**3GPP TSG RAN WG1 e-Meeting #104 R1-210XXXX**

**e-Meeting, January 25th – February 5th, 2021**

Agenda Item: 8.7.1.1

Source: Moderator (MediaTek)

Title: Summary for Paging Enhancements

Document for: Discussion and Decision

# Introduction

In RAN1 #103-e [1][2], RAN1 agrees to support paging early indication (PEI), and it remains to specify the physical design based on DCI, SSS or TRS/CSI-RS:

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| Agreements**:** For NR idle/inactive-mode paging enhancement, paging early indication before paging occasion is supported from RAN1 perspective   * FFS: Physical layer design based on DCI, SSS or TRS/CSI-RS * Send LS to inform RAN2 and kindly ask RAN2 to inform RAN1 if there is anything that RAN1 should take into consideration in the physical layer design for this feature, including any other progress RAN2 has made in this WI which may has RAN1 impact |

There is also an LS on paging enhancement from RAN2 [3]:

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| **1. Overall Description:**  In RAN2#112-e, RAN2 discussed UE grouping for paging enhancement in Rel-17 UE power saving WI. RAN2 confirmed that UE grouping is considered as a candidate of paging enhancements for UE power saving. Regarding paging for UE subgroups, RAN2 has discussed and considered the following methods:   * Paging indication for UE subgroups using paging DCI, with either same-slot or cross-slot scheduling; * Paging early indication (PEI) / wake-up signal (WUS) for UE subgroups; * UE subgroup indication by using multiple P-RNTIs; * Paging for UE subgroups using different time/frequency resources.   From RAN2 perspective, the last two methods are de-prioritized. Notice that these methods are not mutually exclusive.  **2. Actions:**  **To RAN1:**  RAN2 respectfully asks RAN1 to take the above information into consideration and provide information on the feasibility and limitations of carrying subgroup information with their recommended solution. |

Based on the agreement, RAN2 LS and companies’ contributions [4]-[31], this summary is devoted to characterize all possible PEI candidate designs over the agreed design considerations: Impact to paging detection performance, resource occupation, and power saving gain. In Section 2, fundamental assumptions for the characterization will be discussed and decided. And the subsequent sections will further specify and compare the PEI candidate designs toward the selection for PEI physical layer design.

# Initial Characterization for PEI Candidate Designs

In this Section, fundamental assumptions for the characterization will be discussed and decided.

## UE sub-grouping information in PEI

Whether to carry UE sub-grouping information in PEI is fundamental assumption/requirement to PEI physical layer design. From the observation in RAN1 #103-e, combining the two features are beneficial, particularly for the case where the original group paging rate is higher. On the other hand, from companies’ contributions, the power saving gain starts to saturate if there partition more than 8 sub-groups. Consequently, the following proposal and observation are suggested:

Proposal 1: Carrying UE sub-grouping information in paging early indication is supported.

Observation 1: The power saving gain starts to saturate if there partition more than [8] sub-groups for a UE group or a PO.

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| Agreements:  Observation: For NR idle/inactive-mode UEs, UE sub-grouping indication carried in paging early indication can provide the following power saving gains w.r.t Rel-16:   * If the original group paging rate is 10%:   + [10.6%] –[19.1%] where the baseline assumes 1 SS burst for synchronization before PO reception   + [16.0%] –[36.0%] where the baseline assumes 2 SS bursts for synchronization before PO reception   + [14.3%] –[46.0%] where the baseline assumes 3 SS bursts for synchronization before PO reception * Some sources also evaluated performance if the original group paging rate is in the range between 20% and 60% and showed following results:   + [8.0%] –[19.1%] where the baseline assumes 1 SS burst for synchronization before PO reception   + [18.1%] –[34.0%] where the baseline assumes 2 SS bursts for synchronization before PO reception   + [20.6%] –[42.0%] where the baseline assumes 3 SS bursts for synchronization before PO reception   The additional power saving gains w.r.t. paging early indication without UE sub-grouping are given as follows:   * If the original group paging rate is 10%:   + [0.6%] –[2.7%] where the baseline assumes 1 SS burst for synchronization before PO reception   + [0.6%] –[4.0%] where the baseline assumes 2 SS bursts for synchronization before PO reception   + [0.6%] –[4.7%] where the baseline assumes 3 SS bursts for synchronization before PO reception * Some sources also evaluated performance if the original group paging rate is in the range between 20% and 60% and showed following results:   + [1.3%] –[8.0%] where the baseline assumes 1 SS burst for synchronization before PO reception   + [2.1%] –[13.0%] where the baseline assumes 2 SS bursts for synchronization before PO reception   + [3.3%] –[16.1%] where the baseline assumes 3 SS bursts for synchronization before PO reception   The number of UE sub-groups evaluated ranges from 2 to 16.  The power saving gains are dependent on the assumptions about placement of PEI and PO relative to SSB.  Note: It is FFS in RAN1 another group paging rate > 10% for the evaluation of Rel-17 paging enhancement.  Note: Not all sources providing results for paging early indication without UE sub-grouping also provide results for paging early indication with UE sub-grouping. |

Companies please provide comments/suggested revisions to Proposal 1 and Observation 1 in Table 1:

Table 1: Companies’ comments/suggested revisions to Proposal 1 and Observation 1

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| **Company** | **Comment(s)/Suggested Revision(s)** |
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## UE Behavior if UE Misses PEI

For characterizing PEI candidate designs, the required UE behavior when UE misses PEI will cause fundamental difference to the performance metrics. From companies’ contributions, there are two behaviors:

* Behv-A: UE is not required to monitor PO if UE misses PEI for the targeted PO
* Behv-B: UE is required to monitor PO if UE misses PEI for the targeted PO

The proposal is therefore suggested for characterizing PEI candidate designs, and companies please input your comments/suggested revisions in Table 2.

Proposal 2: The following UE behaviors are considered in charactering PEI candidate designs based on PDCCH, TRS/CSI-RS and SSS:

* **Behv-A: UE is not required to monitor PO if UE misses PEI for the targeted PO**
* **Behv-B: UE is required to monitor PO if UE misses PEI for the targeted PO**
* **FFS: Whether selection of the required UE behavior is based on network configuration**

Table 2: Companies’ comments/suggested revisions to Proposal 2

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We can further confirm the following properties based on Behv-A and Behv-B, respectively:

Proposal 3: When Behv-A is assumed for UE,

* **The joint miss-detection rate (MDR) of PEI and paging PDCCH should be no worse than paging PDSCH performance for minimum impact to paging detection performance**
* **The false-alarm rate (FAR) of PEI should be no larger than [1%] for minimum impact to power saving gain with PEI**

Proposal 4: When Behv-B is assumed for UE,

* **The miss-detection rate (MDR) and the false-alarm rate (FAR) of PEI should both be no larger than [1%] for minimum impact to power saving gain with PEI**
* **Note: Conditioned on this UE behavior, there is no impact to paging detection performance**

Companies please input your comments/suggested revisions to Proposal 3 and Proposal 4 in Table 3:

Table 3: Companies’ comments/suggested revisions to Proposal 3 and Proposal 4

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## Assumptions for Resource Occupation

To characterize the resource occupation for PEI candidate designs, the following should be confirmed:

Proposal 5: For PEI design based on PDCCH and Behv-A/B, abbreviated by PEI-PDCCH-Behv-A/B,

* Resource allocation is in CSS
* For PEI-PDCCH-Behv-A: No PEI transmission only if there is no associated UE to be paged
* **For PEI-PDCCH-Behv-B: No PEI transmission only if resource conflict with legacy PDCCH**

Proposal 6: For PEI design based on TRS/CSI-RS and Behv-A/B, abbreviated by PEI-TRS-Behv-A/B,

* Resource allocation is in PDSCH region for connected-mode UEs
  + Rel-15 zero-power CSI-RS rate-matching pattern(s) or RB-symbol rate-matching pattern(s) should be configured to connected-mode UEs to avoid resource conflict
  + For UE supporting rate-matching per dynamic DCI indication, the resource can be utilized for PDSCH transmission to the UE if no PEI is transmitted.
  + For UE not supporting rate-matching per RRC configuration, the resource cannot be utilized for PDSCH transmission to the UE once the rate-matching pattern is configured to the UE.
* For PEI-PDCCH-Behv-A: No PEI transmission only if there is no associated UE to be paged
* **For PEI-PDCCH-Behv-B: PEI is always transmitted (i.e., higher priority than PDSCH of connected-mode UE)**
  + **Note: This allows the PEI to be utilized for synchronization**

Proposal 7: For PEI design based on SSS and Behv-A/B, abbreviated by PEI-SSS-Behv-A/B,

* Resource allocation is in PDSCH region for connected-mode UEs
  + Rel-15 RB-symbol rate-matching pattern(s) should be configured to connected-mode UEs to avoid resource conflict
  + For UE supporting rate-matching per dynamic DCI indication, the resource can be utilized for PDSCH transmission to the UE if no PEI is transmitted.
  + For UE not supporting rate-matching per dynamic DCI indication, the resource cannot be utilized for PDSCH transmission to the UE once the rate-matching pattern is configured to the UE.
* For PEI-PDCCH-Behv-A: No PEI transmission only if there is no associated UE to be paged
* **For PEI-PDCCH-Behv-B: PEI is always transmitted (i.e., higher priority than PDSCH of connected-mode UE)**
  + **Note: This allows the PEI to be utilized for synchronization**

Companies please input your comments/suggested revisions to Proposal 5, Proposal 6 and Proposal 7 in Table 4:

Table 4: Companies’ comments/suggested revisions to Proposal 5, Proposal 6 and Proposal 7

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# 1st Round of Offline Discussion and Proposals

(To be updated)

# Summary

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# References

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