**3GPP TSG RAN Meeting #102 RP-2xxxxx**

**Edinburgh, Scotland, December 11-15, 2023**

**Agenda Item:**  **9.3.1.3**

**Source: China Telecom**

**Title:** **Summary for WI** **on further NR coverage enhancements**

**WI code(s): NR\_cov\_enh2-Core**

**Leading WG: RAN1**

**Release: Rel-18**

### 1 Introduction

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. In Rel-17 work item 900061 “NR Coverage Enhancements” [1], NR coverage has been extended for some of the bottleneck channels identified in the Rel-17 study item 860036 “Study on NR coverage enhancements” [2], 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. This work item [3] specifies PRACH coverage enhancement, power domain enhancement and enhancement to support dynamic waveform switching.

### 2 Description

The following key functionalities are introduced as part of the Work Item:

* **PRACH coverage enhancement**

PRACH repetitions with the same Tx beam is introduced for 4-step RACH procedure. When one or multiple values of {2,4,8} are configured by the gNB for the number of PRACH repetitions, UE determines the number of repetitions based on SSB-RSRP threshold(s) for the first RACH attempt. If the number of PRACH repetitions is determined as 1 (i.e., single PRACH transmission) for the first RACH attempt, when the RACH attempt fails, UE can only perform single PRACH transmissions in re-attempts. If the number of PRACH repetitions is determined as larger than 1 for the first RACH attempt, when the RACH attempt fails, UE can increase the number of PRACH repetitions in re-attempts when certain condition is satisfied. For *N* PRACH repetitions, UE selects a set of *N* valid PRACH occasions (ROs) to transmit the PRACH with a same preamble, where the *N* valid ROs are consecutive in time, with the same frequency resources, and are associated with a same SSB. The whole *N* PRACH repetitions are deemed as one RACH attempt.

A time period, starting from frame 0, is introduced to determine the set(s) of ROs for PRACH repetitions. A time period is the smallest integer number of association pattern periods such that at least one set of valid ROs for each of the transmitted SSB indexes can be determined within the time period for all configured number of PRACH repetitions. The set(s) of valid ROs for each configured number of PRACH repetitions then repeats every time period.

Within a time period, for set(s) of *N* valid ROs associated with the same SSB for PRACH repetitions, and for each frequency resource index for frequency multiplexed PRACH occasions, the first valid RO of the first set is the first valid RO; if a RRC configured parameter *TimeOffsetBetweenStartingRO* is provided, the first valid PRACH occasion of subsequent sets, if any, is after *TimeOffsetBetweenStartingRO* consecutive valid ROs associated with the same SSB in time from the first valid RO of the previous set; if *TimeOffsetBetweenStartingRO* is not provided, the first valid PRACH occasion of subsequent sets, if any, is after the ROs of the previous set.

The feature of PRACH repetitions is supported for CBRA and *ReconfigurationWithSync* case for CFRA.

* **Enhancements to realize increasing UE power high limit for CA and DC**

Reporting the parameter $∆P\_{PowerClass}$ is introduced for FR1 deployments, on a per cell basis. Such reporting occurs whenever duty cycle is exceeded or advertised power capabilities are restored at the UE and may allow network to adjust attainable output power calculation for a given power class. A legacy PHR format carries the reporting, by reusing the 2 bits used for MPE reporting. $∆P\_{PowerClass}$ (valid and applicable for single band with single CC operation) or its variations, e.g., $∆P\_{PowerClass, CA}$ (for NR CA), is indeed used to cap lower and higher limit of configured transmitted power of $P\_{CMAX}$ (per serving cell) or those of $P\_{CMAX}$ (per aggregated cells), respectively. Specifically for the higher limit of the configured transmitted power,$∆P\_{PowerClass}$ et al. are the only parameters which are not configurable by network and must be known to calculate the corresponding higher limit of the configured transmitted power. For instance, for single band with single CC operation case,

$$P\_{CMAX\\_H,f,c}=min\left\{P\_{EMAX,c},P\_{PowerClass}-∆P\_{PowerClass} \right\}$$

where $P\_{EMAX,c}$ is configurable by network and $P\_{PowerClass}$ can be known by network since it is reported as UE capability of *ue-PowerClass* or its extension. Here, reporting $∆P\_{PowerClass}$, whose value can be 0, 3 or 6 dB, allows the network to have more precise information about the higher limit of the configured transmitted power at the UE.

For example, assume a PC 1.5 device, for which $P\_{PowerClass}=29 dBm$, being configured with $P\_{EMAX,c}=29 dBm$. Since $∆P\_{PowerClass}$ may be as high as 6 dB, e.g., due to satisfying regulation like SAR when scheduled uplink symbols % is too high, the $P\_{CMAX\\_H,f,c}$ can be as low as 23 dBm. It is, however, not possible for the network to be aware of when the UE sets $∆P\_{PowerClass}$ from 0 dB to 6 dB since the evaluation period, start and end timing of the evaluation is up to UE implementation. Given that the attainable power is one of the most important information for the network, the introduction of a scheme to allow UE to inform network of the value is beneficial at least when the scheme is configured and triggered by the network.

* **Enhancements to reduce MPR/PAR, including frequency domain spectrum shaping**

MPR reduction is introduced by allowing 1dB power boosting with and without frequency domain spectrum shaping for both pi/2 BPSK and QPSK with PC3 as well as PC2. Specifically, the reference power at the UE is increased equivalent to the power boost while the allowed MPR values are maintained. Such MPR reduction is currently available for the inner allocations with frequency domain spectrum shaping and accompanying spectrum flatness requirement relaxation as well as for a subset of the inner allocations with no frequency domain spectrum shaping and spectrum flatness requirement relaxation.

* **Dynamic waveform switching between DFT-S-OFDM and CP-OFDM**

. Dynamic waveform indication is introduced to allow the network to set the most beneficial waveform (e.g., DFT-S-OFDM waveform is beneficial for coverage, while CP-OFDM waveform is beneficial for capacity) considering the UE coverage situation without requiring RRC reconfiguration. The indication is applicable to PUSCH dynamically scheduled by DCI format 0\_1 or 0\_2 and is realized by introducing a transform precoder indicator field in these DCI formats, where transform precoder enabled or disabled corresponds to DFT-S-OFDM or CP-OFDM waveform, respectively.

In addition, reporting of configured maximum power for assumed PUSCH is introduced to assist the network in determining whether to change the waveform. The assumed PUSCH is with CP-OFDM waveform if the actual PUSCH is with DFT-S-OFDM waveform, and vice-versa. Two new MAC CEs are introduced for reporting this information together with legacy power headroom information of the actual PUSCH within a single entry PHR format or a multiple-entry PHR format.

### 3 References

1. RP-211566, “Revised WID on NR coverage enhancements”, China Telecom, RAN#92e, June 14th – 18th, 2021.
2. TR 38.830, v17.0.0, “Study on NR coverage enhancements”, December, 2020.
3. RP-221858, “Revised WID on further NR coverage enhancements”, China Telecom, RAN#96, June 6th – 9th, 2022.
4. RP-232272, “Status report for Further NR coverage enhancements”, China Telecom, RAN#101, September 11th – 15th, 2023.