**3GPP TSG RAN meeting #94e RP-21xxxx**

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

**Agenda Item: 8.6.1**

**Source: China Telecom**

**Title: Moderator's summary for discussion [94e-09-R18-FurtherCovEnh]**

**Document for: Discussion**

1. Introduction

In RAN#93-e, UL enhancements (e.g. coverage enhancements; excluding MIMO) was identified as one of the potential areas for Rel-18 [1]. During the pre-RAN#94-e email discussion for Rel-18, justification and potential objectives of UL enhancements were discussed and summarized in [2]. After the discussion, a new WID on NR UL enhancements was drafted [3]. Based on the latest guidance in [4], the objectives of further UL coverage enhancements were revised as follows:

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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~~]~~ for FR2   + 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~~ (**moved to CA**)   + ~~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~~]~~ |

This contribution is a summary of email discussion on the new WID of further UL coverage enhancements including justification, objectives and time budget, following the guidance in [4].

1. Email discussion (initial round)

## Justification

Justification is updated to keep alignment with the objectives based on the guidance in [4].

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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. **After further discussion, the scope of UL enhancement is narrowed down to further UL coverage enhancement.**  ~~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.]~~ * ~~[~~DFT-S-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.]~~ |

Companies are encouraged to provide further comments on the justification.

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| **Companies** | **Comments** |
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## Objective 1

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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~~]~~ for FR2   + 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~~ PRACH formats when applicable. |

Companies are encouraged to provide further comments on the above objective, especially the content in the square brackets.

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| **Companies** | **Comments** |
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## Objective 2

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| * ~~[~~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])~~]~~ |

Companies are encouraged to provide further comments on the above objective, especially the content in the square brackets.

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| **Companies** | **Comments** |
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## Objective 3

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| * ~~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~~]~~ |

Companies are encouraged to provide further comments on the above objective.

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| **Companies** | **Comments** |
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## Others

Any other comments?

Note: Based on the guidance in [4], the time budget for the core part of the new WID is reserved for RAN1/2/4, but not yet for the performance part.

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| **Companies** | **Comments** |
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1. Reference
2. RP-262108, RAN Chair’s Summary for RAN Release 18, RAN#93e, 13th – 17th, September 2021.
3. RP-212662, Moderator's summary of discussion [RAN94e-R18Prep-02] UL Enhancements (e.g. coverage enhancements; excluding MIMO), 3GPP RAN# 94e, Dec. 2021.
4. RP-212702, New WID on NR UL Enhancements, 3GPP RAN# 94e, Dec. 2021.
5. RP-213469, Summary for RAN Rel-18 Package, 3GPP RAN# 94e, Dec. 2021.
6. RP-212908 Views on NR UL enhancements for Rel-18 Intel Corporation
7. RP-212941 Discussion on DMRS-less PUCCH for UL Coverage Enhancements EURECOM
8. RP-213051 Views on Rel-18 UL coverage Qualcomm Incorporated
9. RP-213058 Discussion on draft WID of Rel-18 NR UL enhancements NTT DOCOMO, INC.
10. RP-213085 Discussion on NR UL enhancement for Rel-18 China Telecom
11. RP-213154 On Uplink coverage enhancements in Rel-18 Ericsson
12. RP-213159 Comments on Rel-18 Uplink draft WID Huawei, HiSilicon
13. RP-213207 Discussion on WID on NR uplink enhancements CMCC
14. RP-213269 Discussion on Rel-18 UL enhancement vivo
15. RP-213280 On Rel-18 UL Enhancements Nokia, Nokia Shanghai Bell
16. RP-213321 Views on NR UL Enhancements NEC
17. RP-213394 On Uplink Enhancements for 5G Advanced ZTE, Sanechips
18. Appendix

Based on the contributions and pre-RAN#94-e email discussion, companies’ views on the objectives are summarized.

## Companies’ views on PRACH enhancement

* Enhancements also targets on 2-step RACH procedure.

**Support**: Qualcomm, NTT DOCOMO, NEC, Vodafone, Lenovo

**Not Support**: Intel, China Telecom, HW, HiSilicon, CMCC, vivo, ZTE, Ericsson

* Multiple PRACH transmission with different beams is also included

**Support**: Intel, China Telecom, HW, HiSilicon, ZTE, Lenovo, Apple, Spreadtrum

**Not Support**: NTT DOCOMO

* Whether the enhancements of PRACH are format-agnostic or targeting for PRACH format B4?

**Companies support format-agnostic**: NTT DOCOMO, HW, HiSilicon, NEC, Intel, Vodafone, Samsung

**Companies support targeting for PRACH B4**: China Telecom, CMCC, ZTE, Lenovo

To be more specific, 8 companies (Intel, China Telecom, HW, HiSilicon, CMCC, vivo, ZTE, Ericsson) prefer Alt.1-1 for the modifications on the **first bullet**, while 5 companies (Qualcomm, NTT DOCOMO, NEC, Vodafone, Lenovo) prefer Alt.1-2 as follows:

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| **Alt.1-1** Multiple PRACH transmissions with same beams targeting 4-step RACH ~~[and 2-step RACH]~~ procedures  **Alt.1-2** Multiple PRACH transmissions with same beams targeting 4-step RACH ~~[~~and 2-step RACH~~]~~ procedures |

10 companies (Intel, China Telecom, HW, HiSilicon, ZTE, apple, Lenovo, Spreadtrum, Nokia, NSB) prefer Alt.2-1 for the modifications on the **second bullet**, while 3 companies (vivo, Interdigital, NTT DOCOMO) prefer Alt.2-2 as follows:

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| **Alt.2-1** ~~[~~Study, and if justified, specify PRACH transmissions with different beams targeting 4-step RACH ~~[and 2-step RACH]~~ procedures~~]~~  **Alt.2-2** ~~[Study, and if justified, specify PRACH transmissions with different beams targeting 4-step RACH [and 2-step RACH] procedures]~~ |

Regarding the second note, companies’ views are summarized as the following two alternatives:

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| **Alt.3-1** 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~~.  **Alt.3-2** 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. |

## Companies’ views on power domain enhancement

8 companies (Intel, Qualcomm, NTT DOCOMO, HW, HiSilicon, CMCC, ZTE, AT&T) prefer the following modifications on the **first bullet** as in the following table, while some companies prefer to revisit dynamic power aggregation enhancement after the related RAN4 work is finished.

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| * + ~~[~~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.~~]~~ |

8 companies (NTT DOCOMO, China Telecom, HW, HiSilicon, Nokia, NSB, ZTE, AT&T) prefer the following modifications on the **second bullet** as in the following table, while 2 companies (Intel, CMCC) prefer not to include MPR/PAR reduction enhancement in Rel-18 UL enhancement, some companies prefer to revisit this topic when outcome of RAN4 WI is clear.

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| * + ~~[~~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])~~]~~ |

Besides, **HW** proposes some additional refinement on the objectives as:

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| * + …“Increasing UE power high limit for CA and DC”, ~~with checking relevant~~ in compliance with regulations…   + [Enhancements to increase cell-edge data rate, e.g.reduce MPR/PAR, including new transmission mechanism such as spectrum shaping with QPSK, multi-layer DFT-s-OFDM with pi/2 BPSK… |

**ZTE** proposes to delete “new transmission mechanism such as” in the second bullet.

**CMCC** proposes to delete “dynamic” in the first bullet as “~~dynamic~~ power aggregation”.

**Qualcomm** has the following views for dynamic power aggregation:

* The dynamic power aggregation objective should take into account the output of the RAN4 WI fully
* The RAN1 dynamic power aggregation objective should focus on providing the necessary information to the gNB scheduler regarding the UE power management state, in order to enable efficient UL scheduling
* Avoid spending time on defining UE SAR management algorithms, this has multiple RAN4 precedents of being left up to UE implementation
* Focus on FR1, although any specified solution can be specified to FR2 as well, if applicable

**Qualcomm** has the following views for MPR/PAPR reduction:

1. Suggest exclusive focus on improving MPR values via spectrum/waveform shaping

* Equal emphasis on lower and higher order modulations
* Equal emphasis on FR1 and FR2
* Consider both NS and non-NS value cases
* No new waveforms besides CP-OFDM and DFT-S-OFDM to be considered

2. Aspects related to RAN4 test tolerances need not be included in the scope

3. Aspects related to channel filtering are vague and open-ended. No need to include it explicitly.

* Also note that the current MPR tables are already sensitive to the size and location of RB allocation

**Ericsson** proposes additional considerations as:

* Jointly consider MPR and tolerances in deriving UE power backoff for meeting radio requirements (e.g. unwanted emission requirements), with a view toward reducing UE power backoff, in particular for FR2.
* For power domain enhancements, consider reduced spectrum utilization with relaxed requirements on spectrum confinement techniques for both single-carrier transmissions and intra-band contiguous UL CA to reduce MPR and/or reduce filter complexity.

## Companies’ views on enhancements for multi-carrier UL operation

Companies (NTT DOCOMO, China Telecom, HW, HiSilicon, CMCC, vivo, xiaomi, TELECOM ITALIA, Asia Pacific Telecom, CAICT, VODAFONE, LG, OPPO, SoftBank) support to include enhancements for multi-carrier UL operation in Rel-18 UL enhancement, while some companies (Nokia, Ericsson) don’t support this enhancement. Some companies (vivo) propose to move this part to CA/DC enhancement.

## Companies’ views on enhancements for DFTS-OFDM

* **Companies support Alt.1**: CMCC, HW, HiSilicon
  + CMCC only support the first bullet in Alt.1.
* **Companies support Alt.2**: NTT DOCOMO, China Telecom, vivo, Nokia, NSB, ZTE
  + Majority companies only support the first bullet of Alt.2, while Nokia/NSB also supports the second bullet.

Moreover, based on the pre-RAN#94-e email discussion, majority companies (Samsung, CTC, vivo, CM, CATT, HW, ZTE, NTT DOCOMO, Apple, xiaomi, Nokia, Spreadtrum, Rakuten Mobile, OPPO, MediaTek) prefer to only support dynamic switching between DFTS-OFDM and CP-OFDM in Rel-18 UL enhancement.

## Companies’ views on enhancements for UL dense deployment

* **Companies support to include enhancements for UL dense deployment in UL enhancement WID**:

Intel, NTT DOCOMO, Futurewei, Qualcomm, TELECOM ITALIA

* **Companies not support to include** **enhancements for UL dense deployment in UL enhancement WID**:

China Telecom, HW, HiSilicon, CMCC, vivo, ZTE, Samsung, vivo, InterDigital, Lenovo, CATT, ZTE, xiaomi, Ericsson, LG, OPPO, MediaTek

## Companies’ views on enhancements for PUCCH/UCI

* **Companies support the first bullet**: Eurecom, China Telecom, NEC, ZTE, xiaomi, Qualcomm, OPPO
* **Companies support the second bullet:** Qualcomm
* **Companies support the third bullet:** Ericsson, Qualcomm
* **Companies not support the whole objective**: Intel, NTT DOCOMO, CMCC, vivo, CATT, Lenovo, HW, HiSilicon, Samsung, MediaTek, Ericsson