other potential scope, e.g., enhancement for UL dense deployment**

4 Moderator's proposed summary

Based on the above email discussion, the moderator's suggested final summary of this email discussion is shown as below.

[non-controversial]

- **Uplink enhancements, with the following skeleton of the possible objectives:**
  - **Study and if necessary specify >4 Tx UL operation, e.g., for CPE/FWA/vehicle/Industrial devices [leading WG: RAN1]**
  - **Specify enhanced multi-panel uplink operation and/or enhanced multi-TRP uplink operation, potentially including fast UL panel selection, separate UL timings/power controls for different panel/TRP and/or simultaneous multi-panel UL transmission [leading WG; RAN1]**
  - **Study and if necessary specify frequency-selective precoding, mainly targeting devices with >=4 Tx [leading WG: RAN1]**
  - **Specify further coverage enhancements including PRACH enhancement for FR2 e.g., PRACH repetition with same or different beams [leading WG: RAN1]**
  - **Study and if necessary specify power domain enhancements e.g., dynamic power aggregation [leading WG: RAN4 or RAN1]**
  - **Potentially specify other UL enhancements e.g., enhancement for multi-carrier UL operation, enhancements for DFTS-OFDM, enhancement for UL CW mapping [leading WG: RAN1]**

[controversial]

  - **For >4 Tx UL operation,**
    - **FFS: whether only some listed example device types are targeted or even other device types are also targeted**
    - **FFS: target frequency range**
    - **FFS: RAN4 as secondary WG**
  - **For enhanced multi-panel uplink operation and/or enhanced multi-TRP uplink operation,**

    - **FFS: further clarification and narrowing down of the scope for this example area based on listed example scopes as starting point**
    - **FFS: enhancements are based on Rel-17 unified TCI framework**
    - **FFS: target frequency range**
    - **FFS: RAN2/4 as secondary WG**
  - **For frequency-selective precoding,**
    - **FFS: whether this example area can be generalized to enhanced uplink precoding**
    - **FFS: target frequency range and target devices**
    - **FFS: RAN4 as secondary WG**
  - **For further coverage enhancement and power domain enhancement**
    - **FFS: further clarification and narrowing down of the scope for this example area based on listed example scopes as starting point**
    - **FFS: other coverage enhancement e.g., DMRS-less PUCCH**
  - **For other potential UL enhancements**
    - **FFS: further clarification and narrowing down of the scope for this example area based on listed example scopes as starting point**
    - **FFS: other potential scope, e.g., enhancement for UL dense deployment**