

Agenda Item: 10.3.1.12
Source: Ericsson
Title: Power Headroom Reporting in NR
Document for: Discussion, Decision

1 Introduction

Based on RAN1 progress, this contribution analyses RAN2 aspects for PHR to enable further progress in RAN2. There is a corresponding text proposal in [1].

2 Discussion

2.1 Single-cell PHR format

In LTE, The Power Headroom reporting procedure is used to provide the serving eNB with information about the difference between the nominal UE maximum transmit power and the estimated power for UL-SCH transmission or SRS transmission per activated Serving Cell. It is also used to provide the serving eNB with information about the difference between the nominal UE maximum power and the estimated power for UL-SCH and PUCCH transmission on SpCell and PUCCH SCell. A similar procedure would be also required for NR.

LTE defines the following PHR MAC CE in Rel-8 as shown below for single connection (see 3GPP TS 36.321)

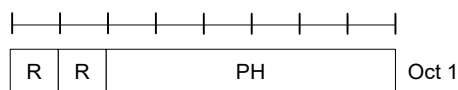


Figure 6.1.3.6-1: PHR MAC control element

It has a fixed size and consists of a single octet which is particularly valuable in scenarios with low bitrates (e.g. VoIP). This format is extended to support carrier aggregation in Rel-10 (up to 8 serving cells), and further extended to support PUCCH SCell and/or 32 serving cells in Rel-13. The DC PHR MAC is also defined in Rel-12 to support dual connectivity.

Since it for the extended PHR MAC CE has been agreed by RAN1 that NR CA supports 16 serving cells/CCs from Rel-15 onwards, it is sufficient to support only the *extendedPHR2* format.

Observation 1 The unified PHR MAC CE format used for both single connectivity and ‘dual connectivity and CA’ is not efficient single connectivity.

Proposal 1 NR reuses LTE PHR MAC CE for single serving cell scenario.

2.2 PHR considering two power control processes per cell

in RAN1-90bis, it was agreed that up to 2 closed loop power control processes (for PUSCH, PUCCH/SRS) can be configured per cell. The working assumption is that two closed loop power control processes can be applied in a NR cell with both SUL carrier and NR UL carrier, i.e. one closed loop power control process can be applied per UL carrier in one cell. Some other possible cases for applying two closed loop power control processes, such as two different serving beams, two different slot sets, two different logical channels etc, are still being discussed in RAN1.

Observation 2 Up to two closed loop power control processes per cell was agreed in RAN1.

The power headroom is estimated based on the difference between the maximum allowed transmission power and the actual transmission power. When there are two closed loop power control processes for PUSCH/PUCCH in a cell, the power adjustments for PUSCH/PUCCH transmissions subjected to different closed loop power control are different. One shared PH for two closed loop power control processes in one cell is infeasible.

Observation 3 It is necessary to estimate power headroom per closed loop power control process in a cell.

In RAN1-90bis, it was agreed that there is only one PUSCH in one slot per cell. When a NR cell has two UL carriers, e.g. NR UL carrier and SUL carrier, the only PUSCH in a single slot can be in either UL carrier configured via RRC/MAC/L1 signal.

Observation 4 Two simultaneous PUSCH transmissions one both SUL carrier and NR UL carrier in a NR cell for the same UE is not supported.

Even though there can be up to two closed loop power control processes per cell, one PUSCH transmission should be subject to only one power control process. This means in a single slot, there is only one PH estimated based on PUSCH transmission. The gNB can interpret the PHR based on the reference PUSCH transmission based on which the PH is generated, i.e. the gNB can determine the correspondence between the closed loop power control process and a PH in PHR based on the PUSCH scheduling information. Hence, we see that the current PHR generation and report procedure is still applicable.

Observation 5 The gNB can determine the mapping between a PH and the closed loop power control process based on the reference PUSCH for PH estimation.

Proposal 2 The support of two closed loop power control processes does not affect the existing PHR MAC CE format.

The propagation loss difference between NR UL carrier and SUL carrier can be very large because the propagation loss is roughly in proportion to the square of carrier frequency. It may be suboptimal to apply the same PHR triggering condition for different UL carriers. It would be preferred that NR provide a method to differentiate PHR triggering conditions for SUL carrier and NR UL carrier in one cell, i.e. one PHR triggering setting for SUL carrier and the other for NR UL carrier.

Proposal 3 NR supports separate PHR triggering settings (e.g. *dlPathLossChange*) for SUL carrier and NR UL carrier in one cell.

For a UE in cell centre, the UE can be served by NR UL carrier to benefit from huge carrier bandwidth since the radio quality can be good enough though the NR UL carrier can be high carrier frequency. When the UE moves to the poor radio quality position, the UE can be switched from NR UL carrier to SUL carrier to ensure the coverage via carrier activation/deactivation procedure. As the UL carrier switch, the PHR based on the old carrier is no longer applicable for the new carrier, and PHR should be triggered for the new carrier so that the gNB can allocate UL grant properly.

Proposal 4 PHR is triggered at carrier switch between SUL carrier and NR UL carrier

2.3 Further aspects

2.3.1 PHR with multiple numerologies

In LTE, an extended PHR may include PHs for multiple active serving cells. This PHR can be transmitted on any one of active serving cell. In NR, each serving cell in CA may be configured with different numerology/TTI duration, this means that a single PHR may include PHs for multiple serving cells with different numerologies.

Even within the same component carrier, it has been agreed in #RAN1 Ad Hoc held on 27th – 29th June 2017, that different BWPs can be configured, and each BWP could be configured with a certain numerology.

Here we see two relevant questions

1. *For CA, how to report a PHR in case multiple numerologies? i.e., which cell to send a PHR (PHR includes PHs for multiple service cells with different numerologies configured)*
2. *Is it necessary to apply numerology/BWP specific PHR configuration?*

We think it is sufficient to reuse LTE rules as we do not think the gNB scheduler and LA are so sensitive to latency. The network is aware of the numerology which is associated with each serving cell. Upon reception of the PHR, the network can interpret PHR accordingly, i.e., the power headroom situation when PHR is transmitted at the time (beginning of the TTI, that used to transmit PHR) for each serving cell. RAN1 has also agreed that NR supports single active BWP configured per UE. The UE may change its active BWP from time to time. This does not affect the PHR report. In other words, the NR UE reports PHR as that in LTE, i.e., report a single PHR for every serving cell. The PH value can be calculated based on the power allocation associated with the active BWP.

Therefore, it is sufficient to apply LTE PHR format and trigger in this case.

Proposal 5 The support of multiple numerologies/BWPs does not impact PHR format and triggers.

2.3.2 PHR with beam switch

A UE may be connected to multi-beams for enhanced bit rate or improved transmission reliability. RAN1 has already agreed that NR supports beam specific power control. The exact details on what this means are yet to be agreed upon but it is clear that it at least implies that the UE will maintain one path loss estimation per beam and it will be up to the gNB, or alternatively gNB and UE jointly, to define the set of monitored beams. The network will use one of these beams for PUSCH transmission and it will also decide when to change to another beam upon reception of UE measurements.

We see there are two options for PHR report with respect to beam specific power control.

Option 1: the UE reports a PHR per beam

Option 2: the UE only reports PHR for the beam used for PUSCH transmission

In Option 1, the UE would report PHRs for every beam although including also those currently not used for PUSCH transmission. The network then would hence obtain more information from PHR than that with Option 2. However, this additional information from non-used beams may be of limited use since the main purpose of PHR is to adopt the link adaptation for PUSCH transmission. At the same time, Option 1 may lead to unnecessary PHR overhead and require changes to the PHR format. Option 2 would on the other hand generate relevant PHR reports and we therefore find it more reasonable. It can use the same LTE PHR format and trigger. The gNB is aware of the serving beam that the UE uses at the TTI when the PHR was sent. Upon reception of a PHR, the gNB interprets the power headroom information for the associated beam.

For beamforming-based transmissions, the pathloss may experience a sudden fluctuation due to frequent blockage as well as the change of serving beam. For Option 2 such a situation would imply, in the case of a beam switch, that the UE measures on the new beam but the reference measurement is from the old beam. If the DL PL change (referred to as “*dl-PathlossChange*”) becomes more than *dl-PathlossChange* dB when switching beam, a new PHR would be triggered. This example explains how the beam switches would operate based on the LTE PHR format and trigger. From this example, it is also indicated that the subsequent DL PL measurements used in the PHR triggers may be from different serving beams.

Observation 6 When evaluating if a PHR can be trigger during the beam switch, the UE MAC entity may compare PL measurements between different beams (i.e. the measurement on a new beam but the reference measurement is from the old beam). In other words, the LTE parameter “*dl-PathlossChange*” is sufficient for PHR during beam-switches.

Hence, it is suggested that

Proposal 6 It is unnecessary to update PHR format and trigger with respect to the change of serving beams.

3 Conclusion

In section 2 we made the following observations:

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Based on the discussion in section 2 we propose the following:

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4 References

- [1] R2-1713574, "PHR Text proposal", Ericsson, RAN2#100
- [2] RP-172108, "Updated work plan of RAN 1 and 4 NR" NTT DOCOMO & drafting group.