

**3GPP TSG RAN#94e**

**RP-212662**

**Electronic Meeting, December 6 - 17, 2021**

**Agenda Item: 8A.1**

**Type: report**

**Source: NTT DOCOMO, INC.**

**Title: Moderator's summary of discussion [RAN94e-R18Prep-02] UL Enhancements (e.g. coverage enhancements; excluding MIMO)**

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## **1 Introduction**

The discussion in this thread covers the topic #2 in [RWS-210659] and [RP-212608] “**Uplink Enhancements (e.g. coverage enhancements; excluding MIMO)**” with the following example areas as captured in [RP-211679]:

- Further coverage enhancements including PRACH enhancement for FR2 e.g., PRACH repetition with same or different beams
- Power domain enhancements (including a possible study phase), e.g., dynamic power aggregation
  - This area may be led by RAN1 or RAN4, to be further discussed
- Potentially other UL enhancements e.g., enhancement for multi-carrier UL operation, enhancements for DFTS-OFDM

Deadline and NWM organization based on the guidelines provided by the RAN Chair in [RP-212657].

As in [RP-212657] the discussion in this thread should follow the guidance below.

- The goal of the email discussion is to focus on potential scope/areas for each potential WI or SI, with NO intention to update the set and the organization of the topics as endorsed in [RP-212608]
  - Any further update/consolidation of the topics/structure is to be handled in RAN#94-e
  - Aim to identify whether a topic should be a SI, or WI (including possibly a study phase for some scope(s))
  - Aim to identify on the leading WG (including if any change compared with those in RP-212608) and the secondary WG(s)
  - Aim to identify on the potential interaction with SA/CT

- Critical to keep all items under rigorous check; important to avoid “number counting” driven discussion, but focus on tangible commercial interests (near & longer terms)
- All companies are expected to provide comments including detailed justification for areas/scopes for each topic in discussion
  - Note: the focus should be on the potential areas/scopes, instead of debating the detailed technical solutions!

In addition, based on this email discussion, the moderator is requested to draft a new WID or SID with clarification whether it is a WI/SI, justification and objectives, and leading WG /secondary WGs, but leaving blank the rapporteur and supporting companies (both will not be subject of this email discussion).

## 2 Initial round

Based on the guidance in [RP-212657], please focus on following points in your initial round input.

- Detailed justification for areas/scopes, instead of the detailed technical solutions
- Whether this topic should be a SI or WI, and whether the area/scope should have a study phase or not
- Leading WG and secondary WG(s) (if any) for each area/scope
- Any potential interaction with SA/CT

### 2.1 Collection of company views

#### 2.1.1 General high level views

Please provide general high level views, e.g., high level justification for “UL enhancements”, whether “UL enhancements” should be a SI or WI, etc.

#### **Feedback Form 1: General high level views**

##### **1 – TELECOM ITALIA S.p.A.**

in general UL performance enhancements in TDD networks is an urgent market need to be addressed. Therefore the suggested way is to have a work Item with clear and prioritised objectives. Proposed priorities: 2.1.4 and 2.1.2

##### **2 – China Telecommunications**

From China Telecom’s point of view, UL enhancement should be a WI including further coverage enhancement and UL Tx switching enhancement.

For further coverage enhancement, although some enhancement schemes are being specified in Rel-17, the performance gaps still exist. Moreover, some channels are identified as bottleneck channels but not included in Rel-17’ Cov\_Enh WI, e.g. PRACH for FR2. 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. Thus, further coverage enhancement in Rel-18 is essential and should be included in the WI of UL enhancement.

For UL Tx switching enhancement, we think it also should be included in the WI of UL enhancement as an extension for R16/R17 work.

Thus, in summary, we think "UL enhancements" should be a WI.

### **3 – Nokia Corporation**

Given the current split between UL MIMO and other UL enhancements, in our view UL enhancements should be a WID in Rel-18, with focus on further coverage enhancements aspects beyond what has been addressed in Rel-17. This seems to match well the status of previous email discussions.

### **4 – MediaTek Inc.**

We generally believe that any further work on Coverage enhancements in Rel-18 needs to be justified based on the outcome of the Rel-17 study and work item and based on what was felt important and not useful at that time, and what has changed since.

### **5 – AT&T**

We support this as a work item

Leading working group can be RAN1. RAN4 if justified by the objectives.

The justification part can be drafted when the final WID is being drafted

### **6 – Futurewei Technologies**

Depending on exactly which objectives / topics are included, UL enhancements may need a Study Item, or may be a WI with or without a study phase in Rel-18. For example, for some power domain enhancements which have not been studied before, some studies are required. But if the objectives mainly include topics already with reasonable common understanding in 3GPP, a Study Item or a study phase may not be necessary.

In our view, the focus should be 2.1.4 multi-carrier UL enhancements.

### **7 – SoftBank Corp.**

We see a strong demand on UL enhancements, so we support going directly to WI.

### **8 – vivo Communication Technology**

In our view it should be WI, and depending on final objectives, study phase can be considered for certain objective(s). Another point to highlight is DFT-s-OFDM related enhancement also includes multi rank transmission, whether it should be handled in this WI or MIMO WI should be clarified.

### **9 – CATT**

We are supportive of UL enhancements in Rel-18 and we think it should be a WI. If power domain enhancements are included, a study phase is needed. For rank>1 transmission for DFT-s-OFDM, we think it should be handled in MIMO discussion.

**10 – 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 strong need to enhance it. We should limit Rel. 18 coverage enhancement to the channels which have been identified but not enhanced, or for new scenario which was not studied in Rel. 17.

On the other hand, we support power domain enhancement (e.g. dynamic power aggregation), because it can improve both UL performance and coverage. We believe it can be WI led by RAN4.

Also, we believe UL dense deployment (UL Rx only point) can improve both UL throughput and coverage. It can be WI led by RAN1.

**11 – Huawei Tech.(UK) Co.. Ltd**

UL enhancements should be a work item, with possible study phase for some objectives. UL enhancements are a key target for Rel-18, which deserve a clear target for normative work.

**12 – Samsung Research America**

Rel-18 UL enhancement should be a WI. For topics that have not been studied in Rel-17, if any, a study phase can be considered within the WI framework as needed.

**13 – ZTE Corporation**

We support UL enhancements in Rel-18 to satisfy the demand coming from both the operators and vertical industries.

We think this should be a RAN1 leading work item.

**14 – Spreadtrum Communications**

We think UL enhancements can be a WI, especially for further UL coverage enhancements. However, considering power domain enhancements and potentially other UL enhancement need further study and evaluation, to achieve common understanding on the use cases, benefits and necessity. Thus a study phase is preferred for the other UL enhancements except UL coverage enhancement.

**15 – NEC Corporation**

UL enhancements excluding MIMO are more like further enhanced Coverage Enhancement. Some left-overs of Rel-17 Coverage Enhancement and some additional objectives beyond Rel-17 TR38.830 are beneficial to further study for the interesting of deployment. We prefer a WI in Rel-18.

**16 – SHARP Corporation**

UL enhancements should start with WI phase in Rel-18.

**17 – EURECOM**

UL enhancements should be a WI. However, for some objectives a short study phase prior to specification might be justified.

**18 – Panasonic Corporation**

Although whether SI or WI should be determined after what topics included, our view is to aim directly to WI as the intention.

**19 – DENSO CORPORATION**

There is also a demand from automotive industry to enhance UL throughput and capacity, e.g. in-car video streaming for remote driving assistance. So, we support the general direction towards UL through and capacity enhancements.

**20 – Rakuten Mobile**

We strongly support the UL coverage enhancement in Rel-18. Moreover, since we've fully discussed in Rel-17 SI phase, the UL Coverage enhancement should be a WI in Rel-18.

**21 – VODAFONE Group Plc**

We strongly support a WID for UL coverage and capacity enhancement in Rel 18.

**22 – China Mobile Com. Corporation**

Most parts of the UL enhancements could lead to a RAN1 work item. But before that, the scope should be clarified and to be more specific.

**23 – InterDigital France R&D**

UL enhancements should be WI as a whole, starting with the topics which were not completed during Rel. 17 WI due to lack of time. However the objectives could include study items for techniques that were not thoroughly evaluated in R17.

**24 – Lenovo (Beijing) Ltd**

Improvement of UL performance, especially further coverage enhancement identified during previous study shall be the top priority. This WI shall be led by RAN1 and supported by RAN4. However, the usage scenario and the scope of these enhancements shall be clarified before making them a R18 WI. If necessary, some topic can be studied as a SI first.

Given the current arrangement of the topics, >1 rank transmission for DFT-s-OFDM shall be part of the MIMO discussion.

**25 – Intel Deutschland GmbH**

Given that coverage enhancement SI was concluded in Rel-17, UL enhancement in Rel-18 may start as a WI. However, depending on exact scope that will be agreed for Rel-18 UL enhancement, some study phase may be needed for some topics.

**26 – China Unicom**

UL enhancement should be a WID led by RAN1, with possible objectives includes coverage enhancement and UL Tx switching enhancement.

**27 – Xiaomi Communications**

we think the uplink enhancement excluding MIMO should be a work item led by RAN1. For power domain enhancements , a study phase maybe needed.

For the DFT-s-OFDM issue, we think it's better to be discussed in the MIMO session.

**28 – Ericsson LM**

The recent discussion so far of Rel-18 UL enhancements has focused on aspects related to coverage enhancement, with most of the UL MIMO aspects moved to the MIMO work item. This is in general OK in our view, and consistent with operators' comments on their desire for further efforts on coverage topics in Rel-18. However, as discussed more in the 'Potentially other UL enhancements' section, we think multi-layer DFT-S-OFDM could be supported together with fast DFT-S-OFDM / CP-OFDM switching in this work item.

We think PRACH enhancements and the multi-layer DFT-S-OFDM and fast DFT-S-OFDM / CP-OFDM switching do not need a study phase and can be RAN1 led items. The MPR reduction and power domain enhancements topic should have a study phase, can be RAN4 led items, and will need to be coordinated with related proposals for the RAN4-centric work items in RAN94e-R18Prep-22.

**29 – Verizon UK Ltd**

We support UL enh as a WI. It is an important area directly impact the basic NW performance. Even without MIMO, there are enough useful items to explore as a WI by itself.

**30 – Apple Computer Trading Co. Ltd**

In general, we support the UL enhancements to be a WI. If the power domain enhancement is included, this part needs to be studied first.

**31 – Telstra Corporation Limited**

We strongly support UL enhancements as a WI in Rel-18.

**32 – Qualcomm Incorporated**

The Rel-17 study item on coverage enhancements identified uplink channels as being the bottleneck in several deployment scenarios. While in some cases control/initial-access channels require additional enhancement, in other cases the data channel requires enhancement. While the Rel-17 WI on coverage enhancement provides some enhancements to close the gap, additional enhancements to uplink are still quite valuable from both coverage and capacity perspective.

With Rel-17 coverage enhancement SI as a background, we think the Rel-18 UL Enhancements work can be a WI directly.

**33 – KDDI Corporation**

We support Rel-18 UL enhancement as a WI given the situation that coverage related topics have been studied in Rel-17 and there is a strong market demand for UL.

## 2.1.2 Further coverage enhancements including PRACH enhancement for FR2 e.g., PRACH repetition with same or different beams

Following is the moderator's summary on this area in [RP-211652].

- Specify further coverage enhancements including PRACH enhancement for FR2 e.g., PRACH repetition with same or different beams [leading WG: RAN1]
  - 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

### **Feedback Form 2: Further coverage enhancements including PRACH enhancement for FR2 e.g., PRACH repetition with same or different beams**

#### **1 – China Telecommunications**

In our view, the potential scopes for further coverage enhancement can include:

- 1) Specification of PRACH enhancements for FR2 [RAN1, RAN2]
  - 1-1) Multiple PRACH transmissions with the same beam
  - 1-2) Multiple PRACH transmissions with different beams
- 2) Specification of PUCCH enhancements [RAN1, RAN4]
  - 2-1) Specify DMRS-less PUCCH with UCI payload up to 11 bits
- 3) Study and if necessary specify power domain enhancement, e.g., UE transmit waveform design to reduce MPR [RAN4, RAN1]
- 4) Left overs of Rel-17 WI on coverage enhancement.

Regarding PRACH enhancement:

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.

Regarding PUCCH enhancement:

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 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.

## **2 – Nokia Corporation**

We are supportive of enhancements in area, as this is one aspect that was not addressed at all during Rel-17 for lack of time budget, despite being identified as one of the bottleneck channels in the Rel-17 SI. However we do not believe the work should be limited to FR2, as there are potential benefits in FR1 as well, e.g. with repetitions using the same beam.

We are also open to work on DMRS-less PUCCH, which is another aspect that has not been exploited in Rel-17.

## **3 – MediaTek Inc.**

We would be ok to work on PRACH enhancement for FR2 considering that this was identified as an issue but not handled in Rel-17. We see no need to consider other control channels though, as those have been addressed already.

## **4 – AT&T**

We would like to see R18 to focus on the power domain, as other areas have already been discussed and addressed in past releases. If there are urgent "left overs" from past releases, they can be included in R18 with sufficient justification as to why. If they were discussed in the past, but turned out to be highly controversial, they should not be re-considered. If they were not specified in the past because of TU constraints, they should be re-considered for R18.

## **5 – Futurewei Technologies**

UL coverage enhancement continues to be important but remains to be very challenging. The potential enhancements listed in TR 38.830 are a bit limited and there does not seem to be much that 3GPP can do. If UL coverage enhancement is to be included in Rel-18, some further study is needed to better understand the potential techniques and possible gains.

For PRACH enhancement, there seems to be only 2 sources providing performance evaluation results. 3GPP needs some further study and evaluations. Both FR1 and FR2 should be considered.

For DMRS-less PUCCH, a wide range of observed SNR gains (-2 dB to 4.8 dB) were provided in TR 38.830, with no definitive conclusion on its benefit. 3GPP needs to better understand when/why there is a gain before specification work can start.

## **6 – SoftBank Corp.**

We support further coverage enhancement in Rel-18. PRACH enh for FR1 and FR2 plus DMRS-less PUCCH would be a good focus.

## **7 – vivo Communication Technology**

We are ok with specifying PRACH enhancement for FR2. DMRS-less PUCCH was studied in Rel-17 and now PUCCH repetition enhancement in place, can be studied whether there is improvement over Rel-17 scheme, if desired.

**8 – CATT**

For coverage enhancements, we are fine with PRACH enhancement for FR2. For PUCCH, coverage enhancements including repetition enhancements and joint channel estimation have been supported in Rel-17. Additional coverage enhancement gain needs to be provided to justify further PUCCH enhancements in Rel-18.

**9 – NTT DOCOMO INC.**

Considering UL coverage enhancement has been carried out in Rel. 17, we should limit Rel. 18 to the channels which have been identified but not enhanced in Rel. 18. We support PRACH coverage enhancements using same or different TX beams for FR2. It can be WI led by RAN1.

**10 – Huawei Tech.(UK) Co.. Ltd**

Rather than leaving a very open objective for further coverage enhancements, we would prefer to focus on the precise objective targeting specifically PRACH repetition with same or different beams for FR2.

**11 – Asia Pacific Telecom co. Ltd**

We support to introduce mechanism for the enhancement on preamble transmission in order to further extend the coverage for RA. The scenario may at least include RA for initial access, system information request and beam failure recovery. In this WI, we support to specify mechanism for PRACH resource applied by the UE for preamble transmission is decided by measurement on SSBs as a baseline in case of Multiple PRACH transmissions with the same beam and different beam. Some of subsequent procedures may also needs to further considered such as RAR monitoring, contention resolution.

**12 – Samsung Research America**

PRACH was identified as a bottleneck channel during Rel-17 Coverage Enhancement SI and it is the channel that was not enhanced in Rel-17 due to TU constraints. We support PRACH coverage enhancements, particularly for FR2 as the performance gap is larger for this case. We are fine to also consider PRACH enhancements for FR1. We don't think other channels need enhancement.

**13 – ZTE Corporation**

We support PRACH enhancement by PRACH repetition with same or different beams. We think at least PRACH repetition with the same beam could be applied to FR1 also. Therefore, we don't need to limit to FR2 only, and actually applicability to FR1 and/or FR2 could be left to RAN1 discussion during the work item. In addition, RAN2 should be added as the secondary working group.

DMRS-less PUCCH could provide large PAPR gain and SNR gain according to the evaluation in Rel-17. So, we prefer to also include it for coverage enhancements. If some companies concern on the performance gain due to unaligned simulation assumptions in Rel-17, we are fine to start with a study phase to first verify the performance gain.

**14 – Spreadtrum Communications**

We agree the leading WG for coverage enhancements is RAN1.

For PRACH enhancements, we think PRACH repetition for FR2 is enough for Rel-18. Whether using the same or different beams, we are open for discussion. At least same beam repetition can be in the scope. Different beams repetition is more complex comparing with only one beam repetition. If TU is limited, or there are many other topics in this item, we are fine to postpone the study of different beam repetition for PRACH in Rel-18.

Regarding other coverage enhancement, DMRS-less PUCCH could be considered in Rel-18. It was in the scope of Rel-17 WI, however, finally it was down scoped. So it can be with low priority due to diverse opinions in Rel-17.

#### **15 – NEC Corporation**

Based on TR 38.830, PUCCH format 1, PUCCH format 3 with 11bit and PUCCH format 3 with 22bit together PRACH format B4 have been identified as the potential bottleneck channels as 2nd priority in FR1 and for Urban 28 GHz scenario. So we think DMRS-less PUCCH for PUCCH format 1 and format 3 up to 11 bits should be resolved in Rel-18.

#### **16 – SHARP Corporation**

For short PUCCH, coverage performance gaps were discussed in SI phase of Rel-17. Although some solution (e.g. joint channel estimation) of Rel-17 coverage enhancements is applicable to short PUCCH, the performance gaps still exist even when the Rel-17 solution is applied. Therefore, at least DMRS-less PUCCH should be included in the scope. SI phase is not necessary, as it was already studied in Rel-17 SI phase.

#### **17 – Panasonic Corporation**

We are ok with the proposal.

#### **18 – EURECOM**

We think that specification of an enhanced "DMRS-less" PUCCH Format is justified for two reasons:

1. Promising improvements in both coding gain and PAPR gain compared to Rel-15 PF3 with correlation-based (advanced) receiver. Those gains are on top of what can be achieved with Rel-17 repetitions. In fact, less repetitions are required if every individual transmission is an enhanced "DMRS-less" PUCCH format.
2. Demand of industry and verticals (e.g. NTN or RedCap) for further UL coverage improvements.

In our opinion work on specifying "DMRS-less" PUCCH can start directly. However, we are also fine with a short study phase to reassess/align the performance of the different proposals prior to specification.

#### **19 – Rakuten Mobile**

For UL Coverage enhancement in Rel-18, we are supportive for PRACH coverage enhancement not only FR2 but FR1, too. Also, DMRS-less PUCCH is a key topic for UL Coverage enhancement in Rel-18. Furthermore, we are open to discuss other left-over items from Rel-17.

#### **20 – VODAFONE Group Plc**

If we need to prioritise, power domain enhancement for UL (FR1 & FR2) is of more interest to us than enhancement for PRACH in FR2

#### **21 – China Mobile Com. Corporation**

The PUCCH has been enhanced during Rel-17. And in the end of the CE SI, the views on the DMRS-less PUCCH performance gain were controversial. The group should be cautious of introducing features that have similar functions.

We do not support extending the PRACH enhancement to FR1. It should be clarified that in which kind of scenarios the PRACH in FR1 needs coverage enhancements.

For even in the FR2, it seems only when the UL beamforming from UE side are not working properly losing the BF gain, the PRACH needs coverage enhancement. When we review the evaluation results, PRACH is still the best among multiple UL channels in coverage.

## **22 – InterDigital France R&D**

PRACH repetition with different beams may not help for coverage enhancement unless the target UE is a UE without beam correspondence capability and requires high standards efforts. As beam correspondence is UE mandatory feature, we don't think PRACH repetition with different beams has to be included in the scope since we don't see clear motivation to study it. Therefore, we only support PRACH repetition with the same beam. For other coverage enhancement, the following items which were studied in Rel. 17 or not included in Rel. 17 due to lack of time should be included. Examples of such topics are the following:

- DMRS-less PUCCH
- Repetition type B based TBoMS
- DM-RS optimization for DM-RS bundling

## **23 – Lenovo (Beijing) Ltd**

PRACH transmission is very important for many procedures, including initial access and contention based beam failure recovery. During the R17 study item phase of coverage enhancement, PRACH format B4 was identified as a potential bottleneck. It is important to address this issue with PRACH repetition with same or different beams, for both 4-step and 2-step RACH. The solution shall apply to FR2, and if possible FR1.

## **24 – Intel Deutschland GmbH**

We are fine to specify coverage enhancement for PRACH repetition with same or different beams in FR2. For DMRS-less PUCCH, during the coverage enhancement SI in Rel-17, RAN1 could not reach consensus whether sequence based PUCCH can provide performance gain compared to existing PUCCH format with advanced receiver (sequence PUCCH like receiver). Given that PUCCH enhancement is already specified in Rel-17 coverage enhancement WI, it is not clear to us whether we need to continue to enhance PUCCH in Rel-18.

## **25 – Xiaomi Communications**

For the coverage enhancements, we support the objective on PRACH in FR2 and we are open to the enhancements like DMRS-less PUCCH.

## **26 – Ericsson LM**

We can be OK to have the objective for PRACH repetition with same or different beams.

Regarding the FFS on DMRS-less PUCCH, this was discussed extensively during the coverage enhancement work item. Companies did not agree on the benefit of such schemes, in part since some companies observed no gains when advanced receivers were used, and since the practical coverage benefit of a new design for PUCCH format 3 with up to 11 bits at this stage of NR can be questioned. Therefore, we don't see the need for DMRS-less PUCCH in Rel-18.

**27 – Verizon UK Ltd**

We support this proposal. Indeed, we feel PRACH is a bottleneck in real system and it is often related to beams are not good during the access. We would like it to repeat on different beams.

**28 – Apple Computer Trading Co. Ltd**

We support PRACH enhancement on FR2 with same or different beams. One aspect needs to be clarified whether all the PRACH formats is to be enhanced or enhancements limit to the PRACH format identified as bottleneck channel in Rel.17 study.

**29 – Qualcomm Incorporated**

PRACH coverage enhancement for FR2, including PRACH repetition with same or different beams is necessary. PRACH for FR2 was identified as a bottleneck in Rel-17 coverage enhancement study and we think its coverage enhancement is necessary. We also think interaction of PRACH repetition with Msg3 repetition (in terms of request indication for Msg3 repetition) should be specified. Also, we think PRACH repetition can be used for beam refinement during random access, which provides additional coverage enhancement for later messages (including Msg3).

**30 – KDDI Corporation**

PRACH was identified as a bottleneck channel in Rel-17 NR Coverage enhancement SI but it was not enhanced in Rel-17 that of WI. Therefore, we support to include PRACH enhancement in the scope of Rel-18.

### 2.1.3 Power domain enhancements (including a possible study phase), e.g., dynamic power aggregation

Following is the moderator’s summary on this area in [RP-211652].

- Study and if necessary specify power domain enhancements e.g., dynamic power aggregation [leading WG: RAN4 or RAN1]
  - FFS: further clarification and narrowing down of the scope for this example area based on listed example scopes as starting point

#### **Feedback Form 3: Power domain enhancements (including a possible study phase), e.g., dynamic power aggregation**

**1 – China Telecommunications**

For power domain enhancement, we think enhancement on power domain is a straightforward way to enhance coverage and can be included in the scope. During Rel-17 SI on coverage enhancement, UE transmit waveform design to reduce MPR is studied and discussed. We think it can be included in power domain enhancement. Moreover, we think a study phase can be added in the WI if necessary.

**2 – Nokia Corporation**

We are highly supportive of this objective, but we do not see a need for listing “dynamic power aggregation” as an example. As for further details of the scope, we consider the following:

- Focus on modulation orders beyond BPSK
- Investigate and specify new methods to reduce PAR/MPR, especially spectrum extension
- Prioritize scenarios with one transmit antenna
- Extend the usage of PC2 to FDD bands

**3 – MediaTek Inc.**

We understand that dynamic power aggregation is very closely related to the RAN4 work item that just started. It would need to be better justified by proponents what is the difference compared to that.

For other power domain enhancements, it needs to be better clarified as to what we are talking about here. It seems extremely premature to agree to a work item on a topic where we have no clarity on the scope in terms of techniques, and therefore no understanding of the potential device impacts and even less idea of the performance gains.

**4 – AT&T**

We support the proposal in its current form, incl. the "e.g." part

**5 – Futurewei Technologies**

Power domain enhancements require further study, in either a SI or a study phase of a WI. The objectives should include at least the study of relevant regulations, which leads to a conclusion of what the regulations allow (e.g., is it allowed to temporarily exceed the maximum power according to regulation, and if yes, for how long and how much, etc.), as well as the study of device feasibility, which leads to a conclusion of what the devices can support (e.g., can the device temporarily transmit higher than the maximum power according to its power class, and if yes, for how long and how much, etc.). At least the study part is highly relevant to RAN4 but not RAN1.

**6 – vivo Communication Technology**

With a new WID "Increasing UE power high limit for CA and DC" for Rel-17 agreed in RAN#93-e. Whether Rel-18 item is needed to be discussed.

**7 – CATT**

The current scope is vague and we need to be more specific what is included. For dynamic power aggregation, we also would like to understand the relationship with RAN4 WI.

**8 – NTT DOCOMO INC.**

Support. We believe it can improve both UL throughput and coverage. It can be WI led by RAN4.

**9 – Huawei Tech.(UK) Co.. Ltd**

As a general comment, the objective should be written more precisely, otherwise this is completely unclear. We should also note that a RAN4 WI was approved at RAN#93e with objective on dynamic UE power aggregation, so it should also be clarified what is the relation between the RAN4 Rel-17 objective and the proposed Rel-18 objective, and what is the impact to RAN1 and RAN4. Based on the clarification from the proponents, we can have further discussion on a more precise proposed objective in the second round.

One reply to Nokia: we do not agree that power domain enhancement techniques should focus on modulation orders beyond BPSK. In TDD, pi/2 BPSK can have 3 dB more maximum power than QPSK.

**10 – SoftBank Corp.**

We are interested in power domain enhancement, and it should be included in Rel-17 scope. We support the inclusion of dynamic power aggregation.

**11 – Samsung Research America**

For power domain enhancement, although some discussions happened during the Rel-17 SI phase, such discussions were not conclusive. If considered in Rel-18, the scope needs further clarification and a study would be needed, led by RAN4.

**12 – ZTE Corporation**

We agree that power domain enhancements could be an effective way for improving UL performance. Among the proposed schemes, we think dynamic power aggregation could be promising. The potential overlap with RAN4 new approved Rel-17 WI could be discussed in RAN4 in Rel-17. The potential RAN1 impacts can be studied and specified in this project.

**13 – Spreadtrum Communications**

We think the leading WG for power domain enhancements is RAN4, the secondary WG is RAN1. A study phase is necessary. From our understanding, the intension of dynamic power aggregation is fully use transmission power, since multi-band UE always have separate PA for different bands. However, it needs more clarifications for relationship of RAN4 WI.

**14 – NEC Corporation**

Since it has not been studied during Rel-17 Study Item. It's better to start from SI or have a study phase in WI before making decision on whether to specify or not.

**15 – SHARP Corporation**

Dynamic power aggregation is effective for power utilization efficiency. However, some researches/discussions in terms of regulatory requirements in each region are needed. In our view, as commented in 2.1.1 and 2.1.2, Rel-18 coverage enhancement covering PRACH and short PUCCH enhancements can start directly with WI phase. Hence, it is not suitable to include the power domain enhancement in the same WI.

**16 – Panasonic Corporation**

Similar to Futurewei, if we aim to target WI, something more clear and explicit targets needs to be described like what Nokia mentioned.

**17 – DENSO CORPORATION**

It is one of the technology potentials to enhance UL throughput and capacity. Although we're supportive, it is reasonable to start from SI and agree that the regulatory requirement needs to be checked.

**18 – VODAFONE Group Plc**

We support power domain enhancement for UL (as it can improve both capacity and coverage).

**19 – China Mobile Com. Corporation**

We have no problem with the power domain enhancement for the coverage.

But as mentioned by many companies, the scope should be more specific and the relation with the Rel-17 item should be clarified.

And whether the “dynamic” is required needs more clarification.

**20 – InterDigital France R&D**

Support this topic as SI. The starting point can be materials studied in Rel. 17.

**21 – Lenovo (Beijing) Ltd**

We think power-level aggregation can be beneficial to enhance the coverage in the UL. However, it is important to identify the applicable scenario and the targeted channels. The scope shall be limited to aggregate multiple transmissions from a same UE in multiple time/frequency/panel/spatial resources, including different bands and multiple beams can be studied jointly in RAN1 and RAN4, with RAN1 as the leading group.

**22 – Intel Deutschland GmbH**

The leading WG should be RAN4.

In RAN#93e a new WI on “Increasing UE power high limit for CA and DC” (RP-212622) was approved and WI also aims to enable more efficient HPUR support for CA/DC scenarios. We encourage further clarifications from the proponents on relation to this WI and potential benefits on top of the Rel-17 solutions which are under discussion.

We also recommend continuing discussion as a part of RAN4 Rel-18 package discussion jointly with other HPUE proposals.

**23 – Xiaomi Communications**

We are interested in this enhancement for its potential benefits, and agree with other companies that clarifications may be needed for the enhancements on top of Rel-17.

We think RAN1 can be the leading WG, and RAN4 can be secondary.

**24 – Ericsson LM**

We think MPR reduction and power domain enhancements that reduce MPR are promising. A study phase is needed, and 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 the objectives, we are open to considering dynamic power aggregation, but think that other possibilities should be studied as well, such as:

- › Investigate impact of spectrum utilization and channel filtering on required MPR for FR2
- › Review/reduce Rel-15 MPR values in RAN4
- › Consider impact of large test tolerances on MPR

These will need to be coordinated with related proposals for the RAN4-centric work items in RAN94e-R18Prep-22.

**25 – Verizon UK Ltd**

Support. This is a promising area we are looking into to get some gains for UL.

**26 – Apple Computer Trading Co. Ltd**

Dynamic power aggregation is out of the Rel.17 Coverage enhancement SI, the detailed concept of dynamic power aggregation is not clear enough. A study phase is needed to understand the concept better and performance benefits.

**27 – Qualcomm Incorporated**

Power is the most valuable resource in uplink and enhancements to unlock additional uplink power are highly valuable. Although power domain enhancements were listed for potential consideration in Rel-17 coverage enhancement SI, they were not eventually pursued. Rel-18 presents us with an opportunity to pursue enhancements in this area.

In particular, we are interested in realizing the full potential of all the PAs at a UEs disposal across all the bands. Dynamic power aggregation lets a UE transmit at full power across different bands subject only to SAR/MPE constraints. UEs have dedicated PAs in different bands designed to meet the power class requirements for that band. However, the power class associated with certain band combinations imposes an artificial constraint on the maximum allowed power and it is this constraint that we wish to remove.

**28 – KDDI Corporation**

We support the proposal to include power domain enhancement in the scope of Rel-18 UL enhancement.

#### 2.1.4 Potentially other UL enhancements e.g., enhancement for multi-carrier UL operation, enhancements for DFTS-OFDM

Following is the moderator’s summary on this area in [RP-211652].

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

**Feedback Form 4: Potentially other UL enhancements e.g., enhancement for multi-carrier UL operation, enhancements for DFTS-OFDM**

**1 – TELECOM ITALIA S.p.A.**

This is a key market requirement, allowing MNOs to improve UL performance in TDD networks where the frame structure is defined by the Regulator and DL-heavy. Carrier aggregation with UL Tx over more than 2 bands and or Tx switching should be a Work Item led by RAN4

## **2 – China Telecommunications**

We think UL Tx switching enhancement can also be included in UL enhancements, the motivation is from two aspects: first, emergence of uplink centric services brings challenge to UL transmission; second, there are some limitations of current specification, e.g. 2TX UE can be configured with at most 2 UL bands, which only can be changed by RRC reconfiguration, and UL Tx switching can be only performed between 2 UL bands for 2Tx UE. Thus, in order to improve uplink performance, UL Tx switching enhancement is needed, the potential scope can be:

1) UL Tx switching schemes across more than 2 bands

1-1) Enable more configured UL bands than UL RF capability and dynamic switching can be performed across the configured bands, e.g. 4 UL bands can be configured, and dynamic switching can be performed across the 4 bands.

## **3 – Nokia Corporation**

As mentioned by a few companies in previous email rounds, there is potential benefit on faster-than-RRC switching between DFT-s-OFDM and CP-OFDM, for more efficient handling of UEs in the cell. Rank >1 aspects of DFT-s-OFDM enhancements are assumed to be covered under the MIMO thread, and hence not commented further here.

On UL carrier switching, we do not see a need for further enhancements in Rel-18. The potential gain mechanisms are very limited given the practical implications of switching in real-world devices.

## **4 – Futurewei Technologies**

One bottleneck for UL performance is the lack of flexibility in allocating the best and a sufficient amount of radio resources in an on-demand way. The following enhancements should be the focus for Rel-18 UL enhancement 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

Similar to China Telecommunications' view, we think it is beneficial for a UE to be configured with more UL bands / carriers than its UL RF capability, and dynamic switching among them should be supported.

The switching of waveforms has been discussed since Rel-15 without a clear conclusion. To us the benefit is only marginal.

## **5 – vivo Communication Technology**

Enhancement for DFT-s-OFDM waveform is important aspect, there are 2 sub-topics to consider, 1) dynamic waveform switching, 2) multi rank transmission. Both have their own use cases, multi rank transmission has been specified in LTE. If multi rank DFT-s-OFDM is included in MIMO WI, only dynamic switching is part of this WI.

## **6 – NTT DOCOMO INC.**

For multi-carrier UL operation, UL CA is not actively used in the current network, due to UL power limitation. Hence, we believe it is low priority.

For enhancement of DFT-S-OFDM, we believe the dynamic switching (by MAC CE or DCI) between CP-OFDM and SFT-S-OFDM is useful, compared to DFT-S-OFDM with multi-layers. The reason is that

DFT-S-OFDM with multi layers is only useful for NW who configures UL MIMO. However, the dynamic switching is useful even if UL MIMO is not configured. The benefit of the dynamic switching is that NW can avoid RRC-reconfiguration to switch the waveform. As summarized below, some UEs are suitable for CP-OFDM and the others are suitable for DFT-S-OFDM, we think both waveforms can be configured for different UEs in the same cell, depending on the UE's SNR. Hence, we believe there is use-case to switch the waveform. This can be WI led by RAN1.

- For high SNR UEs: CP-OFDM is better (Because, freq. resource allocation can be more flexible. DMRS and PUSCH can be FDMed. Also, UL MIMO is possible.).
- For low SNR UEs: DFT-S-OFDM is better (Because of low PAPR.).

We also support UL dense deployment (UL Rx only point) because it can improve both UL throughput and coverage. It can be WI led by RAN1.

## 7 – CATT

For rank>1 transmission for DFT-s-OFDM, we think it should be discussed in MIMO. For dynamic waveform switching, we would like to understand the motivation better. If the motivation is that multi-rank transmission is not supported by DFT-s-OFDM and there is gain to dynamic switch waveform to support multi-rank transmission, it seems that rank>1 transmission for DFT-s-OFDM and dynamic waveform switching do not need to be both supported.

## 8 – Huawei Tech.(UK) Co.. Ltd

1. The objective on enhancement for multi-carrier UL operation is too broad, it should be focused on an identified gap. Today it is not feasible for a 2Tx UE (e.g. a smartphone) to switch Tx across more than 2 bands, although practically networks will support more than 2 bands.

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 rate, spectrum utilization and UL capacity (about 20 50% gain as shown in section A1. of RP-212151).

Therefore we propose that this objective be reformulated as Tx switching for more than 2 bands, e.g.:

*Specify mechanisms to allow a UE (e.g., 2TX UE) to be configured with more UL bands than its simultaneous transmission capability (e.g. 2TX) and to support dynamic carrier selection and TX switching among  $n$  ( $n \geq 2$ ) configured bands.*

We are also ok to start from the formulation proposed by China Telecom:

*1) UL Tx switching schemes across more than 2 bands*

*1-1) Enable more configured UL bands than UL RF capability and dynamic switching can be performed across the configured bands, e.g. 4 UL bands can be configured, and dynamic switching can be performed across the 4 bands.*

2. The objective for enhancements for DFTS-OFDM is also too broad. If this is about enabling up to rank 2 transmission for DFTS-OFDM, then this should be clarified, and it may be better considered under the scope of MIMO enhancements for DL and UL.

We do not see the need to introduce faster-than-RRC switching between DFT-s-OFDM and CP-OFDM.

#### **9 – SoftBank Corp.**

We support either of dynamic switching between DFT-S-OFDM and CP-OFDM or multi-layer DFT-S-OFDM. We are OK to follow the majority view regarding the choice of these two schemes.

We are also supportive for UL Tx switching schemes across more than 2 bands to enable more aggressive use of UL CA.

#### **10 – Asia Pacific Telecom co. Ltd**

Keep the number of active CCs be larger than the number of simultaneous transmission Tx while performing UL carrier switching may significantly enhance the flexibility of UL transmission as well as spectrum utilization. We support the WI to include item regarding on UL carrier switching based on either L1 or L2 approach for switching determination in either CA or DC. Some capability reporting mechanism regarding on the supported number of equipped Tx and number of simultaneous transmitted carrier may be needed.

#### **11 – 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.

Regarding enhancement of DFTS-OFDM, e.g., dynamic waveform switching, it is not clear that there would be a meaningful benefit from dynamic switching.

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

#### **12 – ZTE Corporation**

Regarding enhancement for multi-carrier UL operation, we would like to clarify what is the intended enhancement here. Is it only for Tx switching among more than 2 bands as an extension of Rel-17 Tx switching? Are there any other proposed enhancements here?

Regarding the two proposed enhancements for DFT-S-OFDM, we think it would be redundant to support both 2-layer for DFT-S-OFDM and dynamic switching between OFDM and DFT-S-OFDM. If any enhancement is needed here, supporting one of them should be sufficient. In our view, supporting 2-layer for DFT-S-OFDM would cause very large spec impacts, e.g., define new UL precoder and new DMRS pattern, whether/how to support 2-port PTRS and association between DMRS port and PTRS port, etc. Therefore, if needed, we suggest to only consider dynamic switching between OFDM and DFT-S-OFDM.

Regarding UL dense deployment, we have identify some benefits for UL coverage and capability improvement, and then we are open to consider some corresponding enhancements, e.g., UL beam management, and UL open-loop power control, if we have sufficient TU budget.

#### **13 – Spreadtrum Communications**

We are supportive of DFT-s-OFDM dynamic switching, it is benefit for more efficient UL scheduling. But we do not support RANK > 1 for DFT-s-OFDM, because RANK >1 already supported by CP-OFDM, if dynamic switching between DFT-s-OFDM and CP-OFDM is supported, there is no need to support RANK>1 for DFT-s-OFDM.

#### **14 – Panasonic Corporation**

We think following would be useful to make UL transmission more flexible.

- faster-than-RRC switching between DFT-s-OFDM and CP-OFDM
- UL Tx switching schemes across more than 2 bands

#### **15 – vivo Communication Technology**

Repost with some revision..

Enhancement for DFT-s-OFDM waveform is important aspect, there are 2 sub-topics to consider, 1) dynamic waveform switching, 2) multi rank transmission. Both have their own use cases, multi rank transmission has been specified in LTE. If multi rank DFT-s-OFDM is included in MIMO WI, only dynamic switching is part of this WI.

On enhancement for multi-carrier UL operation, it could be beneficial for dynamically selecting UL band based on traffic, however only 2Tx simultaneous transmission is considered.

#### **16 – Rakuten Mobile**

We are strongly supportive of dynamic switching between DFT-s-OFDM and CP-OFDM. It is an efficient method to make flexible scheduling for UEs in various coverage of a cell. For other items, we are open to discuss.

#### **17 – DENSO CORPORATION**

As commented to RAN94e-R18-Prep-01, dynamic waveform change is interesting and supportive to us.

#### **18 – VODAFONE Group Plc**

(Using the concise statement from Panasonic:) we think the following would be useful to make UL transmission more flexible.

- faster-than-RRC switching between DFT-s-OFDM and CP-OFDM
- UL Tx switching schemes across more than 2 bands

#### **19 – China Mobile Com. Corporation**

The scope of other UL enhancements and the examples are still too open for the next phase's work. The two features raised as examples should be more specific and focused.

The enhancement for multi-carrier UL operation should be more specific as the Enhancement for multi-carrier UL operation to cover more than 2 bands. At least, the assumption of 2 Tx antennas should be considered. And the case of 4 Tx could be in a later phase as there are still discussions in MIMO for the basic function of 4Tx antennas.

Under the umbrella of the enhancements for DFTS-OFDM, two schemes were mentioned in the last round. One is multiple layer transmission for DFT-S-OFDM. The other is dynamic switching between OFDM and DFT-S-OFDM. As mentioned in the last round, both features are used to enhance the UL data rate. Then, supporting one of them is enough. Multiple layer transmission of DFT-S-OFDM is preferred, as compared with OFDM, the DFT-S-OFDM could have a lower PAPR. And besides multiple layer transmission, the benefits of dynamic switching between OFDM and DFT-S-OFDM is not obvious.

Thus, only the multiple layer transmission of DFT-S-OFDM should be supported under the “enhancements for DFTS-OFDM”. And it should be in the scope of MIMO.

#### **20 – MediaTek Inc.**

We fail to see much overall gain from anything proposed in this section.

- **DFT-s-OFDM 2 layers:** It was decided not to specify this all the way since Rel-15. Unclear to us what is the gain over using the configurations we already have specified for DFT-S-OFDM and CP-OFDM. Low priority. (Note: Also commented on this in MIMO thread. It should be decided which thread to cover this in.)
- **DFT-s-OFDM <> CP-OFDM dynamic switching:** Possibly quite easy to specify, and may add some more flexibility. No strong view though.
- **Multi-carrier UL switching:** We have some doubts on the incremental gain of enabling the UE to switch between 3 UL carriers vs 2 carriers, also when considering the extra SRS overhead and switching gaps needed for the UE.

#### **21 – InterDigital France R&D**

As stated in the reply for the second question, the work can focus on topics that were not covered/completed in Rel. 17 due to lack of time, such as Repetition type B based TBoMS and DM-RS optimization for DM-RS bundling.

#### **22 – Lenovo (Beijing) Ltd**

Higher rank transmission under DFT-s-OFDM helps to improve the performance for UEs near, but not quite at the cell edge. This shall be studied under UL MIMO. Fast switching between DFT-s-OFDM and CP-OFDM, as well as other related parameters, is helpful for UEs moving near the cell edge. This shall be studied under UL enhancement, but shall support multi-layer DFT-s-OFDM if it is included under R18 MIMO.

We are open towards multi-carrier UL operation, including UL carrier switching across more than 2 bands. We can start by first comparing the performance for UL carrier selection with RRC/MAC-CE/dynamic switching and narrowing the scope.

We are skeptical towards UL dense deployment. The benefit is not worth the extra effort to support UL only links when compared with the traditional small cell solution.

#### **23 – Intel Deutschland GmbH**

We are fine to specify enhancement for DFT-s-OFDM waveform, i.e., to support dynamic switching between CP-OFDM and DFT-s-OFDM waveform. The leading WG is RAN1.

For multi-carrier UL operation, if this is for the support of UL Tx switching with more than two carriers, the benefit and performance gain are not very clear to us given that this highly depends on Tx switching time that UE can support. It is expected that the Tx switching time can be large compared to case of 2Tx switching within 2 UL bands. Further, to enable this feature, UE will need to periodically transmit SRS over multiple CCs in a periodic manner, which would increase overhead. If this is part of objectives for further UL enhancement, we suggest to start with a SI to further study the feasibility and benefit.

For enhancement for UL dense deployment, it is important to address UL issues in Rel-18 by using TRPs with lower Tx power or Rx only capable TRPs). The corresponding TRPs can be used for densification of the NW in cost efficient manner and addressing UL coverage and performance issues especially in FR2. The detailed objective for this enhancement is provided below.

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

#### **24 – Xiaomi Communications**

For the DFT-s-OFDM enhancements, we think this should be discussed in MIMO session. And for dynamic switching between different waveforms, currently we fail to see the motivation of enabling such fast changing mechanism.

#### **25 – Ericsson LM**

Regarding fast CP-OFDM / DFT-S-OFDM switching and multi-layer DFT-S-OFDM, these are to us low hanging fruits that can improve coverage and straightforwardly be specified as discussed in RP-212344. LTE already supports multi-layer DFT-S-OFDM and fast switching for CP-OFDM and DFT-S-OFDM were already considered in Rel-15. Moreover, while they could in our view be specified in Rel-17 TEIs, some companies commented that they prefer this in Rel-18. Since these proposals have been made for Rel-17 TEIs in a few RAN1 meetings without agreement, it seems that the work may need to be done in Rel-18.

On Tx switching with more than 2 carriers with UL that has been proposed for multi-carrier UL operation, 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.

In summary then, we think it is sufficient for this objective to have both fast CP-OFDM / DFT-S-OFDM switching and multi-layer DFT-S-OFDM. We realize that companies may wish to treat multi-layer DFT-S-OFDM in the Rel-18 MIMO work item, however this has its own downsides, e.g. that the MIMO work is already quite heavy. In our view, little design effort is needed if LTE design principles are reused, and it should be straightforward to specify in this WI. We would also note that MIMO work has been done in parallel work items in the past, e.g. with LTE feCoMP and eFDMIMO in Rel-14. Moreover, we think it is important first to agree if the work is beneficial, and then we can debate on which work item it is covered in, rather than having it ‘fall between the cracks’ of the two work items.

#### **26 – MediaTek Inc.**

Please note that we addressed UL-only TRP for dense deployment under the MIMO discussion, as it related to TRP enhancements. It would be appreciated if we could clarify in which discussion any further comments should be provided on this in the next round.

#### **27 – Verizon UK Ltd**

Support. Especially fast CP-OFDM /DFT-S-OFDM switching and then multi-layer DFT-S-OFDM. Should be low hanging fruit as Ericsson said. We have difficulties with DFT-S-OFDM due to the switching problem practically.

#### **28 – Apple Computer Trading Co. Ltd**

For DFT-S-OFDM enhancement, it needs to clarify the enhancements cover dynamic switching between DFT-S-OFDM and CP-OFDM, or multi-layer DFT-S-OFDM, or both. We consider multi-layer DFT-S-OFDM is falling into MIMO enhancement area. We are open to enhancement for multi-carrier UL operation.

## 29 – Qualcomm Incorporated

We are interested in making DFT-S-OFDM waveform more accessible. Currently, the waveform used in uplink is configured via RRC and cannot be dynamically switched. This imposes a large barrier to switch over to DFT-S-OFDM waveform for coverage-limited/cell-edge UEs. The ability to dynamically switch between CP-OFDM and DFT-S-OFDM is a valuable enhancement to pursue.

Another DFT-S-OFDM related enhancement RAN1 should consider is supporting multi-layer (at least 2-layer) PUSCH in DFT-S-OFDM waveform. To bring NR uplink throughput/spectrum efficiency in par with LTE uplink for cell edge UEs in DFT-S-OFDM waveform, this feature should be introduced. Most of the LTE design can be reused to harvest this low-hanging fruit.

Given the heavy use of short PUCCH formats in FR2, we think extending DFT-S-OFDM to short formats would be a valuable addition. L1 beam report is a sensitive payload carried by PUCCH and it will be good to pursue enhancements to short PUCCH to better protect such payloads.

Another topic that we think is important for UL coverage enhancement is enhancement of CSI report (especially coverage enhancement for L1 report which is very important for reliability of beam management in FR2). For this purpose, we are interested in dynamic PUCCH repetition indication for the P/SP-CSI report.

### 2.1.5 Others

#### Feedback Form 5: Others

## 2.2 Moderator Summary and recommendation for further discussion

### 2.2.1 General

Thank you very much for valuable inputs from many companies. Based on the feedbacks in the initial round, we could observe that almost all companies still consider “UL enhancement” as one of promising topics for Rel-18 even after MIMO-related UL enhancements were moved to MIMO i.e., [RAN94e-R18Prep-01]. As multiple companies commented, we should first decide the objective(s) (i.e., decide which potential objectives we have discussed can be included in draft WID/SID of Rel-18 UL enhancements), and then we should discuss whether it should be WI/SI and leading/secondary WG. However, since we already had discussions on potential objectives and some of them are already studied/discussed in WG(s) (e.g., in RAN1), majority of companies prefer that “Rel-18 UL enhancement” is WI with potentially including study phase for some objective(s) so that this item can meet the urgent market need for UL performance enhancements. In addition, many companies have assumed that “Rel-18 UL enhancement” is RAN1 led item.

### 2.2.2 Further coverage enhancements including PRACH enhancement for FR2 e.g., PRACH repetition with same or different beams

Following observations could be made based on initial round inputs.

– Regarding PRACH enhancement for FR2,

- Majority seems to be supportive to specify multiple PRACH transmissions with same or different beams as PRACH enhancement for FR2.

- Possible justification for this objective is that 1) PRACH transmission is very important for many procedures, including initial access and contention-based beam failure recovery, 2) PRACH (format B4) was identified as a bottleneck channel (for both FR1 and FR2) during Rel-17 Coverage Enhancement SI and it is the channel that was not enhanced in Rel-17 due to TU constraints.
  - The work for this objective can be done by RAN1 as leading WG and RAN2 as secondary WG.
  - In order to further clarify/narrow down the scope of this objective, following points need to be discussed further.
    - Whether to specify same beam case, different beam case or both cases (as there is a company argued that PRACH repetition with different beams may not help for coverage enhancement as beam correspondence is UE mandatory feature)
    - Whether to target both FR1 and FR2 or FR2 only
    - Whether to target all PRACH formats or limited PRACH format identified as bottleneck channel in Rel-17 CovEnh SI
    - Whether to target both 4-step and 2-step RACH or 4-step RACH only
    - Whether the study phase is necessary or not (although majority considers study phase is not necessary)
    - Whether other corresponding enhancement(s) e.g., interaction of PRACH repetition with Msg3 repetition should also be captured in WID or not
- Regarding DMRS-less PUCCH,
- There are multiple companies prefer to support DMRS-less PUCCH in Rel-18, while there are some other companies do not prefer to support it.
  - Supporting companies argued that 1) DMRS-less PUCCH can outperform legacy coherent PUCCH especially in low SINR range which is the typical condition for coverage limited UEs, and 2) based on TR 38.830, PUCCH format 1, PUCCH format 3 with 11bit and PUCCH format 3 with 22bit have been identified as the potential bottleneck channels as 2nd priority in FR1 and for Urban 28 GHz scenario, while objecting companies argued that RAN1 could not reach consensus on the necessity of DMRS-less PUCCH after extensive discussion and Rel-17 coverage enhancement already specified PUCCH coverage enhancement.
  - Based on the above situation, one possible approach is to have study phase for this to have better understanding on the gain, and such study can be done in RAN1 (and RAN4) although RAN1 already had the study.
  - For this potential objective, further discussion on following points would be necessary.
    - Whether this objective can be included in Rel-18 UL enhancements with starting from study phase to have better understanding on the gain
    - Whether to target both FR1 and FR2 or only one of them
    - Which PUCCH format(s) and UCI payload size are targeted
- Regarding other comments,
- Although there are some comments regarding power domain enhancements in the feedback form for “Further coverage enhancements including PRACH enhancement for FR2 e.g., PRACH repetition with same or different beams”, it can be handled together with feedbacks for “Power domain enhancements (including a possible study phase), e.g., dynamic power aggregation”.
  - There are some companies mentioned that leftover of Rel-17 coverage enhancements can be considered depending on Rel-17 progress, and it may include further enhancement based on Rel-17 feature e.g., Repetition type B based TBoMS and DMRS optimization for DMRS bundling.

Based on above observations, the moderator recommendation for intermediate round email discussion is to check companies' views on above observations and following possible objectives.

- **Specify following PRACH coverage enhancements (RAN1, RAN2)**
  - **Multiple PRACH transmissions with same beams for [FR1 and] FR2**
  - **Multiple PRACH transmissions with different beams for [FR1 and] FR2**
- **[Study and if necessary specify following PUCCH coverage enhancements (RAN1, RAN4)]**
  - **[DMRS-less PUCCH with UCI payload up to 11 bits]**

### 2.2.3 Power domain enhancements (including a possible study phase), e.g., dynamic power aggregation

Following observations could be made based on initial round inputs.

- Regarding the dynamic power aggregation,
  - There are multiple companies prefer to support dynamic power aggregation in Rel-18, and possible justification for this objective is that 1) the power is the most valuable resource in uplink and enhancements to unlock additional uplink power are highly valuable, and 2) the dynamic power aggregation lets a UE transmit at full power across different bands subject only to SAR/MPE constraints.
  - On the other hand, since RAN4 WI “Increasing UE power high limit for CA and DC” was approved in RAN#93-e and this WI also aim to achieve higher UL transmission power for CA/DC scenarios, multiple companies request to clarify the difference between the RAN4 WI and this potential Rel-18 objective from proponents.
  - Also, there are multiple companies argued that study phase for this objective is necessary including the study on relevant regulations.
  - The study/work for this objective can be done by RAN1 and RAN4, but companies views on which WG is leading WG may be diverse.
  - Based on the above situation, further discussion on following points would be necessary.
    - What is difference from RAN4 WI (i.e., necessity of this objective in Rel-18)
    - Whether the leading WG is RAN1 or RAN4
    - Whether this objective can be within UL enhancements or not (e.g., part of RAN4 led items)
    - Whether any limitation on the target scope of this objective is necessary (e.g., FR1/FR2, number of UL CCs for dynamic power aggregation, etc.)
- Regarding the reduction of MPR,
  - There are some companies argued that MPR reduction is beneficial to enhance coverage and should be part of Rel-18, while not so many companies commented on this topic in the initial round.
  - Those companies consider the study phase is necessary, this topic would be led by RAN4 and RAN1 can be secondary WG as needed.
  - There is a comment that this item may need coordination with related proposals for potential RAN4 enhancements [RAN94e-R18Prep-22].

- Based on the above situation, further discussion on following points would be necessary.
  - What is key justification for this potential objective
  - Whether this objective can be within UL enhancements or not (e.g., part of RAN4 led items)
  - Whether any limitation on the target scope of this objective is necessary
- Regarding other comments,
  - There is a company proposing to consider followings for power domain enhancements in Rel-18.
    - Focus on modulation orders beyond BPSK
    - Prioritize scenarios with one transmit antenna
    - Extend the usage of PC2 to FDD bands

Based on above observations, the moderator recommendation for intermediate round email discussion is to check companies' views on above observations and following possible objectives.

- **Study and if necessary specify following power domain enhancements [RAN4, RAN1]**
  - **[Dynamic power aggregation to achieve UE transmission at full power across different bands subject only to SAR/MPE constraints, with checking relevant regulations]**
  - **[Reduction of MPR/PAR, including waveform design, channel filtering and spectrum utilization]**

#### 2.2.4 Potentially other UL enhancements e.g., enhancement for multi-carrier UL operation, enhancements for DFTS-OFDM

Following observations could be made based on initial round inputs.

- Regarding enhancement for multi-carrier UL operation,
  - There are multiple companies prefer to support UL Tx switching schemes across more than 2 bands in Rel-18, and possible justification for this objective is that 1) there are some limitations of current specification (e.g. 2TX UE can be configured with at most 2 UL bands, which only can be changed by RRC reconfiguration, and UL Tx switching can be only performed between 2 UL bands for 2Tx UE), and 2) 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 rate, spectrum utilization and UL capacity.
  - On the other hand, there are some other companies do not see a need for this objective, mentioning that the incremental gain of enabling the UE to switch between 3 UL carriers vs 2 carriers would be marginal considering the extra SRS overhead and switching gaps needed for the UE.
  - Based on the above situation, one possible approach is to have study phase for this to have better understanding on the gain, and such study can be done in RAN1 and RAN4.

- For this potential objective, further discussion on following points would be necessary.
  - Whether this objective can be included in Rel-18 UL enhancements with starting from study phase to have better understanding on the gain
  - Whether any limitation on the target scope of this objective is necessary
- Regarding enhancement for DFTS-OFDM,
  - Companies consider that there are two potential enhancements, one is specifying dynamic switching between DFTS-OFDM and CP-OFDM, and another is specifying multi-layer DFTS-OFDM.
  - Majority seems to be supportive to specify at least one of them, but some companies prefer to specify both of them, while some other companies prefer to specify only one of them and there are different views on which one is preferred.
  - For the dynamic switching between DFTS-OFDM and CP-OFDM, possible justification is that 1) currently the waveform used in uplink is configured via RRC and cannot be dynamically switched, 2) this limitation imposes a large barrier to switch over to DFTS-OFDM waveform for cell-edge UEs practically, and 3) compared with multi-layer DFTS-OFDM, this item would have wider usage scenarios (e.g., even when UL-MIMO is not configured) and less spec impacts.
  - For the multi-layer DFTS-OFDM, possible justification is that 1) it has been specified in LTE and most of the LTE design can be reused, and 2) multi-layer DFTS-OFDM can achieve lower PAPR multi-layer UL compared with multi-layer CP-OFDM and it is different use case from the dynamic switching between DFTS-OFDM and CP-OFDM.
  - There are multiple companies argued that the multi-layer DFTS-OFDM should be part of MIMO [RAN94e-R18Prep-01], while other company argued that both dynamic switching and multi-layer DFTS-OFDM should be part of this UL enhancement as MIMO seems already quite heavy.
  - This objective may not need a study phase and can be led by RAN1.
  - Based on the above situation, further discussion on following points would be necessary.
    - Whether to specify both dynamic switching and multi-layer for DFTS-OFDM or only one of them (in such case which one)
    - Whether any limitation on the target scope of this objective is necessary
- Regarding other comments,
  - There are some companies prefer to study and specify enhancements for UL-dense deployment e.g., UL beam management, and UL open-loop power control, while other companies seem not to be so interested in this.
    - Based on the above situation, further discussion on following points would be necessary.
      - Whether this objective can be included in Rel-18 with starting from study phase (either in MIMO or UL enhancements)
      - Whether any limitation on the target scope of this objective is necessary
  - There is a company proposing some other enhancements, such as extending DFTS-OFDM to short PUCCH formats and dynamic PUCCH repetition indication for P/SP-CSI report

Based on above observations, the moderator recommendation for intermediate round email discussion is to check companies' views on above observations and following possible objectives. In addition, based on the checking with the moderator of MIMO email discussion [RAN94e-R18Prep-01], the listed three topics (enhancements for multi-carrier UL operation, enhancements for DFTS-OFDM including both dynamic

switching and multi-layer, and enhancements for UL dense deployment) can/should be discussed in this email thread [RAN94e-R18Prep-02] at least during this email discussion since there are already many other topics in [RAN94e-R18Prep-01].

- [Study and if necessary specify following enhancements for multi-carrier UL operation [RAN4, RAN1]]
  - [UL Tx switching schemes across more than 2 bands, including mechanisms to enable more configured UL bands than its simultaneous transmission capability and to support dynamic Tx carrier switching across the configured bands]
- Specify following enhancements for DFTS-OFDM (RAN1)
  - [Dynamic switching between DFTS-OFDM and CP-OFDM]
  - [Multi-layer transmission with DFTS-OFDM, with considering LTE design]
- [Study and if necessary specify following enhancements for UL dense deployment (RAN1)]
  - [UL beam management and UL power control with UL reception only point or TRP with lower Tx power]

### 3 Intermediate round

Based on the guidance in [RP-212657], the intermediate round discussion aims for initial convergence on the areas/objectives.

#### 3.1 Collection of company views

##### 3.1.1 General high level views

According to the guidance in RP-212657, at the beginning of the final round, moderators are expected to produce an initial draft of the overall justification. The initial draft of the overall justification for UL enhancements will be prepared based on companies’ input, and hence companies are encouraged to provide additional comments if any on top of the initial round comments on the overall justification.

Also, companies are encouraged to provide feedbacks if any on moderator summary in 2.2.1.

#### **Feedback Form 6: General high level views**

<p><b>1 – SHARP Corporation</b></p> <p>In our view, the justification of Rel-17 can be reused and PRACH can be added to target channels.</p>
<p><b>2 – Qualcomm Incorporated</b></p> <p>Uplink enhancements remain a top priority and should receive sufficient focus and attention in Rel-18. A well-balanced focus on issues relevant to FR1 and FR2 is desired.</p>
<p><b>3 – Guangdong OPPO Mobile Telecom.</b></p> <p>We think the UL coverage and UL efficiency should be both included in the justification of WID.</p>

#### **4 – China Telecommunications**

We share the similar view that the justification of Rel-17 can be reused.

For further coverage enhancement, the following justification can be added:

Although Rel-17 manages to enhance the coverage performance of some bottleneck channels, i.e. PUSCH, PUSCH of Msg.3 and PUCCH, remaining performance gap can still be found when we look at the potential gain of solutions included in Rel-17's scope (in Section 6 of TR 38.830) and compare it with the target performance gap (in Section 5 of TR 38.830). Moreover, PRACH is identified as a potential bottleneck channels for both FR1 and FR2, considering the importance of radio access, enhancement on PRACH for is also needed. Thus, it is beneficial to continue enhancing UL coverage in Rel-18 to ensure a better network coverage capability.

For UL Tx switching enhancement, the following justification can be considered:

First, emergence of uplink centric services brings challenge to UL transmission; second, there are some limitations of current specification, e.g. 2TX UE can be configured with at most 2 UL bands, which only can be changed by RRC reconfiguration, and UL Tx switching can be only performed between 2 UL bands for 2Tx UE. Thus, enhancement on UL Tx switching is needed.

#### **5 – Nokia Corporation**

Justification should focus on coverage aspects, and some aspects can be reused from Rel-17 WID. One can consider also the proposal below for the coverage aspects:

”In Rel-17 work item 900061 “NR Coverage Enhancements”, NR coverage has been extended for some of the bottleneck channels identified in the Rel-17 study item 860036 “Study on NR coverage enhancements”, in particular for PUSCH and PUCCH. However, not all needs for coverage enhancement have been addressed by the Rel-17 WID, due to its limited scope. For example, PRACH has not been addressed in Rel-17 WID, despite being identified as one of the bottleneck channels in the corresponding studies. On power domain, it should be noted that in Rel-17 study item 910097 “Study on optimizations of pi/2 BPSK uplink power in NR”, power-domain solutions are already studied for pi/2 BPSK.

In Rel-18 Workshop following RAN#92-e, UL coverage has been identified as one of the key areas of interest by multiple players, as reflected by the number of contributions proposing UL coverage enhancements. Subsequent email discussion on Rel-18 enhancements prior to RAN Plenary has confirmed this understanding, with good alignment on the needs for enhancement on PRACH, PUCCH, and power-domain enhancements beyond BPSK.”

#### **6 – ZTE Corporation**

In our view, the high-level justification for UL enhancements at least includes 1) UL performance could be still the bottleneck in most of scenarios in the real deployment. The situation could be even worse with emerging of vertical use cases that have UL heavy traffic, e.g., video uploading. UL enhancements are needed to satisfy the increasing demand coming from both the operators and vertical industries . 2) Some UL channels, e.g., PRACH and PUCCH, are identified as bottleneck channels in Rel-17 while not pursued due to limited time.

We agree with the moderator summary in 2.2.1.

#### **7 – Ericsson LM**

We agree that UL enhancements can be a RAN1 led work item overall, but think that the power domain objective should be primarily driven by RAN4.

## 8 – Huawei Tech.(UK) Co.. Ltd

Uplink enhancements should be provided sufficient TU in Rel-18 (e.g. 2 TU per RAN1 meeting), as this is one of the areas with the most support in Rel-18 across operators, network and UE vendors, and various industries (MBB, verticals), due to the pressing needs for improving uplink performance.

Multi-carrier uplink operation and coverage enhancements for PRACH should have higher priority, with some additional enhancements on power domain (noting that those potential enhancements have dependency on on-going RAN4 work). Uplink enhancements focusing on MIMO (e.g. rank-2 DFT-s-OFDM) should eventually be in the scope of the MIMO WID.

### 3.1.2 Further coverage enhancements including PRACH enhancement for FR2 e.g., PRACH repetition with same or different beams

#### 3.1.2.1 PRACH coverage enhancements i.e., multiple PRACH transmissions with same or different beams

Companies are encouraged to provide feedbacks if any on moderator summary and recommendation in 2.2.2 regarding PRACH coverage enhancements, including observations and possible objective such as following points.

- *In order to further clarify/narrow down the scope of this objective, following points need to be discussed further.*
  - *Whether to specify same beam case, different beam case or both cases (as there is a company argued that PRACH repetition with different beams may not help for coverage enhancement as beam correspondence is UE mandatory feature)*
  - *Whether to target both FR1 and FR2 or FR2 only*
  - *Whether to target all PRACH formats or limited PRACH format identified as bottleneck channel in Rel-17 CovEnh SI*
  - *Whether to target both 4-step and 2-step RACH or 4-step RACH only*
  - *Whether the study phase is necessary or not (although majority considers study phase is not necessary)*
  - *Whether other corresponding enhancement(s) e.g., interaction of PRACH repetition with Msg3 repetition should also be captured in WID or not*
- **Specify following PRACH coverage enhancements (RAN1, RAN2)**
  - **Multiple PRACH transmissions with same beams for [FR1 and] FR2**
  - **Multiple PRACH transmissions with different beams for [FR1 and] FR2**

### **Feedback Form 7: PRACH coverage enhancements i.e., multiple PRACH transmissions with same or different beams**

## 1 – Charter Communications

We propose to cover both FR1 and FR2. PRACH coverage enhancements will be beneficial for midband spectrum.

## **2 – SHARP Corporation**

We slightly prefer to cover both FR1 and FR2. For FR1, PRACH format B4 is identified as the bottleneck channel of 2nd priority and for FR2, it is identified as the bottleneck channel in TR38.830.

## **3 – vivo Communication Technology**

We are supportive of this item for FR2 with same beam.

## **4 – VODAFONE Group Plc**

For the points raised by the moderator, we prefer to have FR1 included, not only FR2; focusing on all PRACH formats; and both 2-step and 4-step RACH.

## **5 – InterDigital France R&D**

Thank you very much for the summary. We do not need to focus on PRACH enhancements for both same and different beams. Having two enhancements may lead to risk of divergence during initial access. It also leads to lack of focus during study/specification stage. As we mentioned in the previous round, as beam correspondence is UE mandatory feature, we don't think PRACH repetition with different beams has to be included in the scope since we don't see clear motivation to specify it. If any, we can focus on enhancements for the same-beam repetition. In addition, since this is beam-related enhancement, we suggest to focus on FR2 only.

## **6 – Asia Pacific Telecom co. Ltd**

We support prioritize 4-step over 2-step RACH, and targeting on both FR1 and FR2.

## **7 – Lenovo (Beijing) Ltd**

We support multiple PRACH transmission with same or different beams. Repetition with different beams increases robustness even for UE with beam correspondence. Since PRACH format B4 was identified in the R17 coverage enhancement study as the bottleneck, it shall be the primary target of enhancement. We think the specified solution shall apply to both FR2 and FR1, and benefit both 4-step and 2-step RACH. Because of this, enhancement specifically targeting 4-step RACH, such as interaction of PRACH repetition with Msg3 repetition shall be excluded. Given these as the scope of the WI, we do not think a study phase is necessary.

## **8 – Futurewei Technologies**

This discussion needs to be more focused, as currently there are multiple choices to be made, e.g., for FR1 vs FR2, same beam vs different beams, 2-step vs 4-step, some formats vs all formats, etc., which we think could be controversial and take quite some time to converge to agreeable objectives.

In our view, the group needs to either decide a reduced scope now for the WI so that the WI can start and complete on time, or have a study phase first so that the group can identify focused objectives later. Once again we want to point out that for PRACH enhancement, there seems to be only 2 sources providing performance evaluation results. 3GPP needs some further study and evaluations to understand what/how to enhance, so our preference is to have a study phase first for this enhancement.

### **9 – Apple Computer Trading Co. Ltd**

We support multiple PRACH transmission with same or different beams for FR2. For FR1, the coverage is already good enough, we don't see the strong motivation to support PRACH repetition. Thus, PRACH formats could be limited to short formats, e.g. A1/B4, etc.

### **10 – Samsung Research America**

We support enhancing PRACH coverage. The objective proposed by the moderator is fine, including both FR1 and FR2. Targeting only 4-step RACH should be sufficient. There is no need to limit the preamble format in the WI objective, and a RACH coverage enhancement could be applicable to all formats. We don't think there is a need for a study phase.

### **11 – CATT**

We support PRACH coverage enhancement for FR2 only. For FR1, we do not see a strong need. We think PRACH coverage enhancement is targeting for 4-step RACH only since 2-step RACH is mainly used for UEs in good coverage. For same beam vs. different beams, we would like to prioritize same beam if needed.

### **12 – Intel Deutschland GmbH**

Q1/Q2: we are fine to support multiple PRACH transmissions with same or different beams in FR2 only.

Q3: As extensively studied in Rel-17 coverage enhancement SI phase, long sequence PRACH formats were not identified as performance bottleneck. Further, in case of coverage limited scenario, long sequence PRACH format with repetitions, e.g., PRACH format 1 or 2 can be configured by the network to address coverage issue, which indicates that further coverage enhancement for PRACH in FR1 is not needed.

Q4: We are fine to target all short sequence PRACH formats in FR2.

Q5: Given the fact that 2-step RACH is mainly targeted for the cell-center UEs that have good channel conditions, we suggest to focus PRACH coverage enhancement only on 4-step RACH.

Q6: Study phase is not necessary.

Q7: Interaction between PRACH repetitions and Msg3 repetitions will be part of study and does not need to be explicitly listed in the WID.

### **13 – China Mobile Com. Corporation**

1  We do not support to extend the enhancement into FR1. The motivation to enhance FR1 PRACH is not clear. For any real deployment, even the PRACH is coverage limited, how could the network work ? And based on the previous studies, the PRACH channel is the best among all the uplink channels, even 10dB better than PUSCH.

2  Only PRACH format B4 in FR2 have been studied during the SI, we should focus on this format. And if other PRACH format needs enhancement, a study phase are needed to identify the coverage gap and how much are needed for the enhancements. During this study, no new PRACH format should be introduced.

3  4-step is the baseline for the coverage enhancements. And as discussed during Rel-17, the 2 step RACH procedure which carries data in the Step A are mainly targeted for scenarios that coverage are not limited. Then only the enhancements for 4 step RACH is preferred.

4  If the other PRACH formats other than B4 are captured in the work item, a study phase is needed.

5  Theoretically, the interaction between multiple beam PRACH and Msg 3 may bring benefits. But it complicates the initial access procedure and the impact to the specification is too much.

#### 14 – Spreadtrum Communications

1. Same or different beams for FR2 should be focused in Rel-18.
2. Target only 4-step RACH is preferred, as 2-step RACH always has a higher RSRP comparing 4-step RACH.
3. We do not think a study phase is necessary.
4. FFS and open for interaction of PRACH repetition with Msg3 repetition.

#### 15 – Qualcomm Incorporated

We support specifying PRACH repetition with the same or different beams (for both FR1 and FR2, with emphasis on FR2). We think both 4-step and 2-step RACH can be considered (though PRACH repetition for 4-step RACH is more needed). Also, we think interaction of PRACH repetition and Msg3 repetition (e.g. possible link between PRACH repetition and Msg3 repetition request) should be specified.

#### 16 – China Telecommunications

Thanks for the summary. From our point of view, we think:

- Both same beam and different beams should be specified. PRACH repetition with different beams is beneficial for FR2. Moreover, the gain of multiple PRACH transmission with same/different beam(s) is provided in TR 38.830.
- Both FR1 and FR2 can be targeted. PRACH is a potential bottleneck channel for FR2 and also a bottleneck channel for FR2 with second priority. Thus, we don't think FR1 should be excluded.
- At least target on short format PRACH, we are open for other PRACH formats.
- 4-step PRACH should be prioritized; we are open to discuss 2-step PRACH.
- We don't think a study phase is needed since it is extensively studied in Rel-17 coverage enhancement SI.

#### 17 – Guangdong OPPO Mobile Telecom.

Regarding the 2 sub-bullet. The square bracket part is unclear to indicate whether those can be supported or not. It could be stated those are to be studied. We can same "for FR1, if agreed after study", same method can be applied for the FR1.

Then for this part we can have some study to see if FR1 can not be beneficial by that repetition.

We agree the final repetition schemes may not be FR dependent.

#### 18 – Nokia Corporation

**Same and different beams.** Please note that despite beam correspondence being a mandatory feature there are two possibilities that can be indicated by FG 2-20 [TR38.822]:

- UE that fulfils the beam correspondence requirement without the uplink beam sweeping shall set the bit to 1
- UE that fulfils the beam correspondence requirement with the uplink beam sweeping shall set the bit to 0

Hence, we need to be able to address both types of UEs in real deployments. Moreover, there are no RAN4 requirements yet for idle mode UEs, and hence it is not clear how well the network can rely on the beam correspondence implementations during initial access.

**FR1 and FR2:** We agree with Charter that midband spectrum should benefit from PRACH enhancements too, and hence we should not limit it to FR2.

**PRACH format:** A format-agnostic approach is preferred, for simplicity. This logic applies regardless of whether all formats or only short formats will be considered eventually.

**4-step / 2-step RACH:** 4-step RACH only. 2-step RACH is not suitable for coverage limited scenarios. If 2-step RACH is considered for enhancement as well, application should be limited to FR1.

**Study phase is not necessary,** relevant studies have been done in Rel-17 already.

**Interaction with other enhancements:** At least interactions with Msg3 should be considered, in case of different beam case for PRACH enhancement. Details can be left for the WG discussion.

## 19 – ZTE Corporation

We support both the same and different beams for both FR1 and FR2.

Regarding beam correspondence, the UE capability is transparent in random access procedure, and beam correspondence may not be guaranteed due to lack of reciprocity. So, supporting different beams could also be beneficial.

PRACH is a potential bottleneck channel in FR1, and we don't see any difference in terms of spec impacts for different frequency ranges. There is no need to artificially limit to only FR2.

For the details, e.g., the applicable RACH procedure/formats and interaction of PRACH repetition with Msg3 repetition etc., could be discussed in RAN1 during WI phase.

## 20 – Ericsson LM

**Whether to specify same beam case, different beam case or both cases (as there is a company argued that PRACH repetition with different beams may not help for coverage enhancement as beam correspondence is UE mandatory feature)**

- We think at least repetition with a same beam should be supported, and are open to repetition with different beams.

**Whether to target both FR1 and FR2 or FR2 only**

- At least FR2 should be supported, but reusing mechanisms designed with FR2 in mind should not be precluded for FR1.

**Whether to target all PRACH formats or limited PRACH format identified as bottleneck channel in Rel-17 CovEnh SI**

- Repetition for short sequence PRACH formats seems sufficient. We prefer more discussion on if a subset of the short sequence PRACH formats should be prioritized.

**Whether to target both 4-step and 2-step RACH or 4-step RACH only**

- PRACH repetition seems contrary to the low latency normally associated with 2-step RACH, especially since Msg3 PUSCH should probably also be retransmitted or repeated if PRACH requires repetition. Indeed, an SNR threshold to determine where UE uses 2-step RACH can be used, since 2-step is generally used for UEs good channel conditions. Therefore, we don't see a need to specify PRACH repetition enhancements targeting two step RACH.

**Whether the study phase is necessary or not (although majority considers study phase is not necessary)**

- Unless exotic enhancements are proposed, we don't see a need for study.

**Whether other corresponding enhancement(s) e.g., interaction of PRACH repetition with Msg3 repetition should also be captured in WID or not**

- Both Msg3 retransmission and repetition can be considered in the poor channel conditions where PRACH would require repetitions. Whether enhancement to such mechanisms is needed when PRACH repetition is used can be discussed, but should not be required by the WID.

**21 – Rakuten Mobile**

We are supportive of both FR1 and FR2, and 4-step RACH, but we are open to discussion about 2-step RACH.

**22 – Huawei Tech.(UK) Co.. Ltd**

We support focusing this objective to the same beam case including FR1 and FR2, and to prioritize PRACH format B4 and 4-step RACH. We prefer not to rush to consider interaction of PRACH repetition with Msg3 repetition; if a need reveals itself then the objective can be revised later.

**23 – NTT DOCOMO INC.**

Considering that the beam correspondence is mandatory in Rel.15, we agree that the case of the same beam is high priority, where the beam is derived from the measured SSB, assuming the beam correspondence. It is not preferred to have two features for UEs with the beam correspondence and UEs without beam correspondence, especially in initial access. We can only consider the scenario that UE has the beam correspondence. On the other hand, if there is benefit of the different beams for the beam correspondence UEs, we are open to discuss it.

In Rel.15, spatial relation is only defined in FR1, hence, the beam related enhancement can be applied to FR2 only. However, we assume the new PRACH enhancement scheme (e.g. PRACH repetition) is also beneficial for coverage enhancement in FR1, hence we support both FR1 and FR2.

**24 – MediaTek Inc.**

Fine to consider FR1 as well as FR2 here. Probably makes sense to focus on 4-step RACH if that reduces the workload.

**25 – MediaTek Inc.**

(clarification to above) ”consider FR1” means that we should not preclude usage of any enhancement for FR1, but we understand that the real bottleneck is in FR2.

3.1.2.2 PUCCH coverage enhancements i.e., DMRS-less PUCCH

Companies are encouraged to provide feedbacks if any on moderator summary and recommendation in 2.2.2 regarding PUCCH coverage enhancements, including observations and possible objective such as following points.

- *For this potential objective, further discussion on following points would be necessary*
  - o *Whether this objective can be included in Rel-18 UL enhancements with starting from study phase to have better understanding on the gain*
  - o *Whether to target both FR1 and FR2 or only one of them*
  - o *Which PUCCH format(s) and UCI payload size are targeted*
  
- **[Study and if necessary specify following PUCCH coverage enhancements (RAN1, RAN4)]**
  - o **[DMRS-less PUCCH with UCI payload up to 11 bits]**

**Feedback Form 8: PUCCH coverage enhancements i.e., DMRS-less PUCCH**

**1 – Charter Communications**

We propose to cover both FR1 and FR2 for PUCCH enhancement. PUCCH formats are not FR-specific so there is no additional impact on the workload.

**2 – SHARP Corporation**

We prefer to cover both FR1 and FR2, and PUCCH format 2 should be targeted. In our view, Rel-17 CovEnh focused on PUSCH repetition type A but PUSCH repetition type B was deprioritized, because people assumed that special slots were used for SRS and PUCCH. It means there is a demand for short PUCCH in TDD operation. However, since PUCCH format 2 is short PUCCH with more-than-2-bit payload, it requires more improvement than PUCCH format 3 of which the enhancement is adopted in Rel-17. For this reason, we think short PUCCH format needs to be enhanced for utilizing special slots, at least for TDD with single-TRP.

**3 – vivo Communication Technology**

DMRS-less PUCCH was evaluated extensively in Rel-17 SI phase, with PUCCH coverage enhancement is being specified in Rel-17, we don’t see the need for this item.

**4 – VODAFONE Group Plc**

We are supportive of this item and we prefer to have at least FR1 included

**5 – InterDigital France R&D**

It should be included in WI in Rel. 18. We support enhancements for both FR1 and FR2.

**6 – Lenovo (Beijing) Ltd**

Given PUCCH enhancement is part of R17, we do not feel the urge to enhance PUCCH for coverage in R18. This topic can be given lower priority.

**7 – Futurewei Technologies**

Various enhancements for PUCCH coverage have been supported in Rel-17. Given these new enhancements, the additional gain of DMRS-less PUCCH becomes questionable. In existing study for DMRS-less PUCCH, a wide range of observed SNR gains (-2 dB to 4.8 dB) on top of Rel-16 mechanisms were provided in TR 38.830, with no definitive conclusion on its benefit. The gain on top of Rel-17 mechanisms can only be even smaller and more controversial. So we do not see a strong motivation for this topic.

**8 – Apple Computer Trading Co. Ltd**

As supporting DMRS-less PUCCH is controversial since Rel-17 SI, if it is included in Rel.18 UL enhancement, it could be better to evaluate the performance again to have a common understanding of the gain.

**9 – Samsung Research America**

This scheme was already studied in Rel-17 and after extensive discussions there was no consensus to be specified based on performance and complexity considerations. Further studying it at this stage does not seem to be needed.

**10 – CATT**

We do not think PUCCH coverage enhancement should be included in Rel-18 considering that there was no consensus on the performance gain during Rel-17 evaluation and various PUCCH coverage enhancement techniques have been introduced in Rel-17.

**11 – Intel Deutschland GmbH**

As mentioned in the first round of discussions, we do not see the need to list the PUCCH coverage enhancement as an objective in Rel-18 UL enhancement. Based on extensive performance evaluation during Rel-17 coverage enhancement SI phase, there was no consensus on the performance gain of DMRS-less PUCCH over existing PUCCH format 3 when employing advanced receiver algorithm. Further, considering that dynamic repetition factor indication and DMRS bundling for PUCCH repetitions have been specified in Rel-17 PUCCH coverage enhancement, it is not clear to us whether further enhancement is needed for PUCCH in Rel-18.

**12 – Spreadtrum Communications**

We are open for DMRS-less PUCCH in Rel-18. The new results or new justification are highly recommended to avoid repeat/redundancy discussion as in Rel-17; otherwise, this topic will be low priority.

**13 – Qualcomm Incorporated**

We are quite supportive of this proposal. As many companies have pointed out, the Rel-17 discussions came to a rather abrupt halt without achieving a clear conclusion. A small study to get all companies on the same page would be a valuable exercise. We can then determine whether/how we specify this enhancement.

It will be good for RAN1 to pursue at least one enhancement to PUCCH that does not rely on repetitions (TDD bands are resource constrained in uplink, and it's not clear if repetitions will find widespread use). DMRS-less PUCCH and DFT-S-OFDM waveform for short PUCCH are two promising options to pursue.

#### **14 – China Telecommunications**

We don't think a study phase is needed since it is extensively studied in Rel-17 coverage enhancement SI. We think both FR1 and FR2 can be included. The payload size can be up to 11bits.

#### **15 – Guangdong OPPO Mobile Telecom.**

We agree this bullet of DMRS-less PUCCH. It was discussed in the Rel17 and it is not included for standardization is due to the limited resource. Only 2 of the item is selected among 4 items. The PUCCH coverage enhancement is important to overall coverage.

With the scope limited to up to 11 bits, the workload is quite reasonable.

It would be natural to agree moderator's bullets. We suggest removing the "[ ]".

#### **16 – China Mobile Com. Corporation**

During the SI, extensive simulations and evaluations have been carried out. Due to the divergent views on the performance gain, no recommendation had been made. And during the RANP, the controversy had not been solved. We do not see any improvements if we have a study item again and without any change.

Still we should be more cautious about the redundant enhancements.

#### **17 – Nokia Corporation**

As mentioned before we are open to PUCCH enhancement, but scope needs to be limited due to time constraints. Study phase is not needed, this topic has been studied already during Rel-17. Solution should be FR-agnostic.

#### **18 – EURECOM**

We strongly support this objective. As mentioned, in the SI many companies showed promising gains but there was no time to settle the controversy. We think that much of the diverging views are due to unaligned simulation results, especially the baseline scheme. All proposals should be evaluated against PUCCH format 3 with a non-coherent (advanced) receiver and potential gains should include PAPR gains as well as coding gains.

Therefore, we are in favor of a short study phase in order to evaluate potential gains with more restricted simulation assumptions and performance metrics to ensure that the simulation results remain comparable.

Armed with those results, we should be able to draw a conclusion whether to specify a new PUCCH format or not.

#### **19 – ZTE Corporation**

As commented, we see large PAPR gain and SNR gain from DMRS-less PUCCH. Directly proceeding with a WI could be sufficient. On the other hand, we are fine to start with a study phase to first verify the performance gain with more aligned simulation assumptions if this is concerned by some companies.

DMRS-less PUCCH could be applicable for both FR1 and FR2. The payload range should be 3 bits 11bits, and only enhancing long PUCCH format is needed in coverage limited scenarios.

## 20 – Rakuten Mobile

We share with other companies' opinions that it should be required to avoid redundant discussion which was already discussed in Rel-17 SI. Having said that, we prefer to enhance PUCCH coverage in both FR1 and FR2, especially for short PUCCH.

## 21 – Ericsson LM

Whether this objective can be included in Rel-18 UL enhancements with starting from study phase to have better understanding on the gain

As we and other companies commented, there was no consensus on the gain of DMRS-less PUCCH during the coverage enhancement study item.

However, there was consensus in the work item to enhance PUCCH repetition, motivated by observations that is one of the potential coverage bottlenecks in some cases. The Rel-17 work item has excluded enhancement for dynamic repetition of PUCCH carrying CSI, which has meant that this enhancement to spectrally efficient CSI coverage is not included in Rel-17. Joint channel estimation is being specified and can increase CSI coverage, but this has no gain for TDD single UL slot configurations (i.e. DDDSU and similar).

Therefore, we prefer to have enhancements to CSI coverage that can use whole slot repetition in a spectrally efficient manner. This efficiency can be obtained by dynamic control of the repetition factor and/or by aperiodic CSI triggering. At present aperiodic CSI can't be repeated on PUSCH (except for the special case of Rel-17 UL-MTRP operation where at most two repetitions are allowed), aperiodic triggering for repeated CSI on PUCCH is not supported, nor is a dynamically indicated repetition factor for PUCCH carrying persistent or semi-persistent CSI. Rather than introducing an entirely new PUCCH format, we prefer considering one or more of the above approaches if enhanced CSI coverage is contemplated for Rel-18. Such an objective could be formulated as follows:

### **Specify coverage enhancements using repeated CSI in dynamically indicated resources (RAN1)**

Whether to target both FR1 and FR2 or only one of them

We think both can be enhanced, although the greatest need is for FR2.

Which PUCCH format(s) and UCI payload size are targeted

While CSI payloads of roughly 10 bits or less may be the most important coverage use cases, we don't see a particular need to restrict the payload sizes, presuming that existing physical channels and formats are used.

Regarding the formats, the long PUCCH formats are a logical starting point for PUCCH coverage enhancement as they allow the most coverage. However, we note that Rel-17 dynamic PUCCH repetition is to be supported for all PUCCH formats, and so it may not make sense to restrict to specific PUCCH enhancements, although this may depend on the solutions to be specified. Furthermore, as discussed above, support for PUSCH carrying repeated CSI can also enhance coverage.

**22 – Huawei Tech.(UK) Co.. Ltd**

PUCCH coverage was enhanced in Rel-17 so this should only be considered with lower priority, if considered at all.

**23 – NTT DOCOMO INC.**

We don't support PUCCH coverage enhancement, as we commented in the 1st round. However, if it is to be supported due to the large number of supporters, at least, we should limit the scope of PUCCH coverage enhancements, to avoid large TU. We think PUCCH format 2 has large PAPR due to OFDM waveform, and DMRS less PUCCH (UCI payload = 3 11 bit) is promising to enhance the coverage. To support DMRS less PUCCH, we think new PUCCH format will be defined. We think short PUCCH is high priority, but we can easily extend it to long PUCCH, if we observe the gain. Also, both FR1 and FR2 should be considered.

**24 – MediaTek Inc.**

We do NOT support working again on PUCCH coverage enhancements as we have already addressed the PUCCH in Rel-17 work, where in a Study Item it was decided what would be useful and what would not be useful to specify.

3.1.2.3 Others for further coverage enhancements

Companies are encouraged to provide feedbacks if any on moderator summary and recommendation in 2.2.2 e.g., regarding other comments as below.

- *There are some companies mentioned that leftover of Rel-17 coverage enhancements can be considered depending on Rel-17 progress, and it may include further enhancement based on Rel-17 feature e.g., Repetition type B based TBoMS and DMRS optimization for DMRS bundling*

**Feedback Form 9: Others for further coverage enhancements**

**1 – vivo Communication Technology**

Given the proposed items for this WI is already too many, we don't think additional topics should be discussed.

**2 – InterDigital France R&D**

We support to complete the work that was not specified during Rel. 17 due to lack of time. Mainly, Repetition type B like TBoMS was not completed during Rel. 17 due to lack of time. Rep-B like TBoMS will be beneficial in terms of flexibility.

**3 – Lenovo (Beijing) Ltd**

We are open to consider leftovers or further enhancements of features from Rel-17. However, the overall scope of the potential WI should be taken into account. Further enhancements and/or leftovers from Rel-17 could include:

- TBoMS based Msg3 repetitions
- TBoMS based repetition type B

Regarding DMRS optimization for DMRS bundling, evaluations have been done in Rel-17 and no major performance impact is seen. Therefore, we do not suggest revisiting DMRS optimization for DMRS bundling.

#### **4 – Futurewei Technologies**

This WI seems too large already and other topics cannot be accommodated.

#### **5 – Apple Computer Trading Co. Ltd**

For repetition type B based TBoMS, we don't see this is enhancement on Rel-17. As discussed in Rel.17, TBoMS just re-use the TDRA of repetition type A. If repetition type B like TDRA is used for TBoMS, it would require designing new DMRS pattern but the benefits are not clear. For DMRS optimization for DMRS bundling, it's hard to see the benefits if dynamic events are to be agreed.

#### **6 – Samsung Research America**

We can be open to consider some Rel-17 leftovers as straightforward extension of what specified in Rel-17. For example, support of counting based on available slots for PUSCH repetition Type B.

#### **7 – CATT**

We do not think additional coverage enhancements can be accommodated in Rel-18 UL enhancements item given that the current scope is already large.

#### **8 – Intel Deutschland GmbH**

We are open to consider repetition type B based TBoMS, which can be beneficial on the efficient support of special slot in TDD system.

#### **9 – Qualcomm Incorporated**

We don't think this is necessary. We also don't think extending the Rel-17 enhancements to Type B repetitions are likely to yield any meaningful performance gains.

#### **10 – China Telecommunications**

We think left over of Rel-17 coverage enhancement can be included in this WI, the detailed scope can be discussed in Dec. RANP. Currently, we think the following leftovers can be included:

- TBoMS based on Repetition type B like TDRA.
- TBoMS with CB segmentation.
- Joint channel estimation for different TBs.
- Joint channel estimation for PUSCH/PUCCH transmissions across non-consecutive slots.

#### **11 – China Mobile Com. Corporation**

Considering the limited TU, the capacity seems not enough for other topics.

A few mechanisms have been carried out for repetition type B enhancement in Rel-17. No strong motivation is observed for further enhancements.

<p><b>12 – Nokia Corporation</b></p> <p>We do not see a need for further coverage enhancements to be considered in addition to the ones discussed above.</p>
<p><b>13 – ZTE Corporation</b></p> <p>Other leftover of Rel-17 coverage enhancements could be deprioritized.</p>
<p><b>14 – Ericsson LM</b></p> <p>As was discussed in the NR coverage enhancement study and work items, Repetition Type B does not target coverage enhancement scenarios. Also, the net gains of DMRS optimization were also not so clear. Consequently, these enhancements were not supported in Rel-17. We prefer to focus on other enhancements that address coverage more directly and/or have more clear gains.</p>
<p><b>15 – Huawei Tech.(UK) Co., Ltd</b></p> <p>The need for including potential leftovers from Rel-17 can be discussed at RAN#94 once there is better visibility of the outcome of the Rel-17 coverage enhancements WI in RAN1.</p>
<p><b>16 – MediaTek Inc.</b></p> <p>We do not see the need to consider additional topics at this stage.</p>

### 3.1.3 Power domain enhancements (including a possible study phase), e.g., dynamic power aggregation

#### 3.1.3.1 Dynamic power aggregation

Companies are encouraged to provide feedbacks if any on moderator summary and recommendation in 2.2.3 regarding dynamic power aggregation, including observations and possible objective such as following points.

- *Based on the situation, further discussion on following points would be necessary*
  - *What is difference from RAN4 WI (i.e., necessity of this objective in Rel-18)*
  - *Whether the leading WG is RAN1 or RAN4*
  - *Whether this objective can be within UL enhancements or not (e.g., part of RAN4 led items)*
  - *Whether any limitation on the target scope of this objective is necessary (e.g., FR1/FR2, number of UL CCs for dynamic power aggregation, etc.)*
- **Study and if necessary specify following power domain enhancements [RAN4, RAN1]**
  - **[Dynamic power aggregation to achieve UE transmission at full power across different bands subject only to SAR/MPE constraints, with checking relevant regulations]**

#### **Feedback Form 10: Dynamic power aggregation**

**1 – vivo Communication Technology**

We still believe clarification is needed with regard to on going Rel-17 RAN4 WI. In our view, this can wait until Rel-17 RAN4 work is done.

**2 – InterDigital France R&D**

We support the study. RAN1 can work on evaluation of coverage performance for the enhancement.

**3 – Futurewei Technologies**

Based on what we have understood from this enhancement and the ongoing RAN4 WI on CA/DC, we feel they have significant overlap, and hence this enhancement is not needed at least for now. Please correct us if we missed anything. That said, we are generally ok with the further study of power domain enhancement in either the ongoing RAN4 WI or in a future SI/WI.

**4 – SoftBank Corp.**

We support the proposal by moderator.

Even though there is some overlap between this study and RAN4 WI, we believe additional mechanism(s) to guarantee SAR satisfaction is necessary in RAN1. This aspect can be clarified during the study phase.

**5 – Apple Computer Trading Co. Ltd**

As commented by many companies, the proponent could provide clarifications on the relationship with existing RAN4 WI, the dynamic power sharing is also kind of UL CA enhancement. Based on current understanding, RAN4 could lead this work or merge this into RAN4 WI.

**6 – Samsung Research America**

We would be open to study this topic in RAN4. The study can be led by RAN4 and be separate from UL enhancements WI.

**7 – CATT**

Similar as comments from other companies, the relationship with the existing RAN4 WI needs to be clarified.

**8 – Intel Deutschland GmbH**

Q1: As commented in the initial round we are not clear on the scope of proposed enhancements and possible benefits relative to the ongoing Rel-17 work item on “Increasing UE power high limit for CA and DC”. Further clarifications are encouraged.

Q2: The leading WG should be RAN4.

Q3: If the work is considered, then it should be a part of RAN4-led items

Q4: Power domain enhancements should focus on FR1.

**9 – Spreadtrum Communications**

It needs more clarifications for the relationship with RAN4 WI.

## **10 – Qualcomm Incorporated**

The RAN4 WI is specifically focused on removing the artificial power limit imposed on certain band combinations. The exact solution to be adopted is not yet clear.

Once RAN4 addresses this issue as part of their Rel-17 WI, RAN1 then needs to revisit this issue to make sure that it is possible for a gNB to take advantage of this relaxation. One line of investigation is as follows: given the complexities of managing SAR/MPE at the UE and given that, currently, a UE merely reports PHR based on the latest PUSCH transmission, some enhancements to PHR reporting to better convey availability of power across bands and across time, subject to SAR and MPE constraints, may be warranted.

It is therefore important that RAN1 take a closer look at this issue and ensure that sufficient tools/procedures are in place to leverage the relaxation produced by the RAN4 WI.

We think RAN1 should be the leading WG for this item.

## **11 – Guangdong OPPO Mobile Telecom.**

We also think the scope can be further clarified. The scope would be defined after relevant RAN4 item concluded.

## **12 – Nokia Corporation**

Main justification for these enhancements is to allow efficient power utilization for higher data rates than addressed by Rel-17. This is clearly part of the scope of this discussion and forthcoming WID, regardless of later decision on leading WG for this particular objective. The fact this may be considered as more suitable to have RAN4 as leading WG has no impact on including it in this WID or not. It is business as usual to have RAN4-led objectives in RAN1-led WIs, and from procedural perspective it is also fine, given that there are even RAN4-led email threads considered for December approval.

Regarding the limitation of scope, please note that this is the original intention with most of the proposals listed in section 3.1.3.3, repeated here:

- *Focus on modulation orders beyond BPSK*
- *Prioritize scenarios with one transmit antenna*

The reason to propose focus on modulation orders beyond BPSK is because that one is already addressed in Rel-17.

## **13 – Nokia Corporation**

The comment above was intended for MPR/PAR reduction section, sorry for the confusion!

## **14 – Nokia Corporation**

Now commenting on the correction section, we tend to agree that there is a need to clarify a bit more the scope of the work before being able to consider this further. It also needs to be clarified if this is intended for FR1, FR2, or both.

## **15 – ZTE Corporation**

From motivation point of view, we don't see much difference between the RAN4 WI and dynamic power aggregation. However, depending on the solution to be specified in RAN4 WI, it may require further study, e.g., the potential RAN1 impacts. We are ok to start with a study phase to investigate more on this area.

#### **16 – Ericsson LM**

What is difference from RAN4 WI (i.e., necessity of this objective in Rel-18)

Whether the leading WG is RAN1 or RAN4

While we leave it to dynamic power aggregation proponents to address the differences from the RAN4 WI in RP-212622, in our view MPR related aspects should driven by and studied in RAN4, and if there are RAN1 impacts, then RAN1 can be added to the study or work.

Whether this objective can be within UL enhancements or not (e.g., part of RAN4 led items)

We think it can be studied as one potential enhancement in UL enhancements.

Whether any limitation on the target scope of this objective is necessary (e.g., FR1/FR2, number of UL CCs for dynamic power aggregation, etc.)

We also leave this for proponents to address.

#### **17 – China Mobile Com. Corporation**

It seems that the dynamic power aggregation overlapped with the RAN4 WI, at least for the RAN4 part. Then it needs further clarified what's remained for study.

#### **18 – NTT DOCOMO INC.**

Support. We think RAN4 can lead this scope.

#### **19 – MediaTek Inc.**

Typically when RAN4 has worked on things like higher power class and related communication with the network, RAN4 has identified what is needed and the consequence of having nothing communicated, and then informed other groups about the need for signalling. Probably makes sense for RAN4 therefore to identify the requirements first for any dynamic power aggregation, and then involve other groups in a coordinated manner. Does not seem particularly clear whether this would be a RAN1 or RAN2 signalling at this stage, based on the explanation from Qualcomm.

### 3.1.3.2 Reduction of MPR/PAR

Companies are encouraged to provide feedbacks if any on moderator summary and recommendation in 2.2.3 regarding reduction of MPR/PAR, including observations and possible objective such as following points.

- *Based on the situation, further discussion on following points would be necessary*
  - *What is key justification for this potential objective*
  - *Whether this objective can be within UL enhancements or not (e.g., part of RAN4 led items)*
  - *Whether any limitation on the target scope of this objective is necessary*
- **Study and if necessary specify following power domain enhancements [RAN4, RAN1]**
  - **[Reduction of MPR/PAR, including waveform design, channel filtering and spectrum utilization]**

## Feedback Form 11: Reduction of MPR/PAR

### 1 – vivo Communication Technology

We still believe clarification is needed with regard to on going Rel-17 RAN4 WI. In our view, this can wait until Rel-17 RAN4 work is done.

### 2 – InterDigital France R&D

Lowering MPR/PAR will enable the UE to transmit with higher power and thus improve coverage performance. Since the study may include waveform design, RAN1 should lead the study.

### 3 – Futurewei Technologies

The justification for the enhancement is unclear to us. Also the needed clarification as pointed out by vivo should be provided.

### 4 – Apple Computer Trading Co. Ltd

More information is required to understand better on the proposed power domain enhancement schemes. It seems the proposed power domain enhancement is not directly related to the UL enhancements. If it is agreed to be studied further, RAN4 could be the leading group.

### 5 – Samsung Research America

We would be open to study this topic in RAN4. The study can be led by RAN4 and be separate from UL enhancements WI. The scope description is too open, e.g., “waveform design, channel filtering and spectrum utilization”. If agreed to be studied, we’d like more specific enhancement aspects as objectives.

### 6 – CATT

The current scope is not clear and we would like to understand what would be the expected impact to RAN1.

### 7 – Intel Deutschland GmbH

We do not see the need to include reduction of MPR/PAR as part of scope in Rel-18 UL enhancement. In Rel-16, pi/2 BPSK with DFT-s-OFDM waveform and new DMRS sequence design have been specified to reduce the PAPR for uplink transmission. In our view, further reduction of MPR/PAR is not necessary.

### 8 – Spreadtrum Communications

Currently, the objectives are too general to specify the scope. More detailed enhancements or justification are needed.

### 9 – Qualcomm Incorporated

MPR/A-MPR is an important issue that impacts uplink transmit power in a significant way. RAN4 constraints on ACLR, IBE, EVM, SEM, etc, can prove to be quite stringent especially when certain NS cases are enabled.

While we are interested in pursuing enhancements targeting reduced MPR/A-MPR, we think a more targeted scope focused on specific scenarios may be necessary to ensure the overall effort is not too diffused. Focusing on higher order modulations could be one option since they typically are associated with larger MPR values.

Any work on this topic will require significant collaboration between RAN1 and RAN4 along with a thorough understanding on the various constraints that need to be satisfied by a UE.

From a priority and complexity standpoint, for power-domain enhancements, we prefer to focus on dynamic power aggregation over MPR reduction.

#### **10 – China Telecommunications**

During Rel-17 SI on coverage enhancement, UE transmit waveform design to reduce MPR is studied and discussed. We think it is a straightforward method to improve the coverage, a study phase can be added in the WI if necessary.

#### **11 – Guangdong OPPO Mobile Telecom.**

We need more understanding on the issue and the standardization impact to RAN1. It is somehow more a RAN 4 works in the current wording by moderator.

#### **12 – Nokia Corporation**

Main justification for these enhancements is to allow efficient power utilization for higher data rates than addressed by Rel-17. This is clearly part of the scope of this discussion and forthcoming WID, regardless of later decision on leading WG for this particular objective. The fact this may be considered as more suitable to have RAN4 as leading WG has no impact on including it in this WID or not. It is business as usual to have RAN4-led objectives in RAN1-led WIs, and from procedural perspective it is also fine, given that there are even RAN4-led email threads considered for December approval.

Regarding the limitation of scope, please note that this is the original intention with most of the proposals listed in section 3.1.3.3, repeated here:

- *Focus on modulation orders beyond BPSK*
- *Prioritize scenarios with one transmit antenna*

The reason to propose focus on modulation orders beyond BPSK is because that one is already addressed in Rel-17.

#### **13 – ZTE Corporation**

The proposed enhancements are not well discussed before and not very clear to us.

#### **14 – Ericsson LM**

What is key justification for this potential objective

As was discussed during the NR coverage enhancement study, MPR can be quite high, especially for FR2. Enhancements can be studied that are based on new transmission mechanisms as well as on new MPR requirements. New transmission mechanisms include new waveforms and/or spectral shaping. They can also include reduced spectrum utilization and thus less stringent requirements on channel filtering, since these drive MPR values as is being discussed in the beyond 52.6 GHz work item. Furthermore, the relation between the MPR and UE output-power tolerances should be studied; the latter applies on top of the MPR, increases with allowed back-off, and ultimately determines the UE output-power requirements.

We'd suggest the following update:

**Study and if necessary specify following power domain enhancements [RAN4, RAN1]**

**[Reduction of MPR/PAR, including waveform design, channel filtering and spectrum utilization, and potential adjustments to MPR and test tolerance relations]**

Whether this objective can be within UL enhancements or not (e.g., part of RAN4 led items)

We think this objective can be part of the UL enhancements work, but should be primarily driven by RAN4; RAN1 can be a secondary WG.

Whether any limitation on the target scope of this objective is necessary

Enhancements should use DFT-S-OFDM and/or CP-OFDM, and not require completely new waveforms or dramatic changes to gNB receivers.

**15 – Huawei Tech.(UK) Co.. Ltd**

To improve the uplink throughput of the UE at the cell edge, one of the methods is to increase the UE maximum transmission power. One aspect is to reduce the MPR/PAR of the current waveform for QPSK, and the other method could be to use pi/2 BPSK (for which the power already can be boosted by 3dB compared with QPSK). Hence potential pi/2 BPSK enhancements should be also considered as part of power domain enhancement for the uplink coverage, considering the study outcome of the on-going RAN4 pi/2 BPSK SI. RAN4 should be involved for such objective, and the objective should be more focused, e.g. prioritizing enhancements for pi/2 BPSK.

**16 – China Mobile Com. Corporation**

It is the same proposal for CE SI but not recommended for the WI. It needs more justification for the performance gain and impact to the spec.

**17 – NTT DOCOMO INC.**

We are fine with the study, but we think this should be included in RAN4 scope.

**18 – MediaTek Inc.**

We think this should be a study item. RAN4 should as a minimum have strong input into decision-making. See modification below.

**Study and if justified specify following power domain enhancements [RAN4, RAN1]**

3.1.3.3 Others for power domain enhancements

Companies are encouraged to provide feedbacks if any on moderator summary and recommendation in 2.2.3 e.g., regarding other comments as below.

- *There is a company proposing to consider followings for power domain enhancements in Rel-18*
  - *Focus on modulation orders beyond BPSK*
  - *Prioritize scenarios with one transmit antenna*
  - *Extend the usage of PC2 to FDD bands*

## Feedback Form 12: Others for power domain enhancements

### 1 – vivo Communication Technology

Given the proposed items for this WI is already too many, we don't think additional topics should be discussed.

### 2 – InterDigital France R&D

We are fine to study these items if time allows.

### 3 – Futurewei Technologies

This WI seems too large already and other topics cannot be accommodated.

### 4 – Samsung Research America

We don't see these aspects as priorities.

### 5 – CATT

We do not think additional coverage enhancements can be accommodated in Rel-18 UL enhancements item given that the current scope is already large.

### 6 – Intel Deutschland GmbH

1) For "PC2 for FDD" – there is already an ongoing Rel-17 WI on PC2 FDD (RP-212633) and we are not clear what additional enhancements are planned.

2) For "modulations beyond BPSK" we are wondering on which enhancements are proposed and further details are welcome. Meantime, we prefer to handle MPR relevant enhancements in RAN4.

### 7 – Qualcomm Incorporated

We prefer to keep only the example currently listed (dynamic power aggregation). We don't think the above constraints/additions are necessary.

### 8 – Guangdong OPPO Mobile Telecom.

We don't see the list is urgent in Rel-18.

### 9 – Nokia Corporation

See comment on section 3.1.2 about bullets 1 and 2 above, as they are addressing the potential narrowing of scope for objective in section 3.1.2. These were never intended as additional objectives on top of section 3.1.2.

As for extension of usage of PC2 to FDD bands, the motivation is to allow higher transmission power for UEs in FDD bands, while respecting time-domain constraints given by regulations. This would allow, for instance, to experience significant enhancements for applications like VoNR (e.g, to handle the SIP invite problem in coverage-constrained scenarios, highlighted by some companies), or to improve initial access performance in Rural FR1 areas.

## 10 – ZTE Corporation

The proposed enhancements are not well discussed before and not very clear to us.

## 11 – Ericsson LM

Focus on modulation orders beyond BPSK

This can be discussed during the work or study as needed.

Prioritize scenarios with one transmit antenna

This seems premature, as it depends on what power domain enhancements are considered.

Extend the usage of PC2 to FDD bands

This seems completely in RAN4's domain, and we suggest it be discussed there.

## 12 – Huawei Tech.(UK) Co.. Ltd

RAN4 already agreed to have a basket WI for PC2 FDD bands other than the two bands included in the Rel-17 WI. It is not clear why power enhancements should be limited to modulation orders other than BPSK. As mentioned in the previous comment, if the proposal is to reduce the MPR/PAR of the current waveform for QPSK, another more effective method could be to use the currently existing  $\pi/2$  BPSK since the power already can be boosted by 3dB compared with QPSK. Also we do not see any necessity to limit the number of antennas, because for TDD band most of the UE implementation has more than 1 TX antenna.

## 13 – Huawei Tech.(UK) Co.. Ltd

**In our understanding, the item could be specified directly and the objective should be revised as “~~Study and if necessary~~ Specify following enhancements for multi-carrier UL operation”** since there are several obvious benefits by supporting dynamic UL 2Tx switching among more than 2 UL bands.

For example, with access to more UL bands, Tx and power resources can be allocated to the UL bands with larger bandwidth according to D/U configuration of each band. In addition, Tx and power resources can be quickly switched to other band when traffic collides with other UEs or on TDD's UL slots. More detailed examples and principles can be found in RP-212151.

For the comments in the first round we have the responses as following.

1) Comments on the extra overhead of switching gap and SRS.

For the evaluation in RP-212151, we have considered simulation assumptions with 1 symbol switching gap which is referred to Rel-17 and 20ms periodic SRS, and 20% ~ 50% performance gain can still be obtained. Besides, we also found negligible impact on performance gain with larger switching gaps (e.g., 2 or 4 symbols) in our own evaluation. With regard to SRS, for multiple bands including TDD, overhead of SRS carrier switching already exists for TDD DL CSI acquisition, and the information can be reused for multi-carrier UL operation.

2) Comments on the potential extra DL interruptions.

Regarding DL interruption, potential DL interruption is not increased at all by allowing switching among more UL carriers, because the number of configured DL carriers is the same as Rel-16/17 and the number of UL switching occurrence at one time is not increased.

3) Comments by Docomo: UL CA is not actively used in the current network, due to UL power limitation.

It is also one main motivation of the dynamic carrier switching. To be specific, considering the UL power limitation and Tx number limitation, it is hard for UE to enable simultaneous transmission over more than 2 bands. Thus, we need to allocate the limited power and Tx to the most suitable bands via dynamic carrier switching according to the data traffic, TDD DL/UL configuration, bandwidths and channel conditions of each band, instead of RRC-based cell(s) reconfiguration. As a result, it will lead to higher UL data rate, spectrum utilization and UL capacity thanks to making full use of multi-band spectrum resources via limited power and Tx number.

**14 – Huawei Tech.(UK) Co.. Ltd**

Sorry the above comment was misplaced

**3.1.4 Potentially other UL enhancements e.g., enhancement for multi-carrier UL operation, enhancements for DFTS-OFDM**

**3.1.4.1 Enhancements for multi-carrier UL operation**

Companies are encouraged to provide feedbacks if any on moderator summary and recommendation in 2.2.4 regarding enhancements for multi-carrier UL operation, including observations and possible objective such as following points.

- *For this potential objective, further discussion on following points would be necessary*
  - *Whether this objective can be included in Rel-18 UL enhancements with starting from study phase to have better understanding on the gain*
  - *Whether any limitation on the target scope of this objective is necessary*
  
- **[Study and if necessary specify following enhancements for multi-carrier UL operation [RAN4, RAN1]]**
  - **[UL Tx switching schemes across more than 2 bands, including mechanisms to enable more configured UL bands than its simultaneous transmission capability and to support dynamic Tx carrier switching across the configured bands]**

**Feedback Form 13: Enhancements for multi-carrier UL operation**

**1 – vivo Communication Technology**

We can be supportive with the restriction of 2Tx simultaneous transmission only.

**2 – TELECOM ITALIA S.p.A.**

Agree with the moderator’s proposal

**3 – InterDigital France R&D**

We are fine to study these items if time allows.

#### **4 – Futurewei Technologies**

We support this enhancement, and we are in general ok with the moderator's suggestion. We'd like to clarify that for the study part, RAN1 performance evaluations are not needed (which is generally the case for DL multi-carrier mechanisms or other UL carrier-based switching mechanisms). A study in RAN4 on switching times and RF related aspects may be performed, but given the previous work/conclusions on various types of switching times and requirements, we do not expect that extensive RAN4 study is needed. So we think RAN1 should be the leading WG, and RAN1 work can start in the meantime when RAN4 is generating some LS to RAN1 on switching times / RF related aspects.

So our suggestion is to revise as follows:

- [Specify following enhancements for multi-carrier UL operation [RAN1, RAN4]]
- [UL Tx switching schemes across more than 2 bands, including mechanisms to enable more configured UL bands than its simultaneous transmission capability and to support dynamic Tx carrier switching across the configured bands [RAN1]]
- [Specify switching times and other RF aspects [RAN4]]

#### **5 – SoftBank Corp.**

Agree with the moderator's proposal.

#### **6 – Apple Computer Trading Co. Ltd**

We are open to study UL Tx switching schemes across more than 2 bands.

#### **7 – Samsung Research America**

We do not see the value of further enhancements over Rel-16/17 UL Tx switching.

#### **8 – CATT**

We are open to study UL Tx switching schemes across more than 2 bands, but we think the study should include performance evaluations in order to decide whether to specify or not in Rel-18 based on the evaluation results.

#### **9 – Intel Deutschland GmbH**

We are open to include this objective in Rel-18 UE enhancements and start with a study phase. The leading WG should be RAN4. The work can be limited to FR1 UEs with 2Tx chains and up to 3 UL bands.

#### **10 – China Telecommunications**

We are supportive for UL Tx switching enhancement. We don't think study phase is needed since it is an extension work from R16/R17. One restriction can be 2Tx simultaneous transmission. The number of configured UL band can be further discussed.

**11 – Qualcomm Incorporated**

We think starting from study would provide a chance to align the views among companies on the potential benefit by introducing UL Tx switching among more than 2 bands. Meanwhile, we think some necessary restriction might be also needed to avoid overcomplicated design without visible gains. For example, we don't think it is necessary to support two simultaneous bands over four configured bands giving  $(4 \text{ choose } 2) = 6$  different states.

**12 – Guangdong OPPO Mobile Telecom.**

We are fine to study these items, may not be the top priority.

**13 – CAICT**

we are fine to moderator's proposal and include these objectives in the scope of R18.

**14 – Nokia Corporation**

We consider such study very low priority from our point of view, as it is unlikely to provide tangible benefits in practical deployments. Hence, we are not supportive of including them in Rel-18.

**15 – ZTE Corporation**

If the focus is on UL Tx switching schemes across more than 2 bands, it's better to clarify at least 1) what's the assumed transmission capability (only 2 Tx?) 2) how many of bands are we targeting (only for three bands?) 3) how many carriers are we targeting (only for three carriers?).

**16 – China Unicom**

We strongly recommend to remove the square bracket on the objective enhancements for multi-carrier UL operation. The objective of Tx switching across more than 2 bands should be included in Rel-18 UL enhancement WI scope.

**17 – Ericsson LM**

Whether this objective can be included in Rel-18 UL enhancements with starting from study phase to have better understanding on the gain

On Tx switching schemes across more than 2 bands, and similar to comments from other companies, 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.

**18 – Huawei Tech.(UK) Co.. Ltd**

**In our understanding, the item could be specified directly and the objective should be revised as “~~Study and if necessary~~ Specify following enhancements for multi-carrier UL operation”** since there are several obvious benefits by supporting dynamic UL 2Tx switching among more than 2 UL bands.

For example, with access to more UL bands, Tx and power resources can be allocated to the UL bands with larger bandwidth according to D/U configuration of each band. In addition, Tx and power resources can be quickly switched to other band when traffic collides with other UEs or on TDD's UL slots. More detailed examples and principles can be found in RP-212151.

For the comments in the first round we have the responses as following.

1) Comments on the extra overhead of switching gap and SRS.

For the evaluation in RP-212151, we have considered simulation assumptions with 1 symbol switching gap which is referred to Rel-17 and 20ms periodic SRS, and 20% ~ 50% performance gain can still be obtained. Besides, we also found negligible impact on performance gain with larger switching gaps (e.g., 2 or 4 symbols) in our own evaluation. With regard to SRS, for multiple bands including TDD, overhead of SRS carrier switching already exists for TDD DL CSI acquisition, and the information can be reused for multi-carrier UL operation.

2) Comments on the potential extra DL interruptions.

Regarding DL interruption, potential DL interruption is not increased at all by allowing switching among more UL carriers, because the number of configured DL carriers is the same as Rel-16/17 and the number of UL switching occurrence at one time is not increased.

3) Comments by Docomo: UL CA is not actively used in the current network, due to UL power limitation.

It is also one main motivation of the dynamic carrier switching. To be specific, considering the UL power limitation and Tx number limitation, it is hard for UE to enable simultaneous transmission over more than 2 bands. Thus, we need to allocate the limited power and Tx to the most suitable bands via dynamic carrier switching according to the data traffic, TDD DL/UL configuration, bandwidths and channel conditions of each band, instead of RRC-based cell(s) reconfiguration. As a result, it will lead to higher UL data rate, spectrum utilization and UL capacity thanks to making full use of multi-band spectrum resources via limited power and Tx number.

**19 – VODAFONE Group Plc**

Agree with the proposal

**20 – NTT DOCOMO INC.**

For multi-carrier UL operation, UL CA is not actively used in the current network, due to UL power limitation. Hence, we believe it is low priority. However, by using other UL enhancement, e.g., UL dense scenario, we can reduce the pathloss and we can extend the applicability of UL CA. In that case, we agree enhancement for UL CA will be beneficial to improve UL throughput.

**21 – China Mobile Com. Corporation**

Not support moderator's proposal. In the September's email discussion, the UL Tx switching schemes across more than 2 bands seems one stable topic among the UL enhancements. We are not sure why the main bullet is in the bracket.

And for the extension from 2 configured bands to 4 bands, we do not see necessity for the study. As any switching mechanism within one band or between the bands should be clearly studied for the 2 band switching. Then the additional work is not clear.

We support to specify the enhancements of UL Tx switching across more than 2 bands

**22 – MediaTek Inc.**

We are not clear of the benefits of this considering the additional overhead, switching time required, and the actual gain in load balancing compared to what is allowed today. Low priority.

3.1.4.2 Enhancements for DFTS-OFDM, including both dynamic switching and multi-layer

Companies are encouraged to provide feedbacks if any on moderator summary and recommendation in 2.2.4 regarding enhancements for DFTS-OFDM, including observations and possible objective such as following points.

- *Based on the situation, further discussion on following points would be necessary*
  - *Whether to specify both dynamic switching and multi-layer for DFTS-OFDM or only one of them (in such case which one)*
  - *Whether any limitation on the target scope of this objective is necessary*
  
- **Specify following enhancements for DFTS-OFDM (RAN1)**
  - **[Dynamic switching between DFTS-OFDM and CP-OFDM]**
  - **[Multi-layer transmission with DFTS-OFDM, with considering LTE design]**

**Feedback Form 14: Enhancements for DFTS-OFDM**

<p><b>1 – Charter Communications</b></p> <p>We are fine with supporting both, however our preference is to keep at least multi-layer DFT-S-OFDM.</p>
<p><b>2 – vivo Communication Technology</b></p> <p>We are fine with supporting both. There are different application scenarios having own merit.</p>
<p><b>3 – VODAFONE Group Plc</b></p> <p>Agree with the moderators proposal to specify both enhancements, but we prioritize the dynamic switching over multilayer transmission if one of the enhancements is to be scrapped. For the dynamic switching, both L1/L2 signalling seem reasonable improvements to the current procedure, and we are OK to have a initial study phase to determine which signalling is to be specified (while remembering that some of it may have been done already in RAN1 TEI17). Reusing LTE designs for multilayer also seems like a reasonable approach.</p>
<p><b>4 – InterDigital France R&amp;D</b></p> <p>We are fine to study these items if time allows.</p>
<p><b>5 – Futurewei Technologies</b></p> <p>For multi-layer transmission, CP-OFDM can already support it very well. For the fast switching of waveforms, it has been discussed since Rel-15 without a clear conclusion. To us the benefit of either scheme is only marginal.</p>
<p><b>6 – Apple Computer Trading Co. Ltd</b></p> <p>For dynamic switching between two waveforms, we consider the related standard work is limited and it could provide the scheduling flexibility, it can be supported. For multi-layer DFT-S-OFDM transmission, we concern the workload, or it can be discussed under MIMO item.</p>

**7 – SoftBank Corp.**

It is always good to reduce the number of options, even though we understand the benefit of each proposal and the difficulties of down-selection. Our preference is multi-layer transmission but we are fine to further discuss and to go with majority view.

**8 – Samsung Research America**

- We fail to see the need for supporting  $>1$  layers for DFT-S-OFDM simply to enable dynamic switching between single- and multi-layer UL transmission. The PAPR advantage of multi-layer DFT-S-OFDM (over CP-OFDM) is irrelevant since coverage-limited UEs rarely (if ever) engages in multi-layer UL transmission. This doesn't account for the complication in gNB implementation (it has been known since LTE that DFT-S-OFDM waveform complicates the design of MIMO receivers). Hence there is no tangible benefit in introducing multi-layer DFT-S-OFDM.

- If dynamic switching between single- and multi-layer is deemed important, it suffices to specify a mechanism that allows dynamic switching between single-layer DFT-S-OFDM and multi-layer CP-OFDM. We can study and, if needed, specify such feature(s).

**9 – CATT**

For rank $>1$  transmission for DFT-s-OFDM, we still think it should be discussed in MIMO WI. Proponent claimed that by reusing LTE design, the specification efforts would be limited. Then it should not be a big problem to be included in MIMO from work load perspective as long as the benefit is justified. Otherwise, if there is big specification impact so that it cannot be included in MIMO WI, including the objective in UL enhancements is not a good approach and would lead to risk for completion in RAN1.

For dynamic switching between DFT-s-OFDM and CP-OFDM, the benefit needs to be justified. In addition, it is not clear whether dynamic means DCI-based only.

**10 – Intel Deutschland GmbH**

We are fine to specify dynamic switching between DFTS-OFDM and CP-OFDM as this is straightforward extension of existing mechanism.

For multi-layer transmission with DFTS-OFDM, if specified, it will be part of scope in Rel-18 MIMO.

**11 – Spreadtrum Communications**

We would like to prioritize DFT-s-OFDM dynamic switching over multi-layer transmission with DFT-s-OFDM. Since dynamic switching is more efficient for UL scheduling and has limited specification change. RANK  $> 1$  for DFT-s-OFDM is with little gain. Because RANK  $>1$  already supported by CP-OFDM, if dynamic switching between DFT-s-OFDM and CP-OFDM is supported, there is no need to support RANK $>1$  for DFT-s-OFDM.

**12 – China Telecommunications**

For Multi-layer transmission with DFT-S-OFDM, we think it should be discussed in MIMO thread.

**13 – Qualcomm Incorporated**

We agree with the current proposal. We prefer to pursue both. No further limits on the scope are necessary.

**14 – Guangdong OPPO Mobile Telecom.**

We are fine to study these items.

**15 – Nokia Corporation**

Both techniques allow better handling of DFT-s-OFDM, and hence both belong in the scope of this WID. Within this objective dynamic switching has somewhat higher priority given that it provides faster access to multi-layer capabilities of CP-OFDM, and it also applies to 1TX UEs.

Scope of multi-layer transmission with DFT-s-OFDM should be limited to incorporating LTE design into NR framework, with minimal time allocated to it.

**16 – ZTE Corporation**

As commented, supporting only one of the two enhancements is sufficient. We are ok to support dynamic switching between DFT-S-OFDM and CP-OFDM while fail to see the motivation to support multi-layer transmission with DFTS-OFDM due to unclear performance gain and large spec impacts.

**17 – Ericsson LM**

We think both bullets as listed above are fine. We have the same detailed comments as we made in the initial phase.

**18 – Panasonic Corporation**

Our view is to support only Dynamic switching between DFTS-OFDM and CP-OFDM because it can simplify the receiver processing of MIMO is only for CP-OFDM.

**19 – Huawei Tech.(UK) Co.. Ltd**

The two bullets are related to each other. From our side, the need to switch between CP-OFDM and DFT-S-OFDM is about switching between 2 layer and 1 layer uplink transmission. Both CP-OFDM and DFT-S-OFDM have their merits in real deployment. But if DFT-S-OFDM is extended to support 2 layer transmission, then the gain of 2 layer transmission and power gain can be obtained at the same time. From this point of view, multiple layer transmission with DFT-S-OFDM should be seen as more important than dynamic switching between the wave forms.

**20 – NTT DOCOMO INC.**

We support “dynamic switching between DFTS-OFDM and CP-OFDM”.

We don’t support “multi-layer transmission with DFTS-OFDM, with considering LTE design”. We understand it is supported in LTE, however, NR already supports CP-OFDM with multi-layer in Rel.15, and two duplicated features are not necessary to enable UL MIMO. We don’t assume UEs will implement it, considering that UL MIMO is already available for CP-OFDM.

On the other hand, we think the dynamic switching is useful in real deployment, as we commented in the 1st round. Hence, we believe the dynamic switching is high priority. If the dynamic switching is supported, there is no use-case to use DFT-S-OFDM with multi-layer, hence it is low priority.

**21 – China Mobile Com. Corporation**

Q1:

Only one of the mechanisms should be specified. The multiple layer transmission for DFT-S-OFDM is slightly preferred.

We support the enhancement of Multi-layer transmission with DFTS-OFDM with limited specification impacts. The benefit for dynamic switching between DFT-S-OFDM is not clear,

**22 – MediaTek Inc.**

We are ok with the dynamic switching proposal, as it seems intuitive that there could be gains.

For the 2 layer DFT-S- OFDM, we have not seen enough evidence to justify focusing on this, and what the problem is with what we have. So low priority for us.

3.1.4.3 Enhancements for UL dense deployment

Companies are encouraged to provide feedbacks if any on moderator summary and recommendation in 2.2.4 regarding enhancements for UL dense deployment, including observations and possible objective such as following points.

- *Based on the situation, further discussion on following points would be necessary*
  - *Whether this objective can be included in Rel-18 (either in MIMO or UL enhancements)*
  - *Whether any limitation on the target scope of this objective is necessary*
- **[Study and if necessary specify following enhancements for UL dense deployment (RAN1)]**
  - **[UL beam management and UL power control with UL reception only point or TRP with lower Tx power]**

**Feedback Form 15: Enhancements for UL dense deployment**

**1 – vivo Communication Technology**

This is interesting deployment scenario, however it mainly involves MIMO hence should be treated in MIMO item.

**2 – InterDigital France R&D**

We are fine to study these items if time allows.

**3 – Futurewei Technologies**

We support UL dense deployment with UL reception only points. We think UL dense with TRPs with lower Tx power should already be supported via Rel-17 M-TRP framework or can be incorporated into Rel-18 MIMO work. There is no need to study / work on UL dense with TRPs with lower Tx power in UL enhancements.

**4 – Samsung Research America**

These enhancements are discussed in MIMO.

**5 – Intel Deutschland GmbH**

We are fine to include enhancements for UL dense deployment in Rel-18. It can be either in MIMO or UL enhancement. In our view, this feature is critical to address UL coverage issue .

**6 – Spreadtrum Communications**

It can be discussed in MIMO.

**7 – Qualcomm Incorporated**

We believe that this topic belongs to MIMO (SRS, beam management, UL power control) and should be discussed there. In fact, there have been already some discussion / input on the enablers as part of [RAN94e-R18Prep-01].

**8 – Guangdong OPPO Mobile Telecom.**

We prefer to consider this in MIMO enhancement.

**9 – Nokia Corporation**

The target scenario is not clear to us. It seems that the main intention is to consider such UL dense deployment to improve coverage in FR2 deployments, but in FR2 the baseline assumption is that signals are beamformed toward the receiver. How is the UE going to do such beamforming toward reception-only TRP? Are the TRPs instead assumed to handle data only in UL direction, but still provide at least reference signals? Or is the intention to modify the baseline assumption for UEs in FR2, i.e. assume omni-directional transmissions? If study would be limited to FR1, we see little potential benefit given the better spectrum properties in that range.

From the questions raised above, we think this topic is not yet clear enough for inclusion in Rel-18, and it would require further discussion on the potential scope.

**10 – ZTE Corporation**

We are open to consider UL dense deployment in Rel-18 if we have sufficient TU budget. We are fine with the proposed objective.

**11 – Ericsson LM**

The need for specification support for UL dense deployments is not clear to us at this stage. Supporting UL-only TRPs would seem different from supporting TRPs with lower Tx power – this needs to be clarified.

**12 – Huawei Tech.(UK) Co.. Ltd**

If UL dense deployment is considered as an objective for Rel-18, the listed candidate solutions are not solely applicable for <UL reception only point> or <TRP with lower Tx power>, instead they are also applicable for FR2 UE with large antenna array, with which asymmetric UE beamforming can be exploited for better UL coverage/throughput in UL dense deployment (i.e., wide Rx beam for reliable PDCCH reception and narrow Tx beam for high-MCS PUSCH transmission, see RWS-210438). With this in mind, we suggest not to tie this proposal to specific deployment scenarios, or alternatively add <FR2 UE with large antenna array>. Also, we prefer to consider this proposal jointly with other MIMO-related UL enhancements including prioritization in the thread of [RAN94e-R18Prep-01],

**13 – NTT DOCOMO INC.**

Support. As shown in our tdoc (p.7-8 in RWS-210268), we observed large gain for UL dense deployment. We believe UL dense is more suitable for “UL enhancement”, because it can improve both throughput and coverage. Also, the performance for even single layer transmission can be improved by the UL dense deployment.

If we need to limit the scope, we believe “UL power control” is the most essential, because there is no DL PL-RS from the UL only TRP. We are also open to discuss other topics (e.g. UL beam management, etc.).

**14 – China Mobile Com. Corporation**

Not sure to study the UL dense deployment. If the UL only TRPs are connected with the gNB with high-speed fiber (high probability), it seems that this is only a implementation issue.

**15 – MediaTek Inc.**

We are still struggling to understand the benefits of this compared to a normal TRP. Low prio unless this can be better articulated.

3.1.4.4 Others for potential other UL enhancements

Companies are encouraged to provide feedbacks if any on moderator summary and recommendation in 2.2.4 e.g., regarding other comments as below.

- *There is a company proposing some other enhancements, such as extending DFTS-OFDM to short PUCCH formats and dynamic PUCCH repetition indication for P/SP-CSI report*

**Feedback Form 16: Others for potential other UL enhancements**

**1 – vivo Communication Technology**

Given the proposed items for this WI is already too many, we don't think additional topics should be discussed.

**2 – Futurewei Technologies**

This WI seems too large already and other topics cannot be accommodated.

**3 – Samsung Research America**

We don't see these aspects as priorities in R18 UL enhancements. Also, the second aspects on CSI report was discussed in Rel-17 Coverage Enhancement and not agreed.

**4 – CATT**

We do not think additional coverage enhancements can be accommodated in Rel-18 UL enhancements item given that the current scope is already large.

**5 – Intel Deutschland GmbH**

We do not see the need to include both extending DFT-s-OFDM to short PUCCH formats and dynamic PUCCH repetition indication for P/SP-CSI report in Rel-18 UL enhancements. The scope for UL enhancements are already very broad. For the 2nd issue, it was agreed not to support in Rel-17 PUCCH enhancement.

## **6 – Qualcomm Incorporated**

Link budget analysis reveals that FR2 uplink enhancements are valuable. Short PUCCH formats are heavily used in FR2 due to limits on time-domain multiplexing of UEs. We think extending the use of DFT-S-OFDM to short formats could be quite useful. Gains of several dBs can be quite easily realized.

## **7 – Nokia Corporation**

We do not see a need to include such enhancements. Use of dynamic PUCCH repetition factor should be limited to dynamic HARQ-ACK. P/SP reporting is designed not to require further dynamic adjustments. The whole point of configuring this report as P/SP would seem void if this were not the case. Indeed, its payload size is static and fully predictable at the time of the configuration, hence gNB can set static repetition factor accordingly.

## **8 – Ericsson LM**

Regarding DFT-S-OFDM for short PUCCH formats, similar to our comments for DMRS-less PUCCH, we prefer to have coverage enhancements that do not make substantive changes to PUCCH.

For dynamic PUCCH repetition indication for P/SP-CSI reporting, we agree that it would be good to enhance the coverage of CSI, and make a more general proposal that we prefer in section 3.1.2.2 on PUCCH coverage enhancements.

## **9 – Huawei Tech.(UK) Co.. Ltd**

Although improving PUCCH format 2 with DFT-S-OFDM may be feasible, it is not clear whether there is a need to do so in Rel-18 since currently PUCCH has been enhanced in R17.

## **10 – NTT DOCOMO INC.**

We don't understand the benefit of DFT-S-OFDM to short PUCCH formats. In Rel.15, whether to support DFT-S-OFDM to short PUCCH formats was discussed and well evaluated, and finally PUCCH format 0 and 2 were defined with CP-OFDM. DFT-S-OFDM has no PAPR/BER gain compared with PUCCH format 0. If we introduce PUCCH format 2 with DFT-S-OFDM, we can reduce PAPR for PUCCH format 2. However, DFT-S-OFDM requires two OFDM symbols, which disables frequency hopping. Hence, the BER performance of PUCCH format 2 with DFT-S-OFDM becomes worse than existing spec.

## **11 – MediaTek Inc.**

Not very clear to us what the gain of this would be.

## **12 – MediaTek Inc.**

...also see our comments on PUCCH coverage enhancements.

## 3.2 Moderator Summary and recommendation for further discussion

### 3.2.1 General

Thank you very much for valuable inputs from many companies. Following high level observation can be made based on the inputs.

- As described in the initial round summary, many companies consider this potential “Rel-18 UL enhancement WI” as one of promising/important items for Rel-18 considering strong supports from operators, network vendors, UE vendors and various industries based on the real/urgent demand for improving UL performance, as observed in Rel-18 Workshop contributions.
- However, since available TU even for this potential item would be limited, multiple companies concern that current listed possible objectives would be too many, and hence focused objectives are required.
- For some of topics, several companies suggested that “this topic should be discussed in other item (e.g., MIMO, RAN4 item)”. But since RAN chair guidance RP-212657 describes that “NO intention to update the set and the organization of the topics as endorsed in RP-212608”, whether the topics should be moved to other item can be discussed in RAN#94-e. During this email discussion, focusing on justification, possible scopes and leading/secondary WGs would be fine.
- Several companies kindly suggested that general high level justification for this potential WI can reuse that of Rel-17 Coverage enhancement WI with adding justifications for individual objectives.

### 3.2.2 PRACH coverage enhancements

Following observations could be made based on intermediate round inputs.

- Majority seems fine/prefer to support PRACH repetition with both same beam and different beams. Although some companies commented that only same beam case is necessary considering that beam correspondence is mandatory UE feature, some other companies commented that different beam case is also beneficial considering that beam correspondence may not be guaranteed during initial access.
- Regarding target FR, many companies prefer to target both FR1 and FR2, and PRACH format B4 was identified as 2<sup>nd</sup> priority bottleneck channel in TR38.830. So, at least for PRACH format B4, both FR1 and FR2 can be targeted.
- Regarding target PRACH formats, many companies argued that only short PRACH formats (especially B4) should be considered according to TR38.830. On the other hand, as some companies pointed that the PRACH repetition mechanism may be format agnostic, it may be possible to open the possibility for other short formats (e.g., up to RAN1 discussion during the WI).
- Regarding target procedure, many companies argued that only 4-step RACH should be considered as 2-step RACH procedure does not target coverage limited scenarios.
- Regarding the necessity of study phase, many companies consider it is not necessary as it has been done in Rel-17. But for PRACH formats other than B4, RAN1 discussion would be necessary/beneficial as suggested above.
- Several companies argued that the interaction with Msg.3 repetition would be necessary/beneficial, but they also argued that it may not be necessary to be captured in WID.

Based on above observations, the moderator recommendation for final round email discussion is to check companies’ views on above observations and following updated objectives. If there is a concern on the updated objectives, the moderator recommends concerning company to provide a suggested alternative which should be acceptable to other companies according to the discussion so far.

- **Specify following PRACH coverage enhancements (RAN1, RAN2)**

- **Multiple PRACH transmissions with same beams or different beams, targeting at least PRACH format B4, both FR1 and FR2, and 4-step RACH procedure**
  - **Other short PRACH formats can also be considered if identified as necessary, and format-agnostic approach should be considered in such case**

### 3.2.3 PUCCH coverage enhancements

Following observations could be made based on intermediate round inputs.

- Although there are multiple companies supporting DMRS-less PUCCH, even larger number of companies do not support it as it was already extensively discussed in Rel-17 without consensus. Moderator suggested to consider having study again to get better understanding among companies on the gain of DMRS-less PUCCH, but even it was concerned by multiple companies.
- Several companies pointed that although Rel-17 supports some PUCCH coverage enhancements, those mechanisms such as repetition may not be available in case of TDD bands with limited UL slot configuration, and hence PUCCH coverage enhancement not relying on PUCCH repetitions with multiple UL slots would be beneficial. Other than DMRS-less PUCCH, there are some proposals that would meet such demand, such as DFTS-OFDM waveform for short PUCCH and repetition of CSI in dynamically indicated resources.
- There are multiple companies prefer to have PUCCH coverage enhancement for both FR1 and FR2.
- Regarding target PUCCH formats, some companies prefer to target short PUCCH format (PF2) while some other companies prefer to target long PUCCH format (PF3). Majority of companies seems to consider UCI payload size from 3 to 11 bits.

Based on above observations, the moderator recommendation for final round email discussion is to check companies' views on above observations and whether it is possible to study on potential coverage enhancements other than DMRS-less PUCCH, e.g., DFTS-OFDM waveform for short PUCCH and repetition of CSI in dynamically indicated resources. Following potential objective will be included in draft WID with removing bracket only if it can be stable based on final round comments, otherwise it will not be included in draft WID (the moderator does not intend to capture this objective with brackets in draft WID). On the other hand, since the situation on DMRS-less PUCCH has not been changed even after several rounds of discussions, the moderator recommends to stop the discussion on it unfortunately.

- **[Study and if necessary specify following coverage enhancements for PUCCH/UCI (RAN1)]**
  - **[DFTS-OFDM waveform for short PUCCH]**
  - **[Repetition of CSI in dynamically indicated resources]**

### 3.2.4 Dynamic power aggregation and Reduction of MPR/PAR

Following observations could be made for dynamic power aggregation based on intermediate round inputs.

- Regarding the difference from RAN4 WI, companies supporting this item clarified that RAN4 WI addresses the artificial power limit for UL CA while this potential objective is to study necessary RAN1 enhancements. However, as even supporting companies mentioned that RAN4 solution to address the issue is not yet clear, some other companies argued that potential RAN1 study/work should be discussed after RAN4 work is done.
- On the other hand, it seems all companies agree that power domain enhancement is beneficial and hence it may be worth to include one general objective to study power domain enhancement in UL enhancement WID.

Following observations could be made for reduction of MPR/PAR based on intermediate round inputs.

- Regarding possible justification for this objective, some companies argued that since MPR can be quite high especially for FR2 and the reduction of MPR/PAR can increase the UE maximum transmission power, it can allow efficient power utilization e.g., for higher data rate case based on higher order modulation which is typically associated with larger MPR values. In particular, new transmission mechanisms including new waveforms and/or spectral shaping can be studied as well as reduced spectrum utilization with less stringent requirements on channel filtering. In addition, there is a suggestion to include the study on the relation between the MPR and UE output power tolerances.
- Although some companies commented higher order modulation may be the target, there is a comment that enhancements for  $\pi/2$  BPSK should also be considered.
- Prioritizing scenarios with one transmit antenna seems not necessary for many companies.
- Many companies consider that it is RAN4 led objective and RAN1 may be secondary WG.
- As pointed in general observations, although several companies argued that this objective can be a separate RAN4 led item i.e., outside of UL enhancement WI, it can be discussed in RAN#94-e.

Based on above observations, the moderator recommendation for final round email discussion is to check companies' views on above observations and following updated objectives. If there is a concern on the updated objectives, the moderator recommends concerning company to provide a suggested alternative which should be acceptable to other companies according to the discussion so far.

- **Study and if necessary specify following power domain enhancements**
  - **Enhancements to realize dynamic power aggregation based on Rel-17 RAN4 work on “Increasing UE power high limit for CA and DC”, with checking relevant regulations (RAN1, RAN4)**
    - **Note: The study can start after RAN4 work on “Increasing UE power high limit for CA and DC” is done.**
  - **Enhancements to reduce MPR/PAR, including new transmission mechanism such as new waveform and/or spectral shaping, reduced spectrum utilization with relaxed requirements on channel filtering, and potential adjustments to MPR and test tolerance relations (RAN4, RAN1)**

### 3.2.5 Enhancements for multi-carrier UL operation

Following observations could be made based on intermediate round inputs.

- There are strong supports for this objective from multiple companies, while several other companies argued that the actual gain considering overhead and switching gap is not clear yet. In such case, as moderator suggested, having study phase would be beneficial to align views among companies on the potential benefit, although some of proponents argued that the study is not necessary as there would be several obvious benefits. Some of companies not supportive to this objective said it can be considered but with lower priority than other objectives.
- Some companies suggested to add the restriction of 2 Tx simultaneous transmissions only.
- Also, some companies suggested to limit the scope for FR1 UEs with 2 Tx and up to 3 UL bands/carriers to avoid overcomplicated design.
- There is a suggestion to clarify RAN1 work and RAN4 work. RAN4 work would be to study and specify switching time and other RF aspects, while RAN1 work is to specify the necessary mechanism and procedure for UL Tx switching across more than 2 bands.

Based on above observations, the moderator recommendation for final round email discussion is to check companies' views on above observations and following updated objectives. If there is a concern on the updated objectives, the moderator recommends concerning company to provide a suggested alternative which should be acceptable to other companies according to the discussion so far. Especially, whether to have a study phase or not can be discussed further based on companies' inputs in intermediate rounds.

- **Specify following enhancements for multi-carrier UL operation**
  - **UL Tx switching schemes across 3 bands with restriction of 2 Tx simultaneous transmission for FR1 UEs, including mechanisms to enable more configured UL bands than its simultaneous transmission capability and to support dynamic Tx carrier switching across the configured bands (RAN1)**
  - **Switching time and other RF aspects for above UL Tx switching schemes across 3 bands (RAN4)**

### 3.2.6 Enhancements for DFTS-OFDM

Following observations could be made based on intermediate round inputs.

- Same as in initial round, majority companies prefer to support at least one of two enhancements, many companies are fine to support both, and there are some companies prefer to support only one of them. Since it is detailed discussion on use-cases/gain/specification effort of two enhancements and justifications are already provided for both of two enhancements, the moderator thinks WG level discussion may be necessary to have better understanding among companies on two enhancements although there is no company proposing so.
- As pointed in general observations, although several companies argued that multi-layer DFTS-OFDM should be handled in MIMO item i.e., outside of UL enhancement WI, it can be discussed in RAN#94-e.

Based on above observations, the moderator recommendation for final round email discussion is to check companies' views on above observations and following updated objectives, i.e., whether companies can accept to support both of two enhancements. If there is a company having concern on the updated objective, it seems only possible way to proceed these enhancements would be to have a study phase.

- **Specify following enhancements for DFTS-OFDM (RAN1)**
  - **Dynamic switching between DFTS-OFDM and CP-OFDM**
  - **Multi-layer transmission with DFTS-OFDM, with considering LTE design**

### 3.2.7 Enhancements for UL dense deployment

Following observations could be made based on intermediate round inputs.

- Although there are multiple companies supporting the study on enhancements for UL dense deployment, some other companies consider this objective as low priority or even unnecessary. There are also number of companies consider this objective should be handled in MIMO item i.e., outside of UL enhancement WI, it can be discussed in RAN#94-e as pointed in general observation and those companies may also be supportive of this study in Rel-18.
- There are comments from some companies that support for TRPs with lower Tx power is already covered by Rel-17 or Rel-18 MIMO and it would be different from support for UL dense deployment based on UL reception only points.
- There is a comment that target scenario should be clarified, e.g., FR1 or FR2 or both. Also, there is a comment that candidate solutions may also be applicable to FR2 UE with large antenna array where asymmetric UE beamforming can be exploited.

Based on above observations, the moderator recommendation for final round email discussion is to check companies' views on above observations and following updated objectives. If there is a concern on the updated objectives, the moderator recommends concerning company to provide a suggested alternative which should be acceptable to other companies according to the discussion so far.

- **Study and if necessary specify following enhancements for UL dense deployment and/or asymmetric beamforming operation between DL/UL (RAN1)**
  - **UL power control and UL beam management, with considering UL reception only points**
    - **Note: unified mechanisms applicable to both UL dense deployment with UL reception only points and asymmetric beamforming operation between DL/UL with normal TRP(s) are preferred**

### 3.2.8 Other potential enhancements

Following observations could be made based on intermediate round inputs.

- Although there are several other enhancements than above potential objectives mentioned by several companies, many companies consider that the current potential scope/objectives of the UL enhancements are already too many and hence other topics cannot be accommodated.

Based on above observations, the moderator recommends to stop the discussion on other potential enhancements than above items.

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## 4 Final round

### 4.1 Collection of company views

#### 4.1.1 General high level views and feedbacks on draft overall justification

According to the guidance in RP-212657, companies are encouraged to provide feedbacks on the observations in 3.1.1 and the following draft of the overall justification for UL enhancements.

**Table 1: Draft overall justification for UL Enhancements WI**

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Coverage is one of the key factors that an operator considers when commercializing cellular communication networks due to its direct impact on service quality as well as CAPEX and OPEX. UL performance could be the bottleneck in most of scenarios in real deployment, while there are emerging vertical use cases that have UL heavy traffic, e.g., video uploading. In Rel-17 work item 900061 “NR Coverage Enhancements”, NR coverage has been extended for some of the bottleneck channels identified in the Rel-17 study item 860036 “Study on NR coverage enhancements”, in particular for PUSCH and PUCCH. However, not all needs for coverage enhancement have been addressed by the Rel-17 WID, due to its limited scope.

In RAN Rel-18 Workshop in June 2021, UL enhancements have been identified as one of the key areas of interest by multiple players including operators, network and UE vendors and various industries, as reflected by the number of contributions proposing UL coverage and capacity enhancements based on the real and urgent demands for improving UL performance on top of Rel-17 enhancements.

Following justifications for particular UL enhancements have been identified during RAN Rel-18 email discussions.

- In Rel-17, PRACH coverage enhancement has not been addressed, despite being identified as one of the bottleneck channels in the corresponding studies. PRACH transmission is very important for many procedures, including initial access and contention-based beam failure recovery.
- [In Rel-17, PUCCH coverage enhancements are introduced based on repetitions using multiple UL slots. However, those mechanisms may not be available in case of TDD bands with limited UL slot configuration, such as DDDSU. Therefore, there is a demand to enhance the coverage performance of PUCCH/UCI not relying on repetitions using multiple UL slots.]
- The UE transmission power is the most valuable resource in uplink and enhancements to unlock additional uplink power are highly valuable for both UL coverage and capacity. There are some studies and works in Rel-17 on the power domain, such as in “Study on NR coverage enhancements” and “Increasing UE power high limit for CA and DC”, and hence some further study is necessary to exploit the Rel-17 studies/works.
- For multi-carrier UL operation, there are some limitations of current specification, e.g. 2TX UE can be configured with at most 2 UL bands, which only can be changed by RRC reconfiguration, and UL Tx switching can be only performed between 2 UL bands for 2Tx UE. 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 rate, spectrum utilization and UL capacity.
- DFTS-OFDM waveform is beneficial for UL coverage limited scenario because of its lower PAPR compared with CP-OFDM waveform. Currently, UL waveform is configured via RRC and only single layer transmission is supported. These limitation impose a large barrier to switch over to DFTS-OFDM waveform for cell-edge UEs practically.
- In case of dense deployment where pathloss can be low, it would be possible to use wider bandwidth including UL CA for UL transmission with sufficient PSD so that UL performance can be largely improved. Considering that the dense deployment has some practical issues e.g., large cell planning effort for inter-cell interference coordination, one possible scenario to realize the dense deployment for UL is to deploy UL reception only points. In such scenario, since DL and UL are asymmetric, some enhancements are necessary for UL power control and beam management.

**Feedback Form 17: General high level views and feedbacks on draft overall justification**

**1 – vivo Communication Technology**

This bullet point should be in square bracket.

[The UE transmission power is the most valuable resource in uplink and enhancements to unlock additional uplink power are highly valuable for both UL coverage and capacity. There are some studies and works in Rel-17 on the power domain, such as in “Study on NR coverage enhancements” and “Increasing UE power high limit for CA and DC”, and hence some further study is necessary to exploit the Rel-17 studies/works.]

**2 – ZTE Corporation**

For the general justification, Msg3 is also enhanced in Rel-17 work item in addition to PUSCH and PUCCH, and it needs to be reflected.

One more justification for PUCCH enhancements is PUCCH transmission using multiple slots is not practically useful due to existing collision handling rules. The reason adding this is, once PUCCH repetition collides with PUSCH, PUSCH would be dropped according to current specification. This would make it almost impossible to deploy PUCCH repetition in reality.

Regarding DFT-S-OFDM, we still don't see the need for support of multi-layer DFT-S-OFDM, and suggest to remove related justification.

**3 – Futurewei Technologies**

Thank you for the nice summary. We support the justification in general.

**4 – NTT DOCOMO INC.**

<Moderator comment>

Thanks for the feedbacks.

- Based on the final round discussion outcome for each potential objective, corresponding justification part may be updated to be put within a bracket, modified or removed.
- The part "... in particular for PUSCH and PUCCH" regarding Rel-17 CovEnh will be updated as "... in particular for PUSCH, PUCCH and Msg3" based on ZTE's comment.
- The part "However, those mechanisms may not be available in case of TDD bands with limited UL slot configuration, such as DDDSU." regarding PUCCH enhancements will be updated as "However, those mechanisms may not be available in case of TDD bands with limited UL slot configuration, such as DDDSU and may not be practically useful due to existing collision handling rules" based on ZTE's comment.

**5 – AT&T**

We disagree with vivo, the bullet should be kept. As said before, we think Rel 18 should actually focus on these kinds of enhancements. As nicely stated, it's the "most valuable resource in uplink". We don't agree with putting this bullet into squared brackets.

#### **6 – Nokia Corporation**

We agree with AT&T. In any case we assume that the justification will reflect the final status of this discussion, so we will comment on what enhancements we support or not in the following sections instead of addressing them in duplicate here.

#### **7 – TELECOM ITALIA S.p.A.**

We support AT&T comment.

We suggest to completely remove the bullet related to "However, those mechanisms may not be available in case of TDD bands with limited UL slot configuration, such as DDDSU". Other configurations are in many countries not allowed by regulators, unless 3GPP define solutions to allow flexible TDD. Therefore, this is simply a paper exercise.

#### **8 – TELECOM ITALIA S.p.A.**

sorry I would like to revise the previous comment. Please consider the following post and "remove" the previous one.

**We support AT&T's comment.**

#### **9 – Ericsson LM**

For the PUCCH enhancements part, we have a small clarification. Rel-17 joint channel estimation enhancements rely on consecutive UL slots, and so we would suggest "**not relying on repetitions using multiple consecutive UL slots**".

#### **10 – Guangdong OPPO Mobile Telecom.**

The observation for PUCCH enhancement should not have "[ ]". We agree that the PUCCH repetition in many case is limited and can not be use.

Note that this does not means DFT-s-OFDM for short format should be studied. This lack of study before. The short format is not for coverage. We think the observation should lead to the need of DMRS-less PUCCH.

#### **11 – MediaTek Inc.**

We think it would be best to discuss such text after we an agreed set of objectives, given that it is difficult for us to even justify to ourselves at this stage why we progress some of these items.

### 4.1.2 PRACH coverage enhancements

According to the guidance in RP-212657, companies are encouraged to provide feedbacks on the observations in 3.2.2 and the following proposed objectives aiming for final convergence. In the final round, the moderator will appreciate if companies focus on essential comment only.

- **Specify following PRACH coverage enhancements (RAN1, RAN2)**
  - **Multiple PRACH transmissions with same beams or different beams, targeting at least PRACH format B4, both FR1 and FR2, and 4-step RACH procedure**
    - **Other short PRACH formats can also be considered if identified as necessary, and format-agnostic approach should be considered in such case**

## Feedback Form 18: PRACH coverage enhancements

### 1 – vivo Communication Technology

We are fine with format-agnostic approach. However, for the case of "different beam" we are still struggling to understand the motivation for coverage enhancement. For the case of "same beam" the UE applies SSB beam for PRACH but how does UE apply multiple beams in the case of "different beam"? And, how does gNB receive corresponding PRACH?

### 2 – China Mobile Com. Corporation

We still have concerns for the enhancement for FR1 PRACH, as we do not see any usage scenario in practice or with justifications.

The motivations to include FR1 in the last round mostly are just to reuse the FR2 mechanisms which are also beneficial for FR1. And many comments state that FR2 should be emphasized, which is the original starting point for the enhancement. Considering the motivation is just to reuse the mechanisms of FR2, we can make a compromise with modifications to reflect it and FR2 should be emphasized. Current wording "both FR1 and FR2" only does not reflect that view.

We can add a note,

**Note : The enhancements of PRACH should base on FR2, which can also apply to FR1.**

### 3 – NTT DOCOMO INC.

<Moderator comment>

Thanks for the feedbacks. Based on the feedbacks, proposed objective can be updated as below.

**Specify following PRACH coverage enhancements (RAN1, RAN2)**

**-Multiple PRACH transmissions with same beams or different beams, targeting at least PRACH format B4, both FR1 and FR2, and 4-step RACH procedure**

- **Other short PRACH formats can also be considered if identified as necessary, and format-agnostic approach should be considered in such case**
- **Note: the enhancements of PRACH should base on FR2, which can also apply to FR1**

Regarding vivo's question on different beam case, the moderator's understanding based on the inputs so far is as below.

- Main target scenario of different beams would be the case where the UE's beam correspondence may not be ensured e.g., in initial access. UE's beam determined based on SSB reception may not be appropriate one for PRACH transmission in such case, and transmitting multiple PRACHs with different beams (that may include better beam than the beam based on SSB reception) may have better PRACH coverage performance than multiple PRACHs with same beam (the beam based on SSB reception).
- Performance evaluation results for multiple PRACHs with same or different beams are shown in TR38.830 (6.3.2). How to determine transmission beams is also captured as potential specification impact in the TR, i.e., it should be discussed in the WI if multiple PRACHs with different beams are included in objectives.

#### 4 – VODAFONE Group Plc

We overall agree with the moderator’s original proposal. For clarification, on the first bullet for other short PRACH formats, will they be considered based on an initial study phase? On the R17 SI, the bottleneck for PRACH was identified both for FR1 and FR2 so we think both should be equally evaluated

#### 5 – Charter Communications

We prefer the moderator’s original wording, and propose equal priority for both FR1 and FR2.

#### 6 – InterDigital France R&D

We agree with vivo that the mechanism behind the PRACH enhancement with different beams is not clear. The benefit obtained from the scheme is not clear either. In TR 38.830, there are only two sources which studied PRACH enhancement using different beams. Thus, it is still too early to commit to specification of PRACH transmission using different beams. Although we prefer not to include “PRACH enhancement with different beams” in Rel-18 scope, we can accept if we study first and specify it if we observe clear motivation/benefit from the study as a compromise. Therefore, we suggest to reword the objective as follows.

**Specify following PRACH coverage enhancements (RAN1, RAN2)**

- **Multiple PRACH transmissions with same beams ~~or different beams~~, targeting at least PRACH format B4, both FR1 and FR2, and 4-step RACH procedure**
  - o **Other short PRACH formats can also be considered if identified as necessary, and format-agnostic approach should be considered in such case**
- **Study, and if justified, specify PRACH transmissions with different beams.**

#### 7 – Verizon UK Ltd

Agree with CMCC, Docomo etc. that **The enhancements of PRACH should base on FR2, which can also apply to FR1.**

#### 8 – CATT

One the PRACH enhancements, we have the following comments:

- 1) We agree with the comments from vivo and InterDigital that multiple PRACH transmissions with different beams needs to be justified so we support the proposal from InterDigital.
- 2) The original wording may lead to potential misunderstanding that ”at least” applies to 4-step RACH as well (i.e. 2-step RACH is not precluded).
- 3) We agree with the comments from CMCC and Verizon that the enhancements of PRACH is targeting for FR2 and can be applied to FR1 when applicable.

Accordingly, we propose the following update:

**Specify following PRACH coverage enhancements (RAN1, RAN2)**

- **Multiple PRACH transmissions with same beams ~~or different beams~~, targeting 4-step RACH procedure and at least PRACH format B4, ~~both FR1 and FR2~~, and 4-step RACH procedure**
  - o **Other short PRACH formats can also be considered if identified as necessary, and format-agnostic approach should be considered in such case**
- **Study, and if justified, specify PRACH transmissions with different beams**

- **Note: The enhancements of PRACH is targeting for FR2, which can also apply to FR1 when applicable.**

#### 9 – Lenovo (Beijing) Ltd

We support the current proposed text. This shall be given high priority for R18 UL enhancement.

#### 10 – NTT DOCOMO INC.

<Moderator comment>

Thanks again for the feedbacks and constructive suggestions!

The suggested update from CATT below can be considered as the latest proposal from the moderator considering feedbacks so far.

So, please check the following proposed objective and if any, please provide a constructive suggestion which can be acceptable to all (considering all rounds discussion).

**Specify following PRACH coverage enhancements (RAN1, RAN2)**

- **Multiple PRACH transmissions with same beams or different beams, targeting 4-step RACH procedure and at least PRACH format B4, both FR1 and FR2, and 4-step RACH procedure**
  - o **Other short PRACH formats can also be considered if identified as necessary, and format-agnostic approach should be considered in such case**
- **Study, and if justified, specify PRACH transmissions with different beams**
- **Note: The enhancements of PRACH is targeting for FR2, which can also apply to FR1 when applicable.**

#### 11 – ZTE Corporation

The reason only PRACH B4 was identified as bottleneck channel is this is the only PRACH format that was evaluated during Rel-17 SI. However, short PRACH format C2 is more suitable for larger coverage scenario due to larger N<sub>gap</sub> duration. So, we don't think we need to restrict to only PRACH format B4. So, we suggest to make similar change as updated for FR1/FR2.

**Specify following PRACH coverage enhancements (RAN1, RAN2)**

- **Multiple PRACH transmissions with same beams or different beams, targeting 4-step RACH procedure and at least PRACH format B4, both FR1 and FR2, and 4-step RACH procedure**
  - o **Other short PRACH formats can also be considered if identified as necessary, and format-agnostic approach should be considered in such case**
- **Study, and if justified, specify PRACH transmissions with different beams**
- **Note: The enhancements of PRACH is targeting for FR2, which can also apply to FR1 when applicable.**
- **Note: The enhancements of PRACH is targeting for PUCCH format B4, which can also apply to other short PUCCH formats when applicable.**

#### 12 – Xiaomi Communications

We support the moderator's proposal in general, and prefer not to limit to any PRACH specific format in the scope.

### 13 – Futurewei Technologies

The scope of this enhancement is still too large, even after the moderator addressed CMCC's comment. We do not think there is enough time for the WGs to complete this WI. We suggest to reduce the scope, e.g., remove the 1st sub-bullet, and/or remove different beams.

### 14 – NTT DOCOMO INC.

We prefer to include both 2-step and 4-step RACH procedure. For 2-step RACH, although it may not be used for coverage limited scenario, we believe we can extend coverage of 2-step RACH, compared to existing 2-step RACH.

We suggest to add "2-step RACH procedure" in addition to "4-step RACH procedure". Or, we suggest to write as [, and 2-step and 4-step RACH procedure].

Regarding to the PRACH format, when we specify PRACH repetition, we agree PRACH format B4 is the highest priority, because it is the longest PRACH format. However, if we define "PRACH beam" in specification based on the beam correspondence, we believe it is useful for all PRACH formats. Hence, we prefer to specify PRACH beam based on beam correspondence for all PRACH formats.

### 15 – Apple Computer Trading Co. Ltd

In general we support moderator's updated proposal. For the PRACH format supporting the repetition, ZTE's proposal is fine which preclude the repetition of long PRACH format.

### 16 – NTT DOCOMO INC.

<Moderator comment>

Thanks again for feedbacks and suggestions.

Based on the feedbacks, the proposed objective can be updated as below.

#### **Specify following PRACH coverage enhancements (RAN1, RAN2)**

- **Multiple PRACH transmissions with same beams ~~or different beams~~, [targeting 4-step RACH and 2-step RACH procedures] ~~and at least PRACH format B4, both FR1 and FR2, and 4-step RACH procedure~~**
  - o ~~Other short PRACH formats can also be considered if identified as necessary, and format-agnostic approach should be considered in such case~~
- **[Study, and if justified, specify PRACH transmissions with different beams]**
- **Note: The enhancements of PRACH is targeting for FR2, which can also apply to FR1 when applicable.**
- **Note: The enhancements of PRACH is targeting for PRACH format B4, which can also apply to other short PUCCH formats when applicable.**

Current notes on FR1/FR2 and PRACH formats can solve/relax the concern on workload. If there is still concern on the workload, based on the discussion so far, 2-step RACH part and different beams part may be candidates to reduce the scope to be discussed in next round discussion i.e., in RAN#94e.

### 17 – Qualcomm Incorporated

We agree with the proposed objective.

**18 – Huawei Tech.(UK) Co.. Ltd**

We are ok with the proposal on PRACH coverage enhancements from the moderator in comment #10.

**19 – Intel Deutschland GmbH**

Although we do not see the need to specify the PRACH coverage enhancement in FR1 given that network can configure long PRACH formats for coverage limited scenarios, we can be supportive for this.

Other part of proposals is fine to us. We only need to focus on 4-step RACH for PRACH coverage enhancement.

**20 – Nokia Corporation**

We are OK with the proposal from moderator in comment #10. The version in comment#16 is also ok if 2-step RACH is removed. We think adding 2-step RACH increases the workload unnecessarily.

**21 – Spreadtrum Communications**

We support the update objective from the Moderator in #10 and #16 (**without 2-step RACH**). It is good to emphasize FR2, and the method can be apply to FR1. Target only 4-step RACH is preferred, as 2-step RACH always has a higher RSRP comparing 4-step RACH, and many companies have express same concern towards it.

**22 – Samsung Research America**

During the Rel-17 CovEnh SI, B4 format was selected for the simulations for FR2 as short format because this format has the best coverage between all short formats. Since B4 was identified having coverage issues, all other short formats will have more severe coverage issues than B4. Thus, coverage enhancement of short formats other than B4 is even more important. A same specified solution should apply to any short format.

Targeting 4-step RACH is sufficient, and prefer to include different beams.

We propose the following changes (to the last revised Moderator's proposal)

**Specify following PRACH coverage enhancements (RAN1, RAN2)**

- **Multiple PRACH transmissions with same beams or different beams, {targeting 4-step RACH [and 2-step RACH] procedures} and at least PRACH format B4, both FR1 and FR2, and 4-step RACH procedure**
  - o **~~Other short PRACH formats can also be considered if identified as necessary, and format-agnostic approach should be considered in such case~~**
- **~~{Study, and if justified, specify PRACH transmissions with different beams}~~**
- **Note: The enhancements of PRACH is targeting for FR2, which can also apply to FR1 when applicable.**
- **Note: The enhancements of PRACH is targeting for short PRACH format B4, which can also apply to other short PUCCH formats when applicable.**

**23 – Asia Pacific Telecom co. Ltd**

Current proposed objectives looks all fine for us. But would like to clarify Moderator's though a little bit more as below:As the stated by Moderator"UE's beam determined based on SSB reception may not

be appropriate one for PRACH transmission in such case, and transmitting multiple PRACHs with different beams (that may include better beam than the beam based on SSB reception)”, whether the multiple PRACHs are restricted as the PRACHs of same SSB or not?

Opt1. Multiple PRACH transmissions with UE’s same Tx beams or different Tx beams

Opt2. Multiple PRACH transmissions on resource ~~with~~ of same beams or different beams

#### 24 – China Telecommunications

We generally support the moderator’s proposal. We prefer the following modification:

**Specify following PRACH coverage enhancements (RAN1, RAN2)**

· **Multiple PRACH transmissions with same beams or different beams, targeting at least 4-step RACH procedure and at least PRACH format B4, both FR1 and FR2, and 4-step RACH procedure**

o ~~Other short PRACH formats can also be considered if identified as necessary, and format-agnostic approach should be considered in such case~~

· **Note: The enhancements of PRACH is targeting for FR2, which can also apply to FR1 when applicable.**

#### 25 – NTT DOCOMO INC.

<Moderator comment>

Thanks for further feedbacks and suggestions.

On the points companies still not converged, we should put them in brackets and continue discussion in next round i.e., in RAN#94e, considering the remaining time of the final round of this email discussion.

Following is the latest updated objective (clean ver.) based on feedbacks so far.

**Specify following PRACH coverage enhancements (RAN1, RAN2)**

- **Multiple PRACH transmissions with same beams targeting 4-step RACH [and 2-step RACH] procedures**
- **[Study, and if justified, specify PRACH transmissions with different beams targeting 4-step RACH [and 2-step RACH] procedures]**
- **Note: The enhancements of PRACH is targeting for FR2, which can also apply to FR1 when applicable.**
- **Note: The enhancements of PRACH is targeting [for PRACH format B4, which can also apply to other] short PRACH formats when applicable.**

Regarding the question from APT, the moderator’s understanding is Opt.1. If it is common understanding, we can add ”UE’s Tx” before ”beams” later (in RAN#94e).

#### 26 – VODAFONE Group Plc

We support China Telecom latest revised proposal but we think FR1 should have equal priority as FR2.

#### 27 – Ericsson LM

We support the proposal.

<p><b>28 – Nokia Corporation</b></p> <p>We are sorry to amend our previous statement. Actually we are not OK with version #16, we overlooked that in that version the moderator moved PRACH with different beams to be within brackets. This is clearly important for FR2, where operation is beam based.</p>
<p><b>29 – Nokia Corporation</b></p> <p>On the last note, we propose it to be revised as follows to better capture the views so far: <b><u>Note: The enhancements of PRACH is [format-agnostic, but] mainly targeting [PRACH format B4]/[, which can also apply to other short PRACH formats when applicable].</u></b></p> <p>Our preference is to remove the brackets on "format agnostic" and "PRACH format B4", but we added them there because of the other comments above.</p>
<p><b>30 – Rakuten Mobile</b></p> <p>We agree with Moderator's proposal. If it is required to prioritize, our first preference is the enhancement of FR1 and FR2, and 4-step RACH, but we are open to discuss about other items.</p>
<p><b>31 – LG Electronics Inc.</b></p> <p>We are fine with moderator's updated proposal in #10 and #16 (except 2-step RACH) for PRACH coverage enhancement. But, we don't see a motivation to study CE for 2-step RACH.</p>
<p><b>32 – Guangdong OPPO Mobile Telecom.</b></p> <p>We accept the moderator's proposal. This PRACH applicable issue can be discussed in the WG.</p> <p>There is no exclusive conclusion in Rel-17 for PRACH enhancement.</p> <p>Seems this is the current level of details we can reach.</p>
<p><b>33 – SoftBank Corp.</b></p> <p>We are fine with the moderator's proposal</p>
<p><b>34 – MediaTek Inc.</b></p> <p>Moderator proposal is fine.</p>

#### 4.1.3 PUCCH coverage enhancements

According to the guidance in RP-212657, companies are encouraged to provide feedbacks on the observations in 3.2.3 and the following proposed objectives aiming for final convergence. In the final round, the moderator will appreciate if companies focus on essential comment only.

- [Study and if necessary specify following coverage enhancements for PUCCH/UCI (RAN1)]
  - [DFTS-OFDM waveform for short PUCCH]
  - [Repetition of CSI in dynamically indicated resources]

## Feedback Form 19: PUCCH coverage enhancements

<p><b>1 – vivo Communication Technology</b></p> <p>Ok to keep it in square bracket</p>
<p><b>2 – Charter Communications</b></p> <p>OK with square brackets for now</p>
<p><b>3 – InterDigital France R&amp;D</b></p> <p>Ok with the square bracketed objective.</p>
<p><b>4 – CATT</b></p> <p>We are not convinced to include the two PUCCH/UCI enhancements in Rel-18 UL enhancements. First of all, they have been discussed in previous release without consensus to support. It is not desirable to reopen the discussions in Rel-18. In addition, the overall workload needs to be considered and it is clear that this objective has lower priority compared with others in terms of performance gain, urgency and companies' interests.</p>
<p><b>5 – Lenovo (Beijing) Ltd</b></p> <p>As commented in previous rounds, we don't see a strong motivation/justification to consider further PUCCH coverage enhancements following the on-going enhancements in Rel-17. This shall be deprioritized in R18.</p>
<p><b>6 – CAICT</b></p> <p>We are ok to keep this part as low priority and bracket it.</p>
<p><b>7 – ZTE Corporation</b></p> <p>If PUCCH enhancements are to be considered, we still believe DMRS-less PUCCH is the most promising enhancement.</p> <p>Short PUCCH is not the target PUCCH format in coverage limited scenario. For dynamic repetition indication for CSI, it is more about efficiency instead of coverage enhancement.</p>
<p><b>8 – Xiaomi Communications</b></p> <p>Ok with square bracket objective, also we prefer to include the DMRS-less PUCCH as another approach.</p>
<p><b>9 – Futurewei Technologies</b></p> <p>Ok to have the enhancement in square brackets now, but it should be a candidate for potential scope reduction based on the overall situation of the WI.</p>
<p><b>10 – NTT DOCOMO INC.</b></p> <p>We don't understand the benefit of DFT-S-OFDM to short PUCCH formats. In Rel.15, whether to support DFT-S-OFDM to short PUCCH formats was discussed and well evaluated, and finally sequence based PUCCH format 0 and OFDM based PUCCH format 2 were defined. DFT-S-OFDM has no PAPR/BER gain compared with PUCCH format 0. If we introduce PUCCH format 2 with DFT-S-OFDM, we can reduce PAPR for PUCCH format 2. However, DFT-S-OFDM requires two OFDM symbols, which disables</p>

frequency hopping. Hence, the BER performance of PUCCH format 2 with DFT-S-OFDM becomes worse than existing spec.

We believe DFT-S-OFDM to short PUCCH was already discussed in Rel.15. Hence, we suggest to remove it.

### **11 – Apple Computer Trading Co. Ltd**

The repetition was already supported for short PUCCH formats, in a sense, the coverage of short PUCCH is improved. Before studying the further enhancement on short PUCCH, the coverage issue of short PUCCH needs to identify first. The CSI enhancement was extensively discussed in Rel-17 study, no consensus was reached to improve the CSI reporting.

### **12 – Qualcomm Incorporated**

#### **On PUCCH enhancements:**

As we have remarked earlier, PUCCH repetitions are not widely used in TDD systems due to limited uplink resources and enhancements to PUCCH that do not rely on repetitions are more valuable. In particular, FR2 networks would greatly benefit from such enhancements. Rel-17 failed to provide any enhancement to PUCCH that did not rely on repetitions and R18 needs to rectify this.

#### **On DMRS-less PUCCH:**

Companies keep repeating that there was no consensus reached in Rel-17 on this topic but that was because of outlier results, the reasons for which were never sufficiently resolved. Therefore, we believe the Rel-17 work on DMRS-less PUCCH study reached no conclusion, which would need to be rectified. It is unacceptable that companies would not even agree to a small study phase where the discussion on this promising enhancement is concluded in a satisfactory manner.

We urge the moderator to bring this back. A study to resolve the difference is necessary.

#### **On DFT-S-OFDM for PUCCH:**

As several companies may be aware, DFT-S-OFDM for short formats is proposed for Rel-17 TEI. Many companies acknowledged the benefit but indicated that it might be too large a topic to handle as a TEI, and it was suggested that it be taken up for discussion in Rel-18. Among the many items listed under uplink enhancements, this is one item whose scope is clear, and the benefits are rather straightforward to see.

Companies seem broadly open to power-domain enhancements, and it can be argued that this is nothing more than power-domain enhancements for short formats - the same justifications are equally applicable here.

We would urge companies to support this proposal.

#### **Concluding remark:**

Even if not all companies can agree to this set of enhancements, we suggest that we leave the square brackets in place and capture it in the draft WID so that there is further discussion on this important topic. For us to completely drop PUCCH enhancements from the scope of uplink enhancements does not send the right message.

#### **CSI repetition on PUSCH:**

We could support this objective if it is limited to PUSCH. We think that for FR2 the feature could provide coverage enhancement of L1 report for reliability of beam management.

### **13 – Huawei Tech.(UK) Co.. Ltd**

We still think this objective is not critical for Rel-18. Given the number of objectives, we support stopping the discussion on PUCCH coverage enhancements.

#### **14 – Nokia Corporation**

We are fine to leave this whole topic in brackets or remove it, as we don't see the benefits of either DFTS-OFDM waveform for short PUCCH or Repetition of CSI in dynamically indicated resources, as mentioned earlier already and perhaps no need to repeat the same arguments here.

#### **15 – NTT DOCOMO INC.**

<Moderator comment>

Thanks for the feedbacks and suggestions.

Based on the feedbacks, further discussion in next round i.e., in RAN#94e seems necessary.

On other other hand, considering current situation and overall scope for Rel-18 UL enhancements with probably limited TUs, focused small scope for the potential study on PUCCH coverage enhancements should be considered. Based on the feedbacks so far, UCI payload size for DMRS-less PUCCH and DFTS-OFDM for short PUCCH should be limited and CSI repetition should be limited to PUSCH.

Updated potential objective for further discussion is below. Any suggestion for further reduction of the study scope may be considered towards next discussion in RAN#94e.

**[Study and if necessary specify following coverage enhancements for PUCCH/UCI (RAN1)]**

- **[DMRS-less PUCCH with UCI payload size from 3 to 11 bits]**
- **[DFTS-OFDM waveform for short PUCCH with UCI payload size from 3 to 11 bits]**
- **[Repetition of CSI in dynamically indicated PUSCH resources]**

#### **16 – Intel Deutschland GmbH**

As mentioned in previous rounds of discussions, we do not see the need for further enhancement on PUCCH as this is already specified in Rel-17 coverage enhancement WI. Given the scope for UL enhancement in Rel-18 is already very large, it is not clear to us whether both objectives can be accommodated in the scope, especially for the DFTS-OFDM waveform for short PUCCH where substantial effort is needed for the design of a new PUCCH format with new waveform

#### **17 – TELECOM ITALIA S.p.A.**

We suggest to completely remove the bullet on repetition. See comment on the justification part: "However, those mechanisms may not be available in case of TDD bands with limited UL slot configuration, such as DDSU". Other configurations are in many countries not allowed by regulators, unless 3GPP define solutions to allow flexible TDD. Therefore, this is simply a paper exercise.

#### **18 – TELECOM ITALIA S.p.A.**

sorry, please consider the previous Telecom Italia's comment as withdrawn. No comment on this question.

#### **19 – Samsung Research America**

Similar to our earlier comments, we don't think there is a need for further enhancements for PUCCH.

#### **20 – China Telecommunications**

We don't support to preclude DMRS-less PUCCH. We can accept to put it in the list with bracket, i.e. [DMRS-less PUCCH]. The detailed scope can be discussed in Dec. RANP.

<p><b>21 – VODAFONE Group Plc</b></p> <p>We are OK with the latest moderator proposal</p>
<p><b>22 – EURECOM</b></p> <p>We support the latest proposal by the moderator.</p> <p>DMRS-less PUCCH should be included in the WI. It is by far the most promising technique to improve performance in the low SNR regime. As stated earlier, the diverging views on potential gains must be resolved which can be accomplished by a short study phase in Rel-18.</p>
<p><b>23 – Ericsson LM</b></p> <p>We are generally supportive, but would prefer more targeted study, given the need to limit the UL Enhancements workload to 1 TU. As Intel and DOCOMO commented, the gains of DFT-S-OFDM for short PUCCH are not clear. On the other hand, dynamic repetition of CSI was in scope but did not make it into Rel-17 coverage enhancements, and there are a number of possible ways to support repetition of CSI in dynamically indicated resources. Since CSI can't be repeated on PUSCH at present, we prefer to drop 'PUCCH' from the main bullet to allow fixes for this hole in the Rel-15 specs to be studied.</p> <p>Therefore, we prefer the following, although we will not object to the original moderator's proposal.</p> <p>{Study and if necessary specify following coverage enhancements for PUCCH/UCI (RAN1)}</p> <p><del>[-DFTS-OFDM waveform for short PUCCH]</del></p> <p>○ {Repetition of CSI in dynamically indicated resources}</p>
<p><b>24 – LG Electronics Inc.</b></p> <p>For PUCCH coverage enhancement, we are fine with square bracket. But we don't see strong motivation to study coverage enhancement for short PUCCH.</p>
<p><b>25 – Guangdong OPPO Mobile Telecom.</b></p> <p>We still think DMRS-less is the right enhancement as we stated in the general question. But we are ok to keep this part bracketed.</p>
<p><b>26 – MediaTek Inc.</b></p> <p>Given that the Rel-17 Study Item already had lots of discussion and technique selection on PUCCH enhancements which are now being specified to address the coverage bottlenecks, we don't see the value of working on this again in Rel-18.</p> <p>So further PUCCH coverage enhancement is a low priority objective from our perspective.</p>
<p><b>27 – SoftBank Corp.</b></p> <p>We are fine with the latest moderator's proposal with square brackets.</p>

#### 4.1.4 Power domain enhancements

According to the guidance in RP-212657, companies are encouraged to provide feedbacks on the observations in 3.2.4 and the following proposed objectives aiming for final convergence. In the final round, the moderator

will appreciate if companies focus on essential comment only.

– **Study and if necessary specify following power domain enhancements**

- **Enhancements to realize dynamic power aggregation based on Rel-17 RAN4 work on “Increasing UE power high limit for CA and DC”, with checking relevant regulations (RAN1, RAN4)**
  - **Note: The study can start after RAN4 work on “Increasing UE power high limit for CA and DC” is done.**
- **Enhancements to reduce MPR/PAR, including new transmission mechanism such as new waveform and/or spectrum shaping, reduced spectrum utilization with relaxed requirements on channel filtering, and potential adjustments to MPR and test tolerance relations (RAN4, RAN1)**

**Feedback Form 20: Power domain enhancements**

**1 – vivo Communication Technology**

our view remains same, it should be in square bracket.

**[Study and if necessary specify following power domain enhancements**

**Enhancements to realize dynamic power aggregation based on Rel-17 RAN4 work on “Increasing UE power high limit for CA and DC”, with checking relevant regulations (RAN1, RAN4)**

**Note: The study can start after RAN4 work on “Increasing UE power high limit for CA and DC” is done.**

**Enhancements to reduce MPR/PAR, including new transmission mechanism such as new waveform and/or spectrum shaping, reduced spectrum utilization with relaxed requirements on channel filtering, and potential adjustments to MPR and test tolerance relations (RAN4, RAN1)]**

**2 – InterDigital France R&D**

We support the moderator’s objective.

**3 – CATT**

We also think it is premature to be included in the WID and agree with vivo that it should be in square bracket.

**4 – Lenovo (Beijing) Ltd**

We support the first bullet, and this shall be led by RAN4.

Regarding the second bullet, we do not think RAN1 has sufficient TU to study new waveform, and suggest to remove new waveform from the text. We are OK with the rest of the second bullet and think RAN4 should lead this effort.

**Study and if necessary specify following power domain enhancements**

· **Enhancements to realize dynamic power aggregation based on Rel-17 RAN4 work on “Increasing UE power high limit for CA and DC”, with checking relevant regulations (RAN1, RAN4)**

o **Note: The study can start after RAN4 work on “Increasing UE power high limit for CA and DC” is done.**

· **Enhancements to reduce MPR/PAR, including new transmission mechanism such as ~~new waveform and/or~~ spectrum shaping, reduced spectrum utilization with relaxed requirements on channel filtering, and potential adjustments to MPR and test tolerance relations (RAN4, RAN1)**

#### **5 – NTT DOCOMO INC.**

<Moderator comment>

Thanks for the feedbacks.

It seems further discussion on this potential objective (including responsible WG(s)) is necessary in RAN#94-e, and hence the square brackets are to be added as suggested by companies.

**[Study and if necessary specify following power domain enhancements]**

- **[Enhancements to realize dynamic power aggregation based on Rel-17 RAN4 work on “Increasing UE power high limit for CA and DC”, with checking relevant regulations ([RAN1,] RAN4)]**  
**[Note: The study can start after RAN4 work on “Increasing UE power high limit for CA and DC” is done.]**
- **[Enhancements to reduce MPR/PAR, including new transmission mechanism such as new waveform and/or spectrum shaping, reduced spectrum utilization with relaxed requirements on channel filtering, and potential adjustments to MPR and test tolerance relations (RAN4[, RAN1)]]**

#### **6 – Futurewei Technologies**

Ok with the latest version with this in brackets.

#### **7 – AT&T**

We disagree with vivo, CATT, and FutureWei. This should be the main focus of Rel. 18 UL enhancements. It's the one domain that hasn't been sufficiently addressed in past releases. We strongly support this objective including both sub-bullets.

#### **8 – NTT DOCOMO INC.**

Support.

#### **9 – Xiaomi Communications**

Ok with the latest version with this in brackets.

#### **10 – Apple Computer Trading Co. Ltd**

We are ok with the update proposal which keeps the items in the brackets and leading group is RAN4.

#### **11 – Qualcomm Incorporated**

We agree with the proposed objective as long as “new waveform” is deleted. Opening the study to new waveforms would introduce unreasonably large scope.

We also prefer to clearly identify enhancements intended for FR1 and FR2 and list them separately. We also need more clarity on what is meant by “reduced spectrum utilization with relaxed requirements on channel filtering”. For now, please leave this in square brackets.

In case of any further scope reduction, we clearly prefer keeping dynamic power aggregation, since the amount of work required for this is much less than it is for reduced MPR/PAR.

## **12 – Huawei Tech.(UK) Co.. Ltd**

Thank you for updating the proposal on dynamic power aggregation. With this proposal, we can wait for RAN4 conclusion and if RAN4 concludes on allowing higher transmission power by power aggregation then the RAN1 work can be triggered by this objective. We would like to clarify this at the end of the note:

- “the study can start [...] depending on conclusions from RAN4”.

The second bullet on enhancements to reduce MPR/PAR is very broad and provides no real focus for the work in RAN1 and RAN4, as commented by most companies. In particular for RAN1, the work could be significant if new waveforms are considered, but it seems that proponents are actually not considering new waveforms but still only DFT-s-OFDM or CP-OFDM. Then it is unclear what needs to be done in RAN1 since these two waveforms are already supported. Therefore it seems the objective could involve only RAN4. In our view, better exploitation of MPR can be achieved by enabling rank-2 DFTs-OFDM for  $\pi/2$  BPSK (which can already be covered the objective proposed in 4.1.6).

As also stated by some other companies, we prefer the objective to focus on dynamic power aggregation over MPR reduction.

## **13 – Nokia Corporation**

It would be disappointing to have this objective in square brackets, and we agree with AT&T this is an area that has not been exploited before and has very practical implications. Having said that, we do not support the addition of “new waveform”, we find it unwarranted and out of scope of this discussion.

As for relative priorities, we disagree with Qualcomm on the assessment of priority and amount of work required for the dynamic power aggregation. Our priority is clearly on the reduced MPR/PAR, which applies to more general UE architectures.

## **14 – Intel Deutschland GmbH**

For “enhancements to realize dynamic power aggregation”, our view is that this highly depends on Rel-17 ongoing RAN4 work and we suggest to further discuss this objective as part of RAN4 package, and if objectives relevant to RAN1 are identified, they can be introduced later.

We do not see the need for “enhancements to reduce MPR/PAR”. As mentioned previously, in Rel-16,  $\pi/2$  BPSK with DFT-s-OFDM waveform and new DMRS sequence design have been specified to reduce the PAPR for uplink transmission. Note that the objective is very broad and it is not clear to us whether this can be accommodated to the scope for Rel-18 UL enhancement.

We suggest to remove this objective.

## **15 – TELECOM ITALIA S.p.A.**

We support this objective and we believe this is one of the key aspects under this thread.

We support the comment to remove the scope on new waveforms.

Not clear what is intended with the sentence “and potential adjustments to MPR and test tolerance relations” and we propose to remove it.

## **Conclusion**

- keep the objective without square brackets
- remove new waveforms from sub-objective 2
- remove and potential adjustments to MPR and test tolerance relations from sub-bullet 2

## 16 – NTT DOCOMO INC.

<Moderator comment>

Thanks for the further feedbacks.

Although there are strong requests to remove bracket for this objective from multiple companies, there are other multiple companies to request to add the bracket, and since this is the final round of the email discussion, we would need to continue discussion in the next opportunity i.e., in RAN#94e.

The moderator intended to remove waveform part based on previous comments but it was missed.

Based on other feedbacks, following is the updated potential objective for further discussion towards RAN#94e.

**[Study and if necessary specify following power domain enhancements]**

- **[Enhancements to realize dynamic power aggregation based on Rel-17 RAN4 work on “Increasing UE power high limit for CA and DC”, with checking relevant regulations ([RAN1,] RAN4)]**  
**[Note: The study can start after RAN4 work on “Increasing UE power high limit for CA and DC” is done depending on conclusions from RAN4.]**
- **[Enhancements to reduce MPR/PAR, including new transmission mechanism such as ~~new waveform and/or~~ spectrum shaping, [reduced spectrum utilization with relaxed requirements on channel filtering], [and potential adjustments to MPR and test tolerance relations] (RAN4[, RAN1])]**

## 17 – Samsung Research America

We think the study should be done by RAN4. Based on the outcome of the RAN4 study, an objective can be added under UL Enhancement WI including RAN1 responsibility. Hence, we suggest to have a SI in RAN4 only and after completion of the RAN4 SI, if needed, revise the UL enhancement WID and add a corresponding objective for RAN1, RAN4 (to be completed within R18). Moreover, so if this has to be studied, we think the aspect to exploit advanced receiver to handle the relaxed requirement should also be considered in addition to the transmission side.

As a separate RAN4 SI, we suggest the following objective:

**~~– Study and if necessary specify following power domain enhancements~~**

- **Enhancements to realize dynamic power aggregation based on Rel-17 RAN4 work on “Increasing UE power high limit for CA and DC”, with checking relevant regulations (RAN1, RAN4)**  
~~o Note: The study can start after RAN4 work on “Increasing UE power high limit for CA and DC is done.~~
- **Enhancements to reduce MPR/PAR, including new transmission mechanism such as new waveform and/or spectrum shaping, reduced spectrum utilization, and/or including exploiting advanced**

<p><b>receiver, with relaxed requirements on channel filtering, and potential adjustments to MPR and test tolerance relations (RAN4, RAN1)</b></p>
<p><b>18 – China Telecommunications</b></p> <p>We think the bullet for “dynamic power aggregation” should be put into bracket. As many companies comment, its relationship with RAN4’s work on “Increasing UE power high limit for CA and DC” needs to be clarified first.</p>
<p><b>19 – Asia Pacific Telecom co. Ltd</b></p> <p>We agree and support current text. That is, we <b>start after RAN4 work</b></p>
<p><b>20 – Ericsson LM</b></p> <p>We support the proposal, although we worry that “new waveform and/or spectral shaping” is pretty broad. Again, we don’t think the study should diverge from DFT-S-OFDM and CP-OFDM. So some clarification that enhancements should use DFT-S-OFDM and/or CP-OFDM, and what spectral shaping is meant would be helpful.</p>
<p><b>21 – ZTE Corporation</b></p> <p>We are fine to study dynamic power aggregation depending on RAN4 work in Rel-17.</p> <p>As many companies commented, the scope of MPR/PAR reduction is too broad and unclear, we prefer to remove the objective.</p>
<p><b>22 – Guangdong OPPO Mobile Telecom.</b></p> <p>we are Ok with the updated version with this in brackets.</p>
<p><b>23 – SoftBank Corp.</b></p> <p>We support the latest proposal by the moderator.</p>
<p><b>24 – MediaTek Inc.</b></p> <p>We agree with Ericsson that new waveform is too broad for the MPR/PAPR part, and we don’t think we should go in that direction. Seems best to clarify that a new waveform is not in scope of this work.</p>

#### 4.1.5 Enhancements for multi-carrier UL operation

According to the guidance in RP-212657, companies are encouraged to provide feedbacks on the observations in 3.2.5 and the following proposed objectives aiming for final convergence. In the final round, the moderator will appreciate if companies focus on essential comment only.

– **Specify following enhancements for multi-carrier UL operation**

- **UL Tx switching schemes across 3 bands with restriction of 2 Tx simultaneous transmission for FR1 UEs, including mechanisms to enable more configured UL bands than its simultaneous transmission capability and to support dynamic Tx carrier switching across the configured bands (RAN1)**

- **Switching time and other RF aspects for above UL Tx switching schemes across 3 bands (RAN4)**

**Feedback Form 21: Enhancements for multi-carrier UL operation**

<p><b>1 – vivo Communication Technology</b></p> <p>We are fine with the current formulation.</p>
<p><b>2 – Lenovo (Beijing) Ltd</b></p> <p>We prefer to have a study phase on multi-carrier UL operation, and specify the enhancement if the study phase show sufficient benefit.</p>
<p><b>3 – Futurewei Technologies</b></p> <p>Support</p>
<p><b>4 – NTT DOCOMO INC.</b></p> <p>We are fine with the proposal, although UL CA enhancement is not high priority for us.</p>
<p><b>5 – Xiaomi Communications</b></p> <p>We are fine with the proposal, and a short study phase is preferred.</p>
<p><b>6 – Qualcomm Incorporated</b></p> <p>We are ok to limit the switching bands to 3 but still have some concern on overcomplicated switching case combinations. Switching among 3 bands would still have 6 cases, for example. We would suggest setting some restrictions to avoid some unnecessary switching combinations.</p>
<p><b>7 – Huawei Tech.(UK) Co.. Ltd</b></p> <p>We support the objective, but we think the work in RAN1 would be agnostic to the number of bands over which Tx switching is performed. Why should the number of combinations matter, as long as there is a limitation to 2Tx? So we would suggest changing “across 3 bands” to “across more than 2 bands” in the RAN1 objective.</p> <p>We could then let RAN4 decide if they will specify for 3 bands or more (e.g. 4). It is not unusual for an operator to have 4 bands. Perhaps RAN4 could take operators’ input during the WI and make a decision.</p>
<p><b>8 – Nokia Corporation</b></p> <p>We do not support this objective, as consistently stated many times before. It is indeed surprising this topic is not listed under brackets given the amount of concerns raised by many companies earlier, while the power domain enhancements are listed within brackets. It is not clear at all what is the gain potential for this objective, and hence it is not justified to specify it in Rel-18 in our view.</p>

**9 – Intel Deutschland GmbH**

We suggest to start with a study phase for “enhancements for multi-carrier UL operation”. The main bullet can be updated as

**Study and if necessary, specify following enhancements for multi-carrier UL operation**

**10 – TELECOM ITALIA S.p.A.**

ok with the moderator’s proposal.

Also ok with Huawei on ”suggest changing “across 3 bands” to “across more than 2 bands”

**11 – Asia Pacific Telecom co. Ltd**

We agree and support current text. Thanks Moderator.

**12 – NTT DOCOMO INC.**

<Moderator comment>

Thanks for the feedbacks and suggestions.

Based on the feedbacks, it seems this potential objective also needs further discussion in next round i.e., in RAN#94e, at least on target number of bands. Also, to solve the concern on potential gain, study phase would be necessary as suggested by some companies.

Following is the updated proposed objective for further discussion towards RAN#94e.

**Study and if necessary specify following enhancements for multi-carrier UL operation**

- **UL Tx switching schemes across [more than 2] bands with restriction of 2 Tx simultaneous transmission for FR1 UEs, including mechanisms to enable more configured UL bands than its simultaneous transmission capability and to support dynamic Tx carrier switching across the configured bands (RAN1)**
- **Switching time and other RF aspects for above UL Tx switching schemes across [more than 2] bands (RAN4)**

**13 – China Telecommunications**

Fine with the proposal in principle. Some modification as follows:

- **Specify following enhancements for multi-carrier UL operation**
- **UL Tx switching schemes across at least 3 bands with restriction of 2 Tx simultaneous transmission for FR1 UEs, including mechanisms to enable more configured UL bands than its simultaneous transmission capability and to support dynamic Tx carrier switching across the configured bands (RAN1)**
- **Switching time and other RF aspects for above UL Tx switching schemes across at least 3 bands (RAN4)**

**14 – CAICT**

We are fine with moderator’s update proposal.

**15 – VODAFONE Group Plc**

We support last moderator proposal

**16 – Ericsson LM**

We do not support the proposal. As the moderator points out, multiple companies are not clear on the performance benefits of UL Tx switching over more than two bands. Especially in view of the need to further limit the workload in UL enhancements, our preference is to prioritize other UL enhancements over this.

**17 – ZTE Corporation**

We agree that whether there is clear performance gain compared to existing 2-Tx switching across two bands and fast Scell activation needs more investigation.

Switching among more than 3 bands/carriers would only provide even minor gain if any, and therefore we don't support.

**18 – LG Electronics Inc.**

We are fine with moderator's updated proposal in comment#12.

**19 – NTT DOCOMO INC.**

<Moderator comment>

Thanks for the further feedbacks.

Unfortunately it seems even the moderator's updated proposal is not agreeable. Then, further discussion is necessary in RAN#94e on whole this objective and hence this is within a bracket for now.

**[Study and if necessary specify following enhancements for multi-carrier UL operation]**

- **[UL Tx switching schemes across [more than 2] bands with restriction of 2 Tx simultaneous transmission for FR1 UEs, including mechanisms to enable more configured UL bands than its simultaneous transmission capability and to support dynamic Tx carrier switching across the configured bands (RAN1)]**
- **[Switching time and other RF aspects for above UL Tx switching schemes across [more than 2] bands (RAN4)]**

**20 – Guangdong OPPO Mobile Telecom.**

We are fine with the update bullets by moderator.

**21 – China Mobile Com. Corporation**

Thanks for moderator's updates.

As commented in the last round, we still think specifying is more direct way for this item, as the group already has a WI working on the UL Tx switching for 2 bands. Considering the working mode of CA, extending the band number from 2 to 4 or beyond seems not an issue. In addition, RAN1's enhancement is band agnostic, then the necessity of the study is not that obvious.

For the "more than 2 band", we support the more than 2 band should be specified and we do not want to limit the supported band number only to 3. Currently, we have 7 frequency bands which all support CA. Dynamic switching between only 3 bands does not provide sufficient flexibility to make a full use of those bands. Then "more than 3" is more appropriate for us. But we do not want to introduce more controversies in the last few hours in the final round. Then we support the wording of "more than 2 bands" without bracket at current stage.

For the RAN4's work, the switching time should be band agnostic, then it should not be an issue for extending the band number.

**22 – SoftBank Corp.**

we are fine with the latest moderator's proposal.

**23 – MediaTek Inc.**

We are not so convinced of the benefits of this proposal, as mentioned in previous rounds, but ok to proceed if others see value.

4.1.6 Enhancements for DFTS-OFDM

According to the guidance in RP-212657, companies are encouraged to provide feedbacks on the observations in 3.2.6 and the following proposed objectives aiming for final convergence. In the final round, the moderator will appreciate if companies focus on essential comment only.

- **Specify following enhancements for DFTS-OFDM (RAN1)**
  - o **Dynamic switching between DFTS-OFDM and CP-OFDM**
  - o **Multi-layer transmission with DFTS-OFDM, with considering LTE design**

**Feedback Form 22: Enhancements for DFTS-OFDM**

**1 – Samsung Research America**

In our view, the moderator proposal is not well justified. If both the dynamic switching and UL MIMO for DFT-s-OFDM are specified, what does the network do for UL transmission with rank-2 or higher rank? If it happens, the standards will have two options for UL MIMO: 1) CP-OFDM + MIMO (already exists in standard); 2) DFT-s-OFDM + MIMO (new one), meaning that there are TWO duplicated functionalities for the same purpose. This will simply introduce unnecessary burden for product development on both UE and gNB. We really would like to avoid such situation.

In our understanding, the technical motivation for UL MIMO + DFT-s-OFDM, which we are not convinced yet, is as follows:

- The current NR standard supports only the RRC-based switching between DFT-s-OFDM and CP-OFDM.
- Such RRC configuration is very conservative so that typically the DFT-s-OFDM is used in most cases.
- To increase the opportunity of using UL MIMO (to increase the UL peak rate) while keeping the RRC-based switching between DFT-s-OFDM and CP-OFDM, it is necessary to specify UL MIMO for DFT-s-OFDM.

Hence, if the dynamic switching between DFT-s-OFDM and CP-OFDM is specified, there would be no good technical justification to specify UL MIMO for DFT-s-OFDM. If UL MIMO is going to be specified for DFT-s-OFDM, we don't see good justification for introducing the dynamic switching between DFT-s-OFDM and CP-OFDM.

Based on the above consideration, our company position is as follows.

- We object specifying both of the dynamic switching and UL MIMO + DFT-s-OFDM.
- Our preference regarding the UL MIMO is as follows:
  - Study and, if needed, specify feature(s) to facilitate dynamic switching between single-layer DFT-s-OFDM and multi-layer CP-OFDM.” This implies that we don’t specify multi-layer DFT-s-OFDM. This still allows more frequent use of UL MIMO as UL MIMO is already supported for CP-OFDM.

In addition to the technical aspects as above, we think there is no good basis for the moderator proposal as there is an almost even split between companies. It seems that the outcome can be no consensus.

## 2 – NTT DOCOMO INC.

<Moderator’s comment>

Thanks Samsung for feedback and suggestion.

First, let me clarify the background of the current moderator’s proposal.

As described in the observation in my summary,

- Almost all companies would like to support at least one of two enhancements (dynamic switching and multi-layer)
- But there are multiple companies would like to support both, while other multiple companies would like to support only one of them. Even among those companies, there are different preferences on which one should be prioritized/specified.

The moderator’s recommendation should not be based on number-counting, and it should be based on justifications provided by companies. There are following arguments from multiple camps.

- Multiple companies argued that if the dynamic switching is specified, there will be no good technical justification to specify multi-layer DFTS-OFDM as multi-layer CP-OFDM is already available. On the other hand, other multiple companies argued that even if the dynamic switching is specified, multi-layer DFTS-OFDM has different application scenario and own benefit, which is based on lower PAPR compared with multi-layer CP-OFDM.
- There are multiple companies argued that the dynamic switching should be prioritized over multi-layer DFTS-OFDM in terms of scheduling flexibility and potential lower standard efforts, while there are multiple companies having opposite preference (i.e., prioritize multi-layer over dynamic switching) in terms of exploiting DFTS-OFDM with power gain and reuse of LTE design.

Based on the above situation, the moderator’s proposal is provided as compromise in order to proceed the DFTS-OFDM enhancements instead of concluding as ”no consensus”.

Also, as described in the moderator summary and recommendation in 3.2.6, alternative is to have a study phase for this topic to discuss two enhancements in WG level details.

Therefore, following Samsung’s suggestion is aligned with moderator’s suggested alternative in case there is concern on the current proposal. So, companies’ feedback on following suggested proposal from Samsung will be appreciated as well as that for current moderator’s proposal.

- **Study and, if needed, specify feature(s) to facilitate dynamic switching between single-layer DFT-s-OFDM and multi-layer CP-OFDM.” This implies that we don’t specify multi-layer DFT-s-OFDM. This still allows more frequent use of UL MIMO as UL MIMO is already supported for CP-OFDM.**

### **3 – vivo Communication Technology**

We are fine with moderator proposal, however if we need to choose one due to overall scope, our preference is to specify

#### **Dynamic switching between DFTS-OFDM and CP-OFDM**

### **4 – VODAFONE Group Plc**

We support the moderator's original proposal, in our view both enhancements should be pursued with dynamic waveform switching as highest priority

### **5 – China Mobile Com. Corporation**

For the proposal in the front, if the majority view is to down select one of the enhancement, the proposal should be updated with explicit expression. Current both mechanisms are included and forwarded for the further procedure is not acceptable.

If the down-selection could be done at this meeting, we have no problem. It benefits the group with a clear target for the next meeting. If no consensus is reached for choosing any of them, at least we could have a clear conclusion that only one of the enhancements can be specified for Rel-18.

Considering limited TU and current scope of UL enhancements, only one enhancement is preferred.

### **6 – InterDigital France R&D**

We feel that both items (dynamic switching / mutli-layer DFTsOFDM) still require studies, we are also fine to study these items if time allows. We are also fine to limit the scope to study (and if needed specify) one of the items (dynamic switching or multi-layer DFTsOFDM) due to limited amount of TUs.

### **7 – Panasonic Corporation**

Thanks for the discussion. We share the view from Samsung. On the other hand, we also understand the current situation explained by the moderator. Then instead of to agree to specify both, as described by the moderator, to add "Study and, if needed" would be our preference.

On the standardization effort comparison between dynamic switching and multi-layer DFTS-OFDM, we are not so convinced of the reuse of LTE design is simple effort as NR support multiple of SCS and the flexibility of DMRS compared with LTE.

### **8 – CATT**

We agree with the comments from Samsung and we are fine with Samsung's proposal.

### **9 – Lenovo (Beijing) Ltd**

We see the concern from Samsung. As we started early, there is a gap between single-layer DFT-s-OFDM and multi-layer CP-OFDM. This gap cannot be easily smoothed out with dynamic switching between the two waveforms. Adding multi-layer to DFT-s-OFDM will fill this gap, while dynamic switching between the two waveforms allows smooth transition between the two modes. To avoid overlapping between multi-rank DFT-s-OFDM and multi-rank CP-OFDM, the maximal rank supported by DFT-s-OFDM can be limited and this limit can be determined as part of the WID. We propose to add the following note to the last bullet:

**Specify following enhancements for DFTS-OFDM (RAN1)**

- **Dynamic switching between DFTS-OFDM and CP-OFDM**
  - **Multi-layer transmission with DFTS-OFDM, with considering LTE design**
- Note: The maximal rank of DFT-s-OFDM is TBD.**

**10 – NTT DOCOMO INC.**

<Moderator’s comment>

Thanks again for the feedbacks and suggestions.

Based on the feedbacks so far, the moderator thinks that having study for both enhancements with aiming to select one of them may be only possible compromise to proceed this topic.

Updated proposed objective is like below.

**Study and if necessary specify following enhancements for DFTS-OFDM**

- **Dynamic switching between DFTS-OFDM and CP-OFDM**
- **Multi-layer transmission with DFTS-OFDM, with considering LTE design**
- **Note: the study targets to select only one of above enhancements, unless necessity to specify both enhancements is justified in the study**

**11 – Panasonic Corporation**

We support the updated proposal. Thank you very much.

**12 – ZTE Corporation**

We don’t support multi-layer transmission with DFT-S-OFDM.

In coverage limited scenario, one layer transmission would be typically used. That’s the reason only one-layer transmission is supported for PUSCH repetition type A and TBoMS up to Rel-17. If it is for capacity improvement, we can use CP-OFDM instead. We really don’t see clear benefits for multi-layer DFT-S-OFDM. On the contrary, it would cause large spec impacts, e.g, defining new UL precoder and new DMRS pattern, whether/how to support 2-port PTRS and association between DMRS port and PTRS port, etc. Considering LTE design would not save the debate/discussion during the WI. Needless to say, the current WI is already too crowded.

If any enhancement is needed here, we can simply go with dynamic switching between DFTS-OFDM and CP-OFDM.

**13 – Futurewei Technologies**

As we expressed before, there is no strong motivation or clear benefit over existing mechanisms for either enhancement. We suggest to remove this, but we are ok with a down selection to choose only one of them for Rel-18 study and, if justified, for Rel-18 work.

**14 – NTT DOCOMO INC.**

As we commented in intermediate round, we have concern on DFT-S-OFDM with multi-layer, which specifies the duplicated features as existing CP-OFDM with multi-layer. NR already specified and deployed UL MIMO with CP-OFDM, we don’t need to specify DFT-S-OFDM with multi-layer, which enables the same factuality as the existing feature. On the other hand, we have clear use case in our network of the dynamic switching (by MAC CE or DCI) of waveform, which can avoid RRC-reconfiguration. Hence, we believe it should be high priority. When the dynamic switching is specified, we don’t see any use-case to use DFT-S-OFDM with multi-layer.

In intermediate round, Huawei commented that “*if DFT-S-OFDM is extended to support 2 layer transmission, then the gain of 2 layer transmission and power gain can be obtained at the same time.*” However, we don’t agree with it. The benefit of CP-OFDM is not only that it enables UL MIMO, but also that it enables flexible PRB allocation which improves the throughput (e.g. For CP-OFDM, PRB allocation is not limited as consecutive with multiple of 2, 3, or 5 PRBs, and DMRS and PUSCH can be FDMed). Hence, CP-OFDM waveform is beneficial in terms of high throughput, for non-power limited UEs.

However, if there is strong demand of DFT-S-OFDM with multi-layer from companies, we can accept with specifying the both options, only if the dynamic switching is kept in the WID.

#### **15 – Apple Computer Trading Co. Ltd**

Considering the workload, we prefer to study dynamic switching between two waveforms. From this sense, we agree with the Samsung’s proposal.

#### **16 – Xiaomi Communications**

We support the updated moderator’s proposal, and can prioritize dynamic switching between DFTS-OFDM and CP-OFDM first.

#### **17 – Qualcomm Incorporated**

We agree with the current proposed objective.

We don’t agree with some companies’ comment that the above two techniques are mutually exclusive. In our view, these two techniques can bring different benefits and can coexist with each other. Dynamic switching of waveform can help UE to adapt to fast channel condition change (such as hand-blocking in FR2) and adjust waveform accordingly to explore the PAPR gain of DFT-S-OFDM waveform. While multi-layer DFT-S-OFDM transmission can improve the spectrum efficiency of DFT-S-OFDM waveform when it is used. We don’t see why RAN1 has to down select to one from technical point of view. From TU point of view, both are relatively simple enhancements thus do not require many TUs. This is especially true for multi-layer DFT-S-OFDM as most of the LTE design can be reused. Therefore, we support moderator’s proposal to include both of them in Rel-18.

#### **18 – Huawei Tech.(UK) Co.. Ltd**

The proposal from the moderator in comment #10 seems the best compromise WF at this stage.

#### **19 – Nokia Corporation**

We support the revised moderator’s proposal.

#### **20 – Intel Deutschland GmbH**

We are fine with the suggested original objectives in principle.

For dynamic switching between DFT-s-OFDM and CP-OFDM, if there is concern, we can limit this for single layer case as this is mainly for coverage enhancement.

For multi-layer transmission with DFT-s-OFDM waveform, it would be good to mention the maximum number of Tx ports (e.g., 4) and number MIMO layers (e.g., 2) for this enhancement to guide codebook specification.

We suggest to update this objective as

- o Multi-layer transmission with DFTS-OFDM, with maximum 4 Tx ports and 4 MIMO layers.
- o LTE design is considered as baseline.

### **21 – Spreadtrum Communications**

As we commented at the last two rounds, comparing to CP-OFDM, we still cannot be convinced by the justification and use cases for multi-rank DFT-s-OFDM. However, for the progress, we can accept the updated proposal from moderator in #10 for now.

### **22 – China Telecommunications**

We don't support to specify both of them. Considering the spec. impact, we prefer to specify dynamic switching between DFT-S-OFDM and CP-OFDM if necessary.

### **23 – Samsung Research America**

Based on our earlier comment, we can only agree to the first bullet on dynamic switching between DFTS-OFDM and CP-OFDM of the revised proposal by the moderator.

### **24 – NTT DOCOMO INC.**

<Moderator's comment>

Thanks again for the feedbacks and suggestions.

Unfortunately it seems even the moderator's updated proposal for compromise is not agreeable. Then, further discussion is necessary in RAN#94e on whole this objective and hence this is within a bracket for now.

#### **[Study and if necessary specify following enhancements for DFTS-OFDM (RAN1)]**

- **[Dynamic switching between DFTS-OFDM and CP-OFDM]**
- **[Multi-layer transmission with DFTS-OFDM, with considering LTE design]**
- **[Note: the study targets to select only one of above enhancements, unless necessity to specify both enhancements is justified in the study]**

### **25 – Ericsson LM**

We support the moderator's original proposal.

Samsung's statement copied below is not quite correct: we do have rank 1 for DFT-S-OFDM UL MIMO, just not higher than rank 1. So it was already found beneficial in Rel-15 to support both DFT-S-OFDM and CP-OFDM for UL MIMO.

“If it happens, the standards will have two options for UL MIMO: 1) CP-OFDM + MIMO (already exists in standard); 2) DFT-s-OFDM + MIMO (new one), meaning that there are TWO duplicated functionalities for the same purpose”

The original rationale for not supporting > rank 1 for DFT-S-OFDM may have been that some of the new NR precoding matrices for rank 2+ could degrade PAPR. While this is true, it is not so for many of the precoding matrices, and in fact, the LTE precoding matrices (many of which are used in the NR codebooks) were designed specifically to avoid such problems.

Moreover, given the support in LTE since Rel-10 for rank2+ DFT-S-OFDM and the strong commonality of NR and LTE codebooks, we think this is quite straightforward to specify. Lastly, note that DFT-S-OFDM UL MIMO precoders will be quite compatible with the non-coherent UL MIMO operation that is in the field today, and so this is quite a natural enhancement based on commercial experience.

If it is needed to solve Samsung's objection, we would be OK to have a study phase for rank2+ DFT-S-OFDM, and still have fast switching between DFT-S-OFDM and CP-OFDM as 'specify'. We hope this is a reasonable way forward. We prefer this approach to moderator's since we think that switching between single port DFT-S-OFDM and single port CP-OFDM is also important.

#### **26 – Rakuten Mobile**

We support Moderator's proposal. If it is required to set the priority, our first preference is dynamic switching between DFT-s-OFDM and CP-OFDM.

#### **27 – LG Electronics Inc.**

We don't think Rel-18 should support both objectives and diverging preferences for two different proposals justify supporting both proposals. We still think we should be careful in enhancing DFT-S-OFDM UL in NR. However, if we have to choose one, we would prefer multi-layer transmission with a condition of studying the necessity rather than directly specifying it.

#### **28 – Guangdong OPPO Mobile Telecom.**

We think Rel-18 should not enhance both the objectives. We can consider to allow study of DFT-s-OFDM and OFDM dynamic switching first. But that does not promise a normative work.

#### **29 – SoftBank Corp.**

we support the latest proposal by the moderator.

#### **30 – MediaTek Inc.**

In our view the DFT-OFDM multi-layer has not been clearly justified, there is no clear evidence as to how much such a configuration would actually be used in the field considering the other configurations available, and we have concern that we start defining multiple options that just lead to different ways of achieving the same thing, and more complexity for the UE and network, for which the end customer pays the price in the end.

We do intuitively see some value in the dynamic switching between DFT-S-OFDM and CP-OFDM, so would consider that as the only objective to cover here.

#### 4.1.7 Enhancements for UL dense deployment

According to the guidance in RP-212657, companies are encouraged to provide feedbacks on the observations in 3.2.7 and the following proposed objectives aiming for final convergence. In the final round, the moderator will appreciate if companies focus on essential comment only.

- **Study and if necessary specify following enhancements for UL dense deployment and/or asymmetric beamforming operation between DL/UL (RAN1)**
  - **UL power control and UL beam management, with considering UL reception only points**

- **Note: unified mechanisms applicable to both UL dense deployment with UL reception only points and asymmetric beamforming operation between DL/UL with normal TRP(s) are preferred**

### Feedback Form 23: Enhancements for UL dense deployment

#### 1 – Samsung Research America

This topic is already discussed in MIMO email discussion and considered to be included in the MIMO WI. Hence we don't need to consider it in UL enhancement WI.

#### 2 – NTT DOCOMO INC.

<Moderator's comment>

Thanks Samsung for the feedback.

Based on the moderator's checking, although Samsung commented that this topic should be covered in proposed area 5 (UL multi-panel/multi-TRP operation enh.) of MIMO WI, the current proposed objectives for the area 5 seem not include the topic we discussed here.

On the other hand, in previous rounds, there are multiple companies suggesting this topic to be discussed in MIMO WI.

So, one possible WF is to make a conclusion here that this topic should be covered in MIMO WI if we can reach consensus here that having this objective in Rel-18 MIMO is valuable and feasible. In such case, this topic will not be captured in draft WID for UL enhancements.

Companies feedback on above possible WF will be appreciated.

#### 3 – vivo Communication Technology

Our earlier comment was that it is heavily relevant to MIMO, and given the required work it could be independent SI by itself. We don't think it would be possible to conclude here for inclusion in ongoing MIMO scope discussion, as current scope for MIMO already too big which requires down sizing.

#### 4 – InterDigital France R&D

We are fine to study these items in MIMO WI.

#### 5 – Lenovo (Beijing) Ltd

We still have concern about this topic. The benefit of UL reception only point over low power TRP is not clear, while the lack of DL transmission will pose significant problem to issues like power control and beam management. If the UL reception only point still transmits some DL RS, it is possible with gNB implementation. Whether to pursue UL only shall be discussed further in the MIMO session.

#### 6 – CATT

We also think it is highly related to MIMO and should be discussed in MIMO whether to be included or not. It is not appropriate to decide in this discussion that it should be covered by MIMO WI.

#### 7 – ZTE Corporation

We are fine to consider UL dense deployment in MIMO, and suggest to delete the note which is not very clear to us.

**8 – NTT DOCOMO INC.**

<Moderator’s comment>

Thanks for the feedbacks.

Based on the feedbacks, it seems that this topic should be discussed in MIMO (proposed area 5) with considering overall scope of MIMO, i.e., we cannot decide here now that whether this topic can be included as scope of Rel-18 MIMO WI.

The moderator shares this situation with MIMO moderator.

**9 – Futurewei Technologies**

Support the proposed objective and support to study in this WI. If we focus on FR1 enhancement, then this would not be very relevant to MIMO. Furthermore, as this is not explicitly covered in MIMO Area 5 as of now, it is late to re-consider it in MIMO and should be considered in this WI.

**10 – NTT DOCOMO INC.**

Support the proposed objective and support to study in this WI. UL dense scenario can improve UL performance even for single layer in FR1. Hence, it is not always related to MIMO. Also, this topic was discussed in R18Prep-02, we suggest to discuss as part of UL enhancement.

We believe UL enhancement is very important for Rel.18, and we believe the UL dense deployment can improve UL performance significantly.

**11 – Apple Computer Trading Co. Ltd**

We are open to study the UL dense deployment under the MIMO WI.

**12 – Qualcomm Incorporated**

We can accept the proposed objective.

**13 – Xiaomi Communications**

We think this should be discussed in the MIMO session.

**14 – Nokia Corporation**

This topic is more clear, especially the restriction to FR1. While this makes it more feasible, the gain potential is unclear, so we consider this topic is lower priority for Rel-18.

**15 – Huawei Tech.(UK) Co.. Ltd**

We saw only mixed support for this objective in the earlier rounds. We have similar questions as other companies. It is not clear what work can be done on UL power control if there is no DL from the same TRP. In this case the DL from a DL+UL TRP has to be used, and then each UE should have multiple uplinks operating co-channel, which might defeat the goal to transmit at lower power only towards the closest TRP. It seems that some form of coordination among DL+UL TRP and UL-only TRPs would have to be implemented, and that sounds a lot like UL mTRP with joint reception, which is not something new and can be implemented based on current specs, and could also save UE UL power. If the proposal is specifically for FR2, we also wonder how beam-based operation towards a UL-only TRP will work without a corresponding DL Rx beam. There are also potential timing issues if the UE acquires DL timing from another TRP. We understand the current proposal is for a study, so this can be further discussed, but the relation with the work on TCI in MIMO should be clarified.

**16 – Intel Deutschland GmbH**

We are fine with the suggested objectives.

**17 – China Mobile Com. Corporation**

It seems the discussion is leading to a strange direction. We have strong concern on limiting the RX only TRP on FR1.

The original target is for the coverage enhancement with low cost, as it was discussed that the transmit unit of FR2 gNB is expensive and power consuming. While we have tremendous discussion for the PUSCH and PUCCH enhancement in Rel-17 focusing on FR1 (also FR2), we are still discussing to introduce a Rx only TRP restricted to FR1. This is obviously a redundant enhancement.

It is the same as in 4G era, Macro cell products were deployed first and the small cell products were deployed thereafter targeting for coverage hole and increasing the capacity. It is the same logic for the NR mid-band. And currently we have deployed the low power TRP or small cells in our commercial networks.

Under this situation, I see NO motivation for Rx only TRP enhancements only for FR1.

On the other hand, current power control mechanisms could be reused for Rx only TRP with reconfiguration of P0 and adjustment of TPC. And for the UL beam management, SRS in FR1 is omni-directional and SRS in FR2 could be configured with the usage of beam management.

Please the proponents clarify and elaborate more what shall we enhance?

**18 – TELECOM ITALIA S.p.A.**

Support DOCOMO

**19 – China Telecommunications**

We share the similar view that it is related to MIMO and should be discussed in MIMO thread. We don't support to include UL dense deployment in UL enhancement WI.

**20 – NTT DOCOMO INC.**

<Moderator comment>

Thanks for further feedbacks and discussion.

Although whether/where to accommodate this potential objective can be discussed in RAN#94e, here we should try to clarify potential scope for this potential objective as we have discussed during this email discussion.

In that sense, the moderator would like to update the proposed potential objective based on the feedbacks so far like below.

**[Study and if necessary specify following enhancements for UL dense deployment and/or asymmetric beamforming operation between DL/UL, targeting [FR1 and/or FR2] (RAN1)]**

- **[UL power/timing control and UL beam management, with considering UL reception only points, including whether existing mechanisms can work with UL reception only points]**

**21 – Ericsson LM**

While this is an interesting area, it’s still not clear to us what the study entails. Diverse use cases are mentioned such as receive only nodes, low power Tx nodes, and asymmetric beamforming. As there is some need to downselect objectives so that we can have 1 TU for UL enhancements, we prefer to not have this objective at this time.

**22 – LG Electronics Inc.**

We are not sure if this proposed objective has enough discussion and supports during the NWM discussion. The reason for enhancement or necessary specification changes seems unclear yet. We also think this topic should be treated in MIMO item if to be.

**23 – Guangdong OPPO Mobile Telecom.**

This topic can be discussed in MIMO discussion and could be MIMO WI.

**24 – MediaTek Inc.**

We are still pretty unclear what the objective is here. How is UL power control working for an Rx only node? If it is an Rx only node what needs to be specified? If it is not an Rx only node then it anyway needs a DL so what is the value of that commercially? We do not think this objective is ready to be included here, as at least the concept needs to be clear first.

## 4.1.8 Others

Companies are encouraged to provide feedbacks on the observations in 3.2.8 and any other comments. In the final round, the moderator will appreciate if companies focus on essential comment only.

**Feedback Form 24: Others****1 – China Telecommunications**

We don’t think left overs of Rel-17 WI on coverage enhancement can be precluded. We can accept to put it into the bracket, i.e. [Left overs of Rel-17 WI on coverage enhancement].

**2 – Ericsson LM**

We agree with the moderator that current potential scope/objectives of the UL enhancements are already too many and hence other topics cannot be accommodated.

## 4.2 Moderator Summary and recommendation for further discussion

## 4.2.1 General

Thank you very much for valuable discussions, feedbacks and constructive suggestions from many companies.

As confirmed during previous rounds of discussions, the majority considers “UL enhancement” as one of promising topics for Rel-18 and it can be RAN1 led WI while some of objectives would have a study phase.

The initial draft of overall justification for UL enhancements WI can be provided as below based on the

feedbacks. Some parts are within brackets as corresponding objectives still need further discussion in RAN#94-e on whether/where to accommodate the objectives.

**Table 2: Updated draft overall justification for potential UL enhancement WI**

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Coverage is one of the key factors that an operator considers when commercializing cellular communication networks due to its direct impact on service quality as well as CAPEX and OPEX. UL performance could be the bottleneck in most of scenarios in real deployment, while there are emerging vertical use cases that have UL heavy traffic, e.g., video uploading. In Rel-17 work item 900061 “NR Coverage Enhancements”, NR coverage has been extended for some of the bottleneck channels identified in the Rel-17 study item 860036 “Study on NR coverage enhancements”, in particular for PUSCH, PUCCH and Msg3. However, not all needs for coverage enhancement have been addressed by the Rel-17 WID, due to its limited scope.

In RAN Rel-18 Workshop in June 2021, UL enhancements have been identified as one of the key areas of interest by multiple players including operators, network and UE vendors and various industries, as reflected by the number of contributions proposing UL coverage and capacity enhancements based on the real and urgent demands for improving UL performance on top of Rel-17 enhancements.

Following justifications for specific UL enhancements have been identified during RAN Rel-18 email discussions.

- In Rel-17, PRACH coverage enhancement has not been addressed, despite being identified as one of the bottleneck channels in the corresponding studies. PRACH transmission is very important for many procedures, including initial access and contention-based beam failure recovery.
  
- [The UE transmission power is the most valuable resource in uplink and enhancements to unlock additional uplink power are highly valuable for both UL coverage and capacity. There are some studies and works in Rel-17 on the power domain, such as in “Study on NR coverage enhancements” and “Increasing UE power high limit for CA and DC”, and hence some further study is necessary to exploit the Rel-17 studies/works.]
  
- [For multi-carrier UL operation, there are some limitations of current specification, e.g. 2Tx UE can be configured with at most 2 UL bands, which only can be changed by RRC reconfiguration, and UL Tx switching can be only performed between 2 UL bands for 2Tx UE. 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 rate, spectrum utilization and UL capacity.]
  
- [DFTS-OFDM waveform is beneficial for UL coverage limited scenario because of its lower PAPR compared with CP-OFDM waveform. Currently, UL waveform is configured via RRC and only single layer transmission is supported. These limitations impose a large barrier to switch over to DFTS-OFDM waveform for cell-edge UEs practically.]
  
- [In case of dense deployment where pathloss can be low, it would be possible to use wider bandwidth including UL CA for UL transmission with sufficient PSD so that UL performance can be largely improved. Considering that the dense deployment has some practical issues e.g., large cell planning effort for inter-cell interference coordination, one possible scenario to realize the dense deployment for UL is to deploy UL reception only points. In such scenario, since DL and UL are asymmetric, some enhancements are necessary for UL power control and beam management.]
  
- [In Rel-17, PUCCH coverage enhancements are introduced based on repetitions using multiple UL slots. However, those mechanisms may not be available in case of TDD bands with limited UL slot configuration, such as DDDSU and may not be practically useful due to existing collision handling rules. Therefore, there is a demand to enhance the coverage performance of PUCCH/UCI not relying on repetitions using multiple consecutive UL slots.]

#### 4.2.2 PRACH coverage enhancements

Based on the feedbacks, all companies seem to be ok to have this objective as part of UL enhancements WI, but following points need further discussion.

- Whether multiple PRACH transmissions with different beams is included, and if so whether study phase is needed for it
- Whether enhancements are also targeting 2-step RACH procedure
- Whether enhancements are format-agnostic and applicable to all short PRACH formats

Therefore, PRACH coverage enhancements can be considered as one of objectives for potential UL enhancements WI, and following updated objective can be used for further discussion in RAN#94-e.

##### 1. Specify following PRACH coverage enhancements (RAN1, RAN2)

- **Multiple PRACH transmissions with same beams targeting 4-step RACH [and 2-step RACH] procedures**
- **[Study, and if justified, specify PRACH transmissions with different beams targeting 4-step RACH [and 2-step RACH] procedures]**
- **Note: The enhancements of PRACH are targeting for FR2, which can also apply to FR1 when applicable.**
- **Note: The enhancements of PRACH are [format-agnostic and] targeting [for PRACH format B4, which can also apply to other] short PUCCH formats [when applicable].**

#### 4.2.3 PUCCH coverage enhancements

Based on the feedbacks, it seems that companies are still having different views on the necessity of possible objectives for PUCCH coverage enhancements. Following points need further discussion.

- Whether short study on DMRS-less PUCCH with UCI payload size from 3 to 11 bits is included, and if so whether/how any additional scope limitation is done
- Whether short study on DFTS-OFDM for short PUCCH with UCI payload size from 3 to 11 bits is included, and if so whether/how any additional scope limitation is done
- Whether short study on repetition of CSI in dynamically indicated PUSCH resources is included, and if so whether/how any additional scope limitation is done

Therefore, following updated potential objective can be used for further discussion in RAN#94-e, but based on the current situation this potential objective may need to be considered as lower priority.

##### 1. [Study and if necessary specify following coverage enhancements for PUCCH/UCI (RAN1)]

- [DMRS-less PUCCH with UCI payload size from 3 to 11 bits]
- [DFTS-OFDM waveform for short PUCCH with UCI payload size from 3 to 11 bits]
- [Repetition of CSI in dynamically indicated PUSCH resources]

#### 4.2.4 Power domain enhancements

Based on the feedbacks, it seems that there are still several companies not ready to accept the study on power domain enhancement, although multiple companies including multiple operators argued that the power domain enhancement is one of key aspects for UL enhancements. Following points need further discussion.

- Whether study on dynamic power aggregation is included, and if so whether target is FR1, FR2 or both, whether this is RAN1 led objective or RAN4 led objective (including possibility of separate RAN4 SI)
- Whether study on MPR reduction is included, and if so whether target is FR1, FR2 or both, whether this includes RAN1 or not (including possibility of separate RAN4 SI) and whether/how any additional scope limitation/clarification is done

Therefore, following updated potential objective can be used for further discussion in RAN#94-e.

#### 1. [Study and if necessary specify following power domain enhancements]

- [Enhancements to realize dynamic power aggregation based on Rel-17 RAN4 work on “Increasing UE power high limit for CA and DC”, with checking relevant regulations ([RAN1,] RAN4)]
  - [Note: The study can start after RAN4 work on “Increasing UE power high limit for CA and DC is done depending on conclusions from RAN4.]
- [Enhancements to reduce MPR/PAR, including new transmission mechanism such as spectrum shaping, [reduced spectrum utilization with relaxed requirements on channel filtering,] [and potential adjustments to MPR and test tolerance relations] (RAN4[, RAN1))]

#### 4.2.5 Enhancements for multi-carrier UL operation

Based on the feedbacks, it seems that there are still several companies not ready to accept the enhancement for multi-carrier UL operation (even study for it) although multiple companies including operators strongly support this enhancement. Following points need further discussion.

- Whether study on enhancements for multi-carrier UL operation is included, and if so whether target is UL Tx switching across 3 bands or not limited to just 3 bands, and whether/how any additional scope limitation is done

Therefore, following updated potential objective can be used for further discussion in RAN#94-e.

1. [Study and if necessary specify following enhancements for multi-carrier UL operation]

- [UL Tx switching schemes across [more than 2] bands with restriction of 2 Tx simultaneous transmission for FR1 UEs, including mechanisms to enable more configured UL bands than its simultaneous transmission capability and to support dynamic Tx carrier switching across the configured bands (RAN1)]
- [Switching time and other RF aspects for above UL Tx switching schemes across [more than 2] bands (RAN4)]

4.2.6 Enhancements for DFTS-OFDM

Based on the feedbacks, it seems that companies are still having different views on the necessity to have both of two enhancements (dynamic switching and multi-layer) but it has been identified that majority prefers to have at least one of enhancements. Although the moderator suggested to have a study aiming for selecting one of them, there is an objection. Between two enhancements, it seems larger number of companies prefer to support the dynamic switching, but there are several other companies having opposite preference. Following points need further discussion.

- Whether study on enhancements for DFTS-OFDM aiming to select one of two potential enhancements is included or only one is selected in WID (without studying both of them)
- Whether/how any additional scope limitation is done, e.g., maximal rank of DFTS-OFDM if multi-layer is supported
- Where to accommodate this objective especially if multi-layer is to be included, such as in MIMO WI or in UL enhancement WI

Therefore, following alternatives for updated potential objective can be used for further discussion in RAN#94-e.

Alt.1:

1. [Study and if necessary specify following enhancements for DFTS-OFDM (RAN1)]

- [Dynamic switching between DFTS-OFDM and CP-OFDM]
- [Multi-layer transmission with DFTS-OFDM, with considering LTE design]
- [Note: the study targets to select only one of above enhancements, unless necessity to specify both enhancements is justified in the study]

Alt.2:

1. [Specify following enhancements for DFTS-OFDM (RAN1)]

- [Dynamic switching between DFTS-OFDM and CP-OFDM]
- [Study and if justified to support this on top of above dynamic switching, specify multi-layer transmission with DFTS-OFDM, with considering LTE design]

#### 4.2.7 Enhancements for UL dense deployment

Based on the feedbacks, it seems that there are several companies arguing that this should be low priority and/or scope for the study is unclear, while there are multiple companies supporting the proposed study. Also, many companies argued that this objective should be discussed in MIMO discussion. Following points need further discussion.

- Whether study on enhancements for UL dense deployment is included, and if so whether/how any additional scope clarification and limitation are done
- Where to accommodate this objective if included, such as in MIMO WI or in UL enhancement WI

Therefore, following updated potential objective can be used for further discussion in RAN#94-e.

1. **[Study and if necessary specify following enhancements for UL dense deployment and/or asymmetric beamforming operation between DL/UL, targeting [FR1 and/or FR2] (RAN1)]**
  - o **[UL power/timing control and UL beam management, with considering UL reception only points, including whether existing mechanisms can work with UL reception only points]**

#### 4.2.8 Other potential enhancements

Based on the feedbacks, although there is a comment that leftovers of Rel-17 coverage enhancement WI should also be considered, there is another comment that current potential scope/objectives for UL enhancements are already too many and hence other topics cannot be accommodated.

Therefore, **the moderator suggests focusing on current potential scope/objectives for further discussion on UL enhancements in RAN#94-e.**

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## 5 Moderator's proposed summary

Proposal 1: Potential Rel-18 UL enhancements can be RAN1 led WI with no interaction with SA/CT. RAN2 and RAN4 may be secondary WGs but it depends on the final objectives.

Proposal 2: Following draft of overall justification for UL enhancements can be used for further discussion in RAN#94e.

**Table 3: Draft of overall justification for UL enhancements**

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Coverage is one of the key factors that an operator considers when commercializing cellular communication networks due to its direct impact on service quality as well as CAPEX and OPEX. UL performance could be the bottleneck in most of scenarios in real deployment, while there are emerging vertical use cases that have UL heavy traffic, e.g., video uploading. In Rel-17 work item 900061 “NR Coverage Enhancements”, NR coverage has been extended for some of the bottleneck channels identified in the Rel-17 study item 860036 “Study on NR coverage enhancements”, in particular for PUSCH, PUCCH and Msg3. However, not all needs for coverage enhancement have been addressed by the Rel-17 WID, due to its limited scope.

In RAN Rel-18 Workshop in June 2021, UL enhancements have been identified as one of the key areas of interest by multiple players including operators, network and UE vendors and various industries, as reflected by the number of contributions proposing UL coverage and capacity enhancements based on the real and urgent demands for improving UL performance on top of Rel-17 enhancements.

Following justifications for specific UL enhancements have been identified during RAN Rel-18 email discussions.

- In Rel-17, PRACH coverage enhancement has not been addressed, despite being identified as one of the bottleneck channels in the corresponding studies. PRACH transmission is very important for many procedures, including initial access and contention-based beam failure recovery.
  
- [The UE transmission power is the most valuable resource in uplink and enhancements to unlock additional uplink power are highly valuable for both UL coverage and capacity. There are some studies and works in Rel-17 on the power domain, such as in “Study on NR coverage enhancements” and “Increasing UE power high limit for CA and DC”, and hence some further study is necessary to exploit the Rel-17 studies/works.]
  
- [For multi-carrier UL operation, there are some limitations of current specification, e.g. 2Tx UE can be configured with at most 2 UL bands, which only can be changed by RRC reconfiguration, and UL Tx switching can be only performed between 2 UL bands for 2Tx UE. 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 rate, spectrum utilization and UL capacity.]
  
- [DFTS-OFDM waveform is beneficial for UL coverage limited scenario because of its lower PAPR compared with CP-OFDM waveform. Currently, UL waveform is configured via RRC and only single layer transmission is supported. These limitations impose a large barrier to switch over to DFTS-OFDM waveform for cell-edge UEs practically.]
  
- [In case of dense deployment where pathloss can be low, it would be possible to use wider bandwidth including UL CA for UL transmission with sufficient PSD so that UL performance can be largely improved. Considering that the dense deployment has some practical issues e.g., large cell planning effort for inter-cell interference coordination, one possible scenario to realize the dense deployment for UL is to deploy UL reception only points. In such scenario, since DL and UL are asymmetric, some enhancements are necessary for UL power control and beam management.]
  
- [In Rel-17, PUCCH coverage enhancements are introduced based on repetitions using multiple UL slots. However, those mechanisms may not be available in case of TDD bands with limited UL slot configuration, such as DDDSU and may not be practically useful due to existing collision handling rules. Therefore, there is a demand to enhance the coverage performance of PUCCH/UCI not relying on repetitions using multiple consecutive UL slots.]

Proposal 3: Following potential objectives for UL enhancements can be used for further discussion in RAN#94e

**Table 4: Potential objectives for further discussion in RAN#94e**

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Specify following PRACH coverage enhancements (RAN1, RAN2)

- Multiple PRACH transmissions with same beams targeting 4-step RACH [and 2-step RACH] procedures
- [Study, and if justified, specify PRACH transmissions with different beams targeting 4-step RACH [and 2-step RACH] procedures]
- Note: The enhancements of PRACH are targeting for FR2, which can also apply to FR1 when applicable.
- Note: The enhancements of PRACH are [format-agnostic and] targeting [for PRACH format B4, which can also apply to other] short PUCCH formats when applicable.

[Study and if necessary specify following power domain enhancements]

- [Enhancements to realize dynamic power aggregation based on Rel-17 RAN4 work on “Increasing UE power high limit for CA and DC”, with checking relevant regulations ([RAN1,] RAN4)]
  - [Note: The study can start after RAN4 work on “Increasing UE power high limit for CA and DC” is done depending on conclusions from RAN4.]
- [Enhancements to reduce MPR/PAR, including new transmission mechanism such as spectrum shaping, [reduced spectrum utilization with relaxed requirements on channel filtering,] [and potential adjustments to MPR and test tolerance relations] (RAN4[, RAN1))]

[Study and if necessary specify following enhancements for multi-carrier UL operation]

- [UL Tx switching schemes across [more than 2] bands with restriction of 2 Tx simultaneous transmission for FR1 UEs, including mechanisms to enable more configured UL bands than its simultaneous transmission capability and to support dynamic Tx carrier switching across the configured bands (RAN1)]
- [Switching time and other RF aspects for above UL Tx switching schemes across [more than 2] bands (RAN4)]

Alt.1:

[Study and if necessary specify following enhancements for DFTS-OFDM (RAN1)]

- [Dynamic switching between DFTS-OFDM and CP-OFDM]
- [Multi-layer transmission with DFTS-OFDM, with considering LTE design]
- [Note: the study targets to select only one of above enhancements, unless necessity to specify both enhancements is justified in the study]

Alt.2:

[Specify following enhancements for DFTS-OFDM (RAN1)]

- [Dynamic switching between DFTS-OFDM and CP-OFDM]

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Proposal 4: There are already too many potential scope/objectives for UL enhancements, and hence RAN should focus on current potential objectives in Proposal 3 for further discussion in RAN#94e.

Proposal 5: Following points would need further discussion in RAN#94e.

**Table 5: Controversial discussion points**

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For PRACH coverage enhancements,

- Whether multiple PRACH transmissions with different beams is included, and if so whether study phase is needed
- Whether enhancements are also targeting 2-step RACH procedure
- Whether enhancements are format-agnostic and applicable to all short PRACH formats

For PUCCH coverage enhancements,

- Whether short study on DMRS-less PUCCH with UCI payload size from 3 to 11 bits is included, and if so whether/how any additional scope limitation is done
- Whether short study on DFTS-OFDM for short PUCCH with UCI payload size from 3 to 11 bits is included, and if so whether/how any additional scope limitation is done
- Whether short study on repetition of CSI in dynamically indicated PUSCH resources is included, and if so whether/how any additional scope limitation is done

For power domain enhancements,

- Whether study on dynamic power aggregation is included, and if so whether target is FR1, FR2 or both, whether this is RAN1 led objective or RAN4 led objective (including possibility of separate RAN4 SI)
- Whether study on MPR reduction is included, and if so whether target is FR1, FR2 or both, whether this includes RAN1 or not (including possibility of separate RAN4 SI) and whether/how any additional scope limitation is done

For enhancements for multi-carrier UL operation,

- Whether study on enhancements for multi-carrier UL operation is included, and if so whether target is UL Tx switching across 3 bands or not limited to just 3 bands, and whether/how any additional scope limitation is done

For enhancements for DFTS-OFDM,

- Whether study on enhancements for DFTS-OFDM aiming to select one of two potential enhancements is included or only one is selected in WID (without studying both of them)
- Whether/how any additional scope limitation is done, e.g., maximal rank of DFTS-OFDM if multi-layer is supported
- Where to accommodate this objective especially if multi-layer is to be included, such as in MIMO WI or in UL enhancement WI

For enhancements for UL dense deployment,

- Whether study on enhancements for UL dense deployment is included, and if so whether/how any additional scope clarification and limitation are done
- Where to accommodate this objective if included, such as in MIMO WI or in UL enhancement WI