3GPP TSG-RAN2 Meeting #116-e R2-210xxxx

eMeeting, 1st – 12th November, 2021

Agenda Item: 8.9.2.2 Control and Procedure details

Source: Ericsson

Title: Summary of [AT116-e][046][ePowSav] Paging Early Indication

Document for: Discussion and Decision

# Introduction

This report provides a summary of the following offline discussion:

* [AT116-e][046][ePowSav] Paging Early Indication (Ericsson)

Scope: Address PEI proposals submitted to this meeting (pl select top down the most important proposals) collect comments, and identify agreeable proposals.

Intended outcome: Report

Deadline: Wed W2

The deadline for providing comments is **Monday 8th November 13:00 UTC**.

A summary will be provided for the online session **Wednesday** **10th November 05:00 UTC.**

# Contact information

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# Background

The following contributions are treated in this offline (from chairman notes):

PEI

1. [R2-2109453](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2//TSGR2_116-e/Docs/R2-2109453.zip) PEI configuration and monitoring procedures Qualcomm
2. [R2-2109491](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2//TSGR2_116-e/Docs/R2-2109491.zip) Discussion on PEI monitoring OPPO
3. [R2-2109521](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2//TSGR2_116-e/Docs/R2-2109521.zip) UE Idenity for paging subgrouping Samsung
4. [R2-2110415](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2//TSGR2_116-e/Docs/R2-2110415.zip) PEI monitoring in last used cell Ericsson, Vodafone
5. [R2-2111135](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2//TSGR2_116-e/Docs/R2-2111135.zip) Remaining issues on PEI monitoring Xiaomi

The rapporteur thinks that the following proposals in [1-5] are being discussed in RAN1 and should not be discussed in this offline, i.e. RAN2 should wait for the RAN1 outcome:

From [1]:

**Proposal 1. PEIs are directly associated with paging occasions and this association can cross paging frames.**

**Proposal 2. PEI is transmitted at least T>1 slots before its associated POs.**

**Proposal 3. PEI is transmitted in a monitoring occasion (MO) in paging search space (SS) which is the closest to its associated POs and satisfies the following additional conditions:**

* **it is within the first set of MO in paging SS right after an SSB;**
* **it is at least T slots before any of the POs associated the PEI.**

**Proposal 4. If multiple PEIs are configured for a PO, then two adjacent PEIs for the same PO are separate by at least K≥1 SSBs, where K is configured by network.**

**Proposal 5. PEI configuration is cell specific.**

From [5]:

1. Wait for more RAN1’s input for UE PEI capability design in RAN2.
2. RAN2 to confirm that one PEI can be configured to indicate up to 4 PO(s) in a PF as well as can be applied to the subsequent PO monitoring in the next paging cycle.

# Discussion

For some questions additional background information is provided. But in any case a reference to the contribution is provided when more background information is needed.

## PEI monitoring basic

**Question 1**: Do companies agree with the following proposal [1]?:

**Proposal: If PEI is detected, UE expects to receive paging DCI in the associated PO, which contains the scheduling information for paging PDSCH as in legacy.**

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| --- | --- | --- |
| **Company** | **Yes/No** | **Comments** |
| Ericsson | Yes | With the correction/addition that the associated PO may also include Short Message in Paging DCI only, see next question. |
| Vodafone | yes |  |
| Samsung | Yes |  |
| MediaTek | Yes | Such agreement should be made by RAN1? But it’s fine to confirm again in RAN2. |
| OPPO | Yes with comments | We want to clarify that “PEI is detected” means “PEI is detected which indicates UE to wake up” since there may be the other case that “PEI is detected which indicates UE not to wake up”. Also since PEI can be mapped to several POs, this should be reflected. Modification of proposal is proposed as:  **If PEI is detected which indicates UE ~~to wake up~~has a page, UE expects to receive paging DCI in the associated PO(s), which contains the scheduling information for paging PDSCH as in legacy.**  [QC] Agree with the change. And we think “has a page” is better than “to wake up”. The intention of this proposal is to confirm that scheduling information for paging PDSCH is provided in paging PDCCH as in legacy, even if PEI is configured. |
| LGE | Yes |  |
| Qualcomm | Yes | Based on the comment by OPPO, we suggest to update the proposal as follows:  “Scheduling information for paging PDSCH is provided in paging PDCCH as in legacy, even if PEI is configured, i.e. if PEI is detected which indicates UE has a page, UE expects to receive paging DCI in the associated PO(s), which contains the scheduling information for paging PDSCH as in legacy.” |
| Futurewei | Yes with | the assumption that the PEI refers to the PEI with the subgroup ID of the UE being indicated.  The subgroup ID of the UE being indicated in the PEI doesn’t necessarily means that the UE has a page. So, we disagree with Qualcomm’s suggested change. Oppo’s suggested change is OK. |
| Intel | Partially Yes | With the correction/addition that UE is only expected to receive paging DCI if its subgroup is indicated in the PEI |
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**Question 2**: Do companies agree with the following proposal [1]?:

**Proposal: Network sends PEI if there is a short message for UE, but the short message itself is sent in paging DCI as in legacy.**

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| **Company** | **Yes/No** | **Comments** |
| Ericsson | Yes |  |
| Samsung | See comments | It can be beneficial to include short message in DCI of PEI. However, if majority view is that short message is only included in paging DCI, network will send PEI. |
| MediaTek | Yes |  |
| OPPO | Yes |  |
| LGE | No | RAN1 is discussing this issue and it should be decided by RAN1. One of option on the table is the SI change notification and ETWD/CMAS notification are indicated in PEI DCI. |
| Qualcomm | Yes | In our view, the main use of PEI is to wake up UE. The reason of this wakeup, whether it is due to a page and a short message, should be signalled in paging DCI as in legacy. Such a design would keep PEI processing as simple (hence low power) as possible. In addition, it gives UE an option to skip PEI if it chooses to do so (e.g. after not receiving PEI for several paging cycles in a row). |
| Futurewei | Yes |  |
| Intel | Yes | We assume the PEI here refers to the PEI with the subgroup ID of the UE being indicated as well. |
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## PEI monitoring with and without eDRX

The rapporteur took the liberty to reformulate Proposals 8 and 9 in [1]. First a quick recap on the PO monitoring requirements in Idle and Inactive mode. In 38.300 it is specified that the UE monitors the PO according to **used DRX cycle** (DRX cycle T in 38.304):

The Paging DRX cycles are configured by the network:

1) For CN-initiated paging, a default cycle is broadcast in system information;

2) For CN-initiated paging, a UE specific cycle can be configured via NAS signalling;

3) For RAN-initiated paging, a UE-specific cycle is configured via RRC signalling;

- The UE uses the shortest of the DRX cycles applicable i.e. a UE in RRC\_IDLE uses the shortest of the first two cycles above, while a UE in RRC\_INACTIVE uses the shortest of the three.

According to 38.331 the UE monitors Paging in Idle and Inactive according to:

**- RRC\_IDLE**:

…

- The UE:

- Monitors Short Messages transmitted with P-RNTI over DCI (see clause 6.5);

- Monitors a Paging channel for CN paging using 5G-S-TMSI;

…

**- RRC\_INACTIVE**:

…

The UE:

- Monitors Short Messages transmitted with P-RNTI over DCI (see clause 6.5);

- Monitors a Paging channel for CN paging using 5G-S-TMSI and RAN paging using fullI-RNTI;

Then about extended DRX (eDRX) in NR: under the RedCap work item it was agreed:

1. eDRX feature is optional for any UE (including RedCap and non-RedCap UEs).

The eDRX is up to 3 hours in Idle and up to 10,24 sec in Inactive mode.

**Question 3**: Do companies agree with the following updated proposal from [1]?:

**Proposal: If UE is not configured with eDRX,**

* **UE monitors PEI according to the used DRX cycle in RRC Idle and RRC Inactive**

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| **Company** | **Yes/No** | **Comments** |
| Ericsson | Yes |  |
| Vodafone | Yes |  |
| Samsung | Yes |  |
| MediaTek | Yes |  |
| OPPO | Yes |  |
| LGE | Yes |  |
| Qualcomm | See comment | It seems that the rapporteur misunderstood our intention and the proposal. We are fine to support the proposal from the rapporteur and keep ours as UE implementation. |
| Futurewei | Yes |  |
| Intel | Yes |  |
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It is the understanding of the rapporteur that RAN1 assumes that the NR UE uses 4 antennas when monitoring PEI, while a RedCap UE may use only 1-2 antennas, i.e. whether PEI can be used by RedCap UE should be further discussed under RedCap work item.

Furthermore it is not clear to the rapporteur if PEI can be used when the NR UE wakes-up from a very long sleep period (e.g. up to 3 hours in Idle mode). Furthermore eDRX is making use of a Paging Transmission Window (PTW) where the UE monitors consecutive POs according to the legacy DRX during the PTW duration, which RAN1 has not considered. It is questionable what is the additional power saving of PEI when a long eDRX is configured. The rapporteur thinks that RAN1 should first discuss if PEI can be used with eDRX as defined in RedCap, before RAN2 makes further agreements:

**Question 4**: Do companies agree with the following updated proposal from [1]?:

**Proposal: RAN2 to check with RAN1 if PEI can be used with eDRX as introduced for NR UE under RedCap work item.**

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| **Company** | **Yes/No** | **Comments** |
| Ericsson | Yes | In our understanding this has not been discussed in RAN1, and this should be checked with RAN1. We are not sure if an LS needs to be sent to RAN1 about this, or companies can just bring this up in RAN1. |
| Vodafone | Not sure | I don’t yet see the RAN 1 impact. The eDRX concept is that the UE does a pre-wake up to synchronise, see if it has changed cell, needs to (re)read SI, etc. So no real problem in receiving the PEI? While I agree that there is not much battery gain from PEI over a few DRX cycles, the issue may be that the gNB has difficulty in determining (from the NGAP paging message sent by the AMF) whether the UE is in eDRX and hence should or should not use PEI for that UE. To reduce AMF and gNB software development (and error cases), why not assume that the PEI handling is common for eDRX and normal DRX cases? |
| Samsung | See comments | We do not see impact to RAN1. Irrespective of eDRX cycle or DRX cycle, UE supporting PEI can monitor PEI before its monitored PF/PO. |
| MediaTek | See comments | PEI should be applicable to UEs configured with eDRX, i.e., PEI is transmitted somewhere before PF/PO. But we agree that some eDRX-related issues (e.g., PTW) need to be discussed |
| OPPO | Yes | In our understanding, if PEI is applied to eDRX, the time required for DL synchronization may be longer than that for DRX case since UE wakes up from deep sleep for a long time. This may have an impact on the offset required between PEI and PO, which is RAN1 scope. We think we need to check with RAN1. |
| Qualcomm | See comments | Agree with Samsung. We also don’t see impact on RAN1. |
| Futurewei | Yes |  |
| Intel | See comments | From RAN2 point of view, we do not see why RAN2 need to impose any restriction regarding the use of PEI with eDRX for both RedCap and non-RedCap UE. Companies who have concernsed can just bring this up in RAN1. |
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## Mapping of PEI to multiple POs

RAN1 has a few open issues on the mapping/association of PEI to multiple POs:

Agreement

For PEI, a new DCI format is supported to include at least paging indications to UE group(s)/subgroups of the associated PO(s)

* One bit in the DCI payload indicating one UE subgroup of a PO or one UE group/PO
* The maximum number of total bits for paging indication field in PEI DCI format is x
  + One PEI can be configured to indicate up to 4 PO(s) in a PF
    - FFS whether to supporting map PEI to 3 POs in a PF
  + FFS: 1 PEI for POs across multiple PFs
  + FFS: value of x

In [2] there is a discussion about the available bits needed for a 1:N mapping, i.e. whether a 1:N mapping (N>1) can be enabled with the same number of bits, but a separate PDCCH search space and/or CORESET:

*In the case that multiple POs are associated with the same PEI occasion, if the available bits for subgrouping indication in PEI DCI cannot support all grouping numbers for all the associated POs, separate resources (e.g. PDCCH search space, CORESET) for PEI should be considered.*

It is the view of the rapporteur that RAN1 should first complete their discussions/agreements concerning possible 1:N mapping and the PEI DCI format, i.e. the number of bits available for subgrouping and 1:N mapping, before RAN2 should sent an LS to RAN1 about the need for separate PEI resources. But perhaps RAN2 can make a working assumption that the 1:N (N>1) for PEI to PO mapping is configurable in gNB:

**Question 5:** Do companies agree with the following updated proposal from [2]?:

Proposal: RAN2 assumes that 1:N (N>1) of PEI to PO mapping is configurable in gNB.

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| **Company** | **Yes/No** | **Comments** |
| Ericsson | Yes |  |
| Samsung | See comments | We prefer to wait for RAN1 to conclude its discussion |
| MediaTek | See comments | This should be discussed in RAN1 |
| OPPO | No | The mapping between PEI and PO is still under RAN1 discussion. We can wait for RAN1’s progress. |
| LGE | See comments | This should be decided by RAN1 |
| Qualcomm | See comment | We think RAN2 can assume that, unless RAN1 make other agreements.  N should be >**=**1. |
| Futurewei | Yes but | Only up to 4 POs within the same PF, assuming there can be up to 32 bits in one PEI. |
| Intel | See comments | Agree with Samsung that RAN2 should check RAN1 on this since it is being discussed there |
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**Question 6:** Do companies agree with the following proposal [2]?:

Proposal: Send an LS to RAN1 to ask for separate PEI resources (e.g. PDCCH search space, CORESET) to enable 1:N (N>1) mapping of PEI to PO?

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| **Company** | **Yes/No** | **Comments** |
| Ericsson | No | Premature, the number of available bits in the PEI DCI is not decided yet by RAN1. If companies think that separate PEI resources is a good solution, then they can bring this up in RAN1 directly, i.e. RAN2 cannot judge if this is a reasonable question to ask to RAN1. |
| Samsung | No | We prefer to wait for RAN1 to conclude its discussion |
| MediaTek | No |  |
| OPPO | Yes | The need for separate PEI resources depends on the number of bits available for subgrouping and 1:N mapping. An LS to RAN1 is needed. |
| LGE | No | We prefer to wait for RAN1 to conclude its discussion. |
| Qualcomm | No | RAN2 can wait for RAN1’s decision. |
| Futurewei | No if | if we limit a PEI to only the POs within a same PF and assuming there can be up to 32 bits in one PEI. |
| Intel | No |  |
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## UE identity used with UE-ID based assignment of subgroup

In [3] there is a very informative description how the UE identity is used in legacy to determine the Paging Frame (PF) and Paging Occasion (PO).

Based on the legacy paging framework principles it is proposed to:

**Proposal: For UE identity based paging subgrouping, UE identity = 5G-S-TMSI mod X, where X is equal to 1024 \* maximum number of paging subgroups, is used.**

It is the understanding of the rapporteur that RAN1 has decided that up to 8 subgroups can be used:

**Question 7:** Do companies agree with the following proposal [3]?:

Proposal: For UE-ID based subgroups the UE identity used is UE\_ID = 5G-S-TMSI mod X, where X is 8129 (1024\*8) is used.

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| **Company** | **Yes/No** | **Comments** |
| Ericsson | Yes | The UE-ID subgroup formula has formally not been agreed yet, but all contributing companies seem to agree that is should be:  i\_g = (UE\_ID/N\*Ns) mod Ng  With:  Ng: Total number of groups  i\_g: group index ranging from 0 to Ng-1  N: number of total paging frames in T  Ns: number of paging occasions for a PF  PS: Currently only 10-bits are conveyed on the F1 interface for RAN paging and more bits need to be added to enable UE-ID based subgrouping on neighbour cell during RAN paging, but this should be further discussed in RAN3. |
| Samsung | Yes |  |
| MediaTek | Yes |  |
| OPPO | Yes | Seems reasonable |
| LGE | Yes |  |
| Qualcomm | Yes |  |
| Futurewei | Yes |  |
| Intel | Yes |  |
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## PEI in last used cell

PEI in last used cell was discussed during email discussion #089 ([R2-2109647](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2//TSGR2_116-e/Docs/R2-2109647.zip)) but no consensus was reached:

**Proposal 14 (13/20): No consensus on the PEI monitoring by UE to the last used cell**

The reader finds background information and motivation in [4].. The rapporteur, which is also the proponent in this case, chooses not to repeat the motivation described in [4]. But companies are invited to consider the following basics in this discussion:

* The probability that the UE is reached in the first paging attempt of the NW is high (e.g. 80-90%) even in NR where the UE is mobile. With low probability UE is not found on the "last used cell" and paging escalation is needed (which is expensive because the NW needs to page in the complete TA).
* This also means that there is little power saving gain when PEI would used during mobility, because in most of the cases the UE is paged on the "last used cell".
* But there is big power savings gains when a stationary UE (i.e. UE camped on the last used cell) does not receive paging due to mobility, i.e. in case there is paging outside the last used cell during paging escalation the PEI is not set, and the stationary UE does not receive this paging. We think that the majority of paging in the network is due to mobility.

**Question 8:** Do companies agree with the following proposal [4]?:

Proposal: UE monitors PEI only in last used cell

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| **Company** | **Yes/No** | **Comments** |
| Ericsson | Yes | From a NW vendor perspective we are concerned and critical on the PEI transmissions required during paging escalation, while the UE is only to be found in a single cell, i.e. we think this is much wasted NW PEI transmission.  However UE vendors really need to have a close look at this discussion, because it is also beneficial from a UE perspective to not receive Paging due to mobility! We think that some UE vendors have not given this aspect enough thought, but think that Ericsson as a NW vendor just wants to limit PEI transmissions. But it is a fact that if the majority of false paging alarms is caused by mobility, then it is beneficial for the UE to not receive paging due to mobility and limit PEI to the last used cell! Please inform yourself and make a decision based on that. |
| Vodafone | Yes | It is important that a mobile UE (or any UE for which the AMF pages over a wide area to reduce latency) does not reduce battery life of other devices.  The safe way to do this is to limit the use of PEI to the last used cell. |
| Samsung | No strong view |  |
| MediaTek | No | We still prefer to have PEI outside last used cell. But we will follow majority to help conclude on this issue. |
| OPPO | No | We see no need to introduce such restriction as UEs will not always camp on the last used cell, which will reduce the benefit a lot for introducing PEI. |
| LGE | No | Such a restriction is suitable only for stationary UE such as IoT. It will seriously reduce the power saving gain. |
| Qualcomm | No | Such a restriction would eliminate the power saving benefits of PEI for NR UEs, as most NR UEs are mobile (like in LTE, WUS is mainly for stationary IoT devices). In addition, the new power savings features introduced in R17 can help reduce paging load and false paging alarms. If companies still think this issue can be a critical issue, maybe they can bring quantitative results (e.g. by either simulation or numerical analysis) and show in what scenarios and network configurations it can happen and the severity of the problem. |
| Futurewei | No | Agree with Qualcomm. |
| Intel | No | We think the scenario is a bit different with eMTC/NBIoT where the UEs are mainly stationary. In this case where UE power saving also applies to eMBB, mobility may need to be considered for PEI. We understand that restricting the PEI monitoring by UE to the last used cell may reduce the false alarm for other UEs when the paging is reattempted over the whole paging area. However, this is done at the expense of the paged UE as it will act as legacy UE in other cells other than the last used cell. Without further evaluation and knowledge of the paging probabilities of the UEs in the last used cell and outside, it is difficult to judge which way is more efficient from UE power saving point. |
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## *UERadioPagingInfo* IE in *UECapabilityInformation* message

In LTE there is a separate *ue-RadioPagingInfo* IE in the *UECapabilityInformation* message [4]:

UECapabilityInformation ::= SEQUENCE {

…

UECapabilityInformation-v1250-IEs ::= SEQUENCE {

ue-RadioPagingInfo-r12 UE-RadioPagingInfo-r12 OPTIONAL,

…

This enables the eNB to just copy the IE in signalling message towards the RAN when forwarding the capabilities to the CN.

In NR the gNB has to inspect the general UE capabilities signalled by the UE and extract/understand the paging capabilities to construct such IE. It would be beneficial for the gNB when UE signals a separate IE:

**Question 9:** Do companies agree with the following proposal [4]?:

**Proposal**: Introduce a *UERadioPagingInfo* IE in the *UECapabilityInformation* message in NR in Rel-17 (similar as in LTE).

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| **Company** | **Yes/No** | **Comments** |
| Ericsson | Yes | This can reduce the gNB effort when the gNB does not support certain paging features, but has to forward the UE capabilities for those paging features. |
| Vodafone | Yes | This is an essential mechanism for “forward compatibility” as most operators have multiple RAN vendors in their networks (and this is relevant as the *UERadioPagingInfo* is derived “only” in the gNB where the UE does its Initial Registration and this gNB could be hundreds of miles from the UE’s current gNB.) |
| Samsung | Yes |  |
| MediaTek | Yes |  |
| OPPO | Yes |  |
| LGE | Yes |  |
| Qualcomm | Yes |  |
| Futurewei | Yes |  |
| Intel | Yes | We agree with this proposal. Additionally, we also need a solution to handle Rel-15/Rel-16 gNB that does not support PEI/subgrouping. |
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## Missed PEI

In [5] it is proposed that when the UE missed the PEI occasion, e.g. during cell re-selection, then the UE shall monitor the following PO(s) until the next PEI occasion.

The rapporteur wondered if this should be captured the other way around, i.e. when the UE is allowed to skip PO monitoring?

**Question 10:** Do companies agree with the following proposal [5]?:

**Proposal**: If the UE was not able to monitor the PEI occasion the UE shall monitor the following PO(s) until the next PEI occasion.

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| **Company** | **Yes/No** | **Comments** |
| Ericsson | Yes, but.. | The intention of the proposal seems correct, but we think this should be captured the other way around, i.e. when the UE is allowed to skip PO monitoring.  Furthermore the proposal assumes that the UE is aware of the PEI occasions, e.g. after cell re-selection the UE first needs to acquire SIB info to check of the target cell has configured PEI.  Finally we assume that "missed PEI" excludes "missed detection", i.e. the UE was monitoring the PEI occasion and PEI was transmitted, but PEI was not detected by the UE. |
| Vodafone | yes | The proposal seems simple and appears to covers all cases…  Perhaps change it to:  If the UE was not able to monitor, or successfully receive, the PEI occasion the UE shall monitor the following PO(s) until the next PEI occasion. |
| Samsung | Yes |  |
| MediaTek | Yes | The intended behaviour is correct; descriptions can be modified if needed. |
| OPPO | Yes |  |
| LGE | No | UE cannot distinguish whether PEI is missed or is not transmitted. If PEI is not detected, UE should skip monitoring the corresponding PO. |
| Qualcomm | See comment | We are fine with the intention of the proposal. We agree with Ericsson that “was not able to” can use some clarification, e.g. when UE is allowed to skip a PO |
| Futurewei | Not sure | If we mandate the UE to monitor POs whenever it missed PEI, we may also need to mandate the gNB to send out a dummy PEI (with no subgroups being indicated) when no UEs are being paged during a cycle. |
| Intel | Yes at least for cell reselection | it is unclear to us the context of the proposal. We agree that it will be needed for at least after cell reselection. |
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## Any other urgent PEI issue

This section gives companies the possibility to add an urgent PEI topic that should also be treated.

**Question x:** Do companies agree with the following proposal?:

**Proposal**: TBD.

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| **Company** | **Yes/No** | **Comments** |
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# Summary of email discussion

TBD

# Conclusions

TBD

# References

1. [R2-2109453](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2//TSGR2_116-e/Docs/R2-2109453.zip) PEI configuration and monitoring procedures Qualcomm
2. [R2-2109491](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2//TSGR2_116-e/Docs/R2-2109491.zip) Discussion on PEI monitoring OPPO
3. [R2-2109521](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2//TSGR2_116-e/Docs/R2-2109521.zip) UE Idenity for paging subgrouping Samsung
4. [R2-2110415](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2//TSGR2_116-e/Docs/R2-2110415.zip) PEI monitoring in last used cell Ericsson, Vodafone
5. [R2-2111135](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2//TSGR2_116-e/Docs/R2-2111135.zip) Remaining issues on PEI monitoring Xiaomi