**3GPP TSG RAN WG1 #106-e R1-210XXXX**

**e-Meeting, August 16th –27th, 2021**

Agenda Item: 8.7.1.1

Source: Moderator (MediaTek)

Title: Summary#4 of Paging Enhancements

Document for: Discussion and Decision

# Introduction

In RAN1#105-e meeting [1][2], there agreed to make the final decision on **one** PEI physical-layer channel/signal:

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| **Conclusion:**  To down-select one solution for PEI physical-layer channel/signal in RAN1 #106-e, using below as a starting point:   * PDCCH-based PEI * SSS-based PEI * TRS/CSI-RS-based PEI   Note: Additional details for each of the above 3 solutions are encouraged for more informed down-selection  Note: further refinement of the above list is possible, e.g., by merging/further splitting, depending on significance of the commonality and/or differences |

Before the final decision, it is useful to identify what are the remaining specification works for each PEI candidate designs. In the following sections, we will further collect and discuss proposed design for the following aspects before conducting the final decision:

* Section 2: Subgroups indication design
* Section 3: PEI monitoring occasion determination
* Section 4: Other design details/issues
* Section 5: Decision and potential way forward
* Section 6: Summary

Note that all companies’ inputs are collected in Appendix A, and all agreements are collected in Appendix B.

# Further Details of Subgroups Indication Design with PEI

In previous meeting the following are agreed. There are remaining design details FFS, and companies’ inputs are collected in Table 1.

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| Agreement:  For UE subgroups indication in physical layer, maximum of 8 subgroups per PO is supported.  Agreement:  For paging indication to the subgroups in a PO,   * For PDCCH-based PEI, subgroups in a PO are indicated by one PEI   + One bit in the DCI payload indicating one UE subgroup is supported     - **FFS**: Whether code-point based mapping is utilized, and, if so, how to map to the subgroups in a PO * For SSS-based PEI, subgroups in a PO are indicated by a set of sequence realizations   + **FFS**: Sequence mapping design for supporting up to 8 subgroups per PO   + Physical-layer configuration(s) and sequence generation design are subject to no impact to initial access and RRM measurements of legacy UEs * For TRS/CSI-RS-based PEI, subgroups in a PO can be indicated by the following alternatives   + Alt 1: One TRS sequence with orthogonal cover as PEI transmitted in the PEI monitoring occasion where one orthogonal cover of the PEI indicates one subgroup or combination of subgroups     - **FFS**: Design details for the orthogonal cover   + Alt 2: A set of TRS sequences indicating the subgroups with one selected sequence transmitting in one TRS resource     - **FFS**: Sequence mapping design for supporting up to 8 subgroups per PO and combination of subgroups   + Alt 3: Multiple TRS/CSI-RS resources FDMed/TDMed /CDMed in the same monitoring occasion where one TRS/CSI-RS resource indicates one subgroup     - Reuse Rel-15/16 CSI-RS FDM/TDM/CDM patterns for supporting up to 8 subgroups per PO * Note : It is RAN1 understanding that Physical-layer configuration(s) for paging early indication to the subgroups is subject to the same idle-mode reception bandwidth as CORESET-0 frequency span |

Table 1: Companies’ inputs on further details of subgroups indication design

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| Company | Companies’ inputs |
| Huawei, HiSilicon | *Observation 13. PDCCH-based PEI can support to indicate 8 sub-groups per PO with little standard work, and the payload can be used for sub-group indication and associated with multiple POs flexibly.*  *Observation 14. More standard effort would be needed, e.g. new time-frequency allocation and sequence/cover code mapping and required RAN1 simulation and RAN4 requirement, to support sub-grouping indication if SSS-based/TRS-based PEI is adopted.*  *Observation 25. As summarized in Table 1, For SSS-based PEI and TRS-based PEI, significant standard work needs to be introduced, including time, frequency and sequence/code resources and mapping rules , and new monitoring occasions needs to be defined, while PDCCH based PEI just needs little standard work.*  Table 1 Comparison of specification impact with respect to different PEI designs   |  |  |  |  | | --- | --- | --- | --- | |  | Information bearing/  Sub-grouping/multiple POs indication | Frequency resource allocation | Monitoring occasion | | PDCCH-based PEI | Directly DCI Bit mapping,  Little spec work | Reuse CORESET | Based on search space set | | TRS-based PEI | Sequence mapping definition;  Time/frequency resource allocation and mapping;  Common sequence definition;  Cover code design | May reuse NZP CSI-RS resource set | New design is required | | SSS-based PEI | Sequence mapping definition;  Time/frequency resource allocation and mapping;  Common sequence definition;  Cover code design | New resource allocation signaling | New design is required | |
| TCL | **Proposal 1: In PDCCH based PEI, code-points can also be utilized to map subgroups in a PO. The payload size of code-points can be design according to the number of PO configured in a PF.**  **Proposal 2: For SSS based PEI, one to one sequence mapping and/or a common sequence mapping to 8 subgroups of UEs in a PO can be considered.**  **Proposal 3: For TRS based PEI, subgroups in a PO can be indicated by One TRS sequence with orthogonal cover as PEI transmitted in the PEI monitoring occasion where one orthogonal cover of the PEI indicates one subgroup or combination of subgroups.** |
| ZTE | Observation 20: It will decrease power saving gain if TRS-like PEI generated by sequence with orthogonal cover is used to indicate a combination of subgroups.  Observation 21: The detection performance will be degraded if   * the resources TRS-like PEI and legacy TRS are shared; or, * TRS sequence with orthogonal cover is used to indicate sub-grouping information.   Observation 23: For sequence based PEI associated with multiple POs/sub-groups,   * for Alt-1, if PEI with orthogonal cover is used, the UE power saving gain or the detection performance will decrease; * for Alt-2, if PEI is generated by different sequences, the performance of sequence-based PEI will be deteriorated with the increased blind detection； * for Alt-3, if TDM or FDM technique is used for sequence-based PEI, the resource overhead will be multiplied.   Observation 24: For sequence-based PEI associated with multiple POs or sub-groups, Alt 3 (TDM or FDM) are considered.  Observation 27: Compared with sequence-based PEI, DCI-based PEI has less workload.  **Proposal 3: The sub-grouping information should be indicated by PEI.**  **Proposal 9: For DCI-based PEI, bitmap can be used to indicate the sub-grouping information.** |
| vivo | Observation 1: Sub-grouping method introduced in Rel-16 NB-IoT can save the number of candidate sequences by defining a “common sequence” representing the case that no less than two sub-groups need to be paged.  Observation 2: The additional false alarm rate and power consumption caused by the common sequence is marginal.  Observation 3: Based on the sub-grouping method introduced in Rel-16 NB-IoT, the network only needs to transmit one certain sequence for each PEI occasion to indicate its associated PO(s).  **Proposal 1: Adopt the sequence-based grouping method introduced in Rel-16 NB-IoT as described in Table 1. With this method, UE only needs to detect the following two sequences of PEI per PEI occasion, if sub-groups are configured.**   * **The sub-group specific sequence, to indicate only the sub-group which the UE belongs to receive paging, and** * **The common sequence, to indicate no less than two sub-groups to receive paging.**   Proposal 2: Sub-grouping indication only carried in PEI should be supported for paging enhancement. |
| Spreadtrum |  |
| Sony | ***Observation 5 – Resource overhead when sub-grouping is indicated through sequence-based PEI is lower than the one in DCI-based PEI.***  ***Proposal 4 – Use sequence-based PEI as a paging enhancement scheme for UE sub-grouping to reduce overhearing and false-wake-up cost.*** |
| Samsung | **Observation 1:** Potential specification efforts needed for the three PEI candidates are:   * PDCCH based PEI: a new DCI format, new CSS set, and CORESET/PDCCH candidate determination * SSS-based PEI: sequence generation to avoid impact to SSB detection, and sequence mapping for UE subgroup indication * CSI-RS/TRS based solution: method for UE subgroup indication if not reusing Rel-15/16 CSI-RS FDM/TDM/CDM patterns.   **Proposal 7: Deprioritize UE subgroup indication in PEI due to the limited power saving gain and increased resource overhead.**  **Proposal 8: Support paging PDCCH for UE subgrouping indication for the benefit of no additional resource overhead.** |
| CATT | *Observation 9: With the increase of the number of sub-group, the gain of power saving gain is tending flat.*  *Observation 10: To support sequence-based PEI with sub-grouping, the power saving gain of option 1 relative to option 2 is negligible.*   * *Option 1: Multiple sub-grouping PEI can be transmitted in a resource.* * *Option 2: Single sequence is transmitted in a resource.*   ***Proposal 4: The number of code points generated from multi-segment orthogonal cover is up to 222 to indicate either or all paging subgroup/subgroup combination, paging occasions/occasions combination, and TRS/CSI-RS resource availability indication with the same detection performance.***  ***Proposal 6: For TRS/CSI-RS-based PEI, subgroups in a PO can be indicated by the combination of Alt1 and Alt2.***   * + ***Alt 1: One TRS sequence with orthogonal cover as PEI transmitted in the PEI monitoring occasion where one orthogonal cover of the PEI indicates one subgroup or combination of subgroups***   + ***Alt 2: A set of TRS sequences indicating the subgroups with one selected sequence transmitting in one TRS resource***   ***Proposal 10: If one-to-N between PEI and PO is supported, the cover code index of sequence-based PEI is related to sub-group number and PO\_index.*** |
| Transsion | ***Proposal 2: Subgrouping indication should be carried by PEI*** |
| Nordic | ***Observation-6:*** *Gains from sub-grouping are having large variance among companies and depend on group paging rate. Specification effort to support sub-grouping is the lowest for PDCCH based PEI.*  ***Proposal-3:*** *A dedicated PDCCH in dedicated search-space set contains:*   * *TRS validation bits, see our contribution in sub-agenda 8.7.1.2 for details* * *bitmap for up to 8 sub-groups to indicate wake-up or not in upcoming PO for each sub-group* * *define monitoring window before PO to monitor the dedicated search-space set for PEI, follow 2\_6 design principles.* |
| Lenovo, Motorola |  |
| OPPO | ***Proposal 4: The sub-grouping indication is supported by PEI, while sub-grouping indication by paging PDCCH is not supported.*** |
| Qualcomm | Observation 1: UE sub-groups can be indicated by   * Paging PDCCH   + Unused bits and/or reserved bits of the DCI, this includes cross-slot scheduling based paging PDCCH as PEI * PDCCH based PEI   + DCI field bits * RS or sequence-based PEI   + Different sequences, these sequences can be transmitted in different sets of RBs and symbols.   Observation 5: In the 20MHz bandwidth, to indicate which UE sub-group(s) of 8 UE sub-groups is paged   * For SSS based PEI, 3 unique sequences are needed * For CSI-RS based PEI, 12 unique sequences are needed.   **Proposal 1: Support UE sub-group indication carried by narrowband sequence-based (e.g., SSS) PEI for Rel-17 idle/inactive mode power saving.**  **Proposal 7: Rel-17 PEI design is based on sequence**   * **Narrowband sequence such as SSS is preferred. Different SSS sequences can be multiplexed in the frequency domain in the same OFDM symbol** * **Availability of TRS at configured occasion(s) is indicated by paging PDCCH** * **How paging PDCCH and paging PDSCH are transmitted follows legacy rules but is not impacted by PEI**   **Proposal 8: One of three sequences is transmitted to indicate whether a UE sub-group is paged within the associated set of time and frequency resources according to the following rules**   * **Sequence 1: UE sub-group A is paged** * **Sequence 2: UE sub-group B is paged** * **Sequence 3: Both sub-groups A and B are paged** |
| CMCC | **Proposal 4. If UE subgrouping is configured, define M is the number of subgroups in one PO and the UE subgroup index m is 0, 1, … M-1,**   * **If one PEI associates with one PO, the mth bit in PEI is used to indicate wake up information of UE with subgroup index m.** * **If one PEI associates with Ns POs in one PF, the [i\_s\*M+m]th bit in PEI is used to indicate wake up information of UE with subgroup index m in i\_sth PO.** * **If one PEI associates with K\*Ns POs in K PFs, the [(SFN\*N/T mod K) \*Ns+ i\_s]\*M+m th bit in PEI is used to indicate wake up information of UE with subgroup index m in i\_sth PO, which SFN is the SFN for the PF, N is the number of PFs in one DRX cycle and K is the ratio between the periodicity of PEI and PF.** |
| LG | Observation 1: The UE sub-group indication using PEI outperforms UE sub-group indication within a PO.  **Proposal 1: PEI should at least convey the information on UE sub-group indication and short message, and TRS/CSI-RS availability indication.**  **– FFS: UE group indication via PEI** |
| MTK | Proposal 2: To enable UE to directly apply non-coherent sequence detection over the limited PDCCH PEI realizations, 4-bit code-point based mapping for indicating up to 8 subgroups is supported.  Table 4: Comparison for bit-map based and code-point based mapping design for subgroup indication   |  |  |  | | --- | --- | --- | | **Subgroup indication mapping type** | **DCI to UE subgroups mapping for 8 UE subgroups** | **#PDCCH realizations  for UE to detect** | | Bit-map | 1 bit per UE (sub)group; total 8 bits |  | | Code-point | 1000: Wake up all (sub)groups | 2  (e.g. UE belongs to  2nd subgroup) | | 0000: Wake up only 1st (sub)group  0001: Wake up only 2nd (sub)group  0010: Wake up only 3rd (sub)group  …  0111: Wake up only 8th (sub)group | |
| Intel | **Proposal 4: Both PEI and paging DCI may jointly indicate UE sub-grouping information, especially when number of sub-groups is large and PEI is sequence based.**  **Proposal 5: Sub-grouping indication by TRS-based PEI can be achieved as follows:**   * + **Subgroups in a PO can be indicated by a set of TRS sequences indicating the subgroups with one selected sequence transmitting in one TRS resource** |
| Panasonic | **Proposal 5: Sub-grouping information can also be carried in the paging DCI. When PEI is configured, more refined sub-grouping indication is achieved. When PEI is not configured, just sub-grouping indication within paging DCI can also serve the function.** |
| Apple |  |
| IDC |  |
| DoCoMo |  |
| Xiaomi | ***Proposal 2: Sub-grouping methods by 1) reserved bits in legacy paging DCI and 2) DCI-based PEI should be further studied.*** |
| Ericsson |  |
| Nokia |  |
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By the above summary, the following proposals are suggested for further specification on subgroups indication design.

Proposal 2-1

For PDCCH-based PEI,

1. Subgroups indication provided is by PEI-only
2. Include code-point based mapping for providing at least up to 8 per-subgroup indication(s) and one common indication to all subgroups (for the case more than one subgroups are indicated)
   * Up to 4 bits for maximum of 8 UE subgroups
   * FFS: Detailed DCI content design

Proposal 2-2

For SSS-based PEI,

* One sequence is transmitted in one SSS PEI resource for indicating one subgroups in a PO or multiple subgroups in a PO
* FFS: One or multiple FDMed resources in a slot are utilized for indicating up to 8 subgroups in a PO
* FFS: Subgroups indication provided is by PEI-only or jointly with paging PDCCH
* FFS: Physical-layer configuration(s) and sequence generation design are subject to no impact to initial access and RRM measurements of legacy UEs

Proposal 2-3

For TRS-based PEI, further down-select one of the following two alternatives

* Alt 1: One TRS sequence with orthogonal cover as PEI transmitted in the PEI monitoring occasion where one orthogonal cover of the PEI indicates one subgroup or combination of subgroups
  + **FFS**: Design details for the orthogonal cover
* Alt 3: Multiple TRS/CSI-RS resources FDMed/TDMed /CDMed in the same monitoring occasion where one TRS/CSI-RS resource indicates one subgroup
  + Reuse Rel-15/16 CSI-RS FDM/TDM/CDM patterns for supporting up to 8 subgroups per PO
* FFS: Subgroups indication provided is by PEI-only or jointly with paging PDCCH
* FFS: Physical-layer resource configuration(s) subject to the same idle-mode reception bandwidth as CORESET-0 frequency span

Companies please provide your views/suggestions for the above proposals in the table below:

Table 2: Companies’ views/suggestions for Proposals 2-1, 2 and 3

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|  | Companies’ views |
| Huawei, HiSilicon | **For Proposal 2-1**: we are in general OK with it.   1. We are fine with sub-bullet a); 2. We have already agreed to support one bit indicating one UE sub-group for PDCCH-based PEI in RAN1#105 as baseline. Maybe this could be clarified in the proposal somehow to make it clear. Sub-bullet b) resolves the FFS point in the agreement, and we are also fine with the sub-bullet b) as another option for sub-group indication. 3. Not sure whether FFS should be there considering it is straight forward as the next step of PDCCH based PEI.   **For Proposal 2-2:**   1. It is not clear in the proposal on how many sub-groups can be indicated by one transmitted sequence, especially considering this would significantly impact the benefit of sub-group indication for high paging rate case. Therefore, we propose to add FFS before the multiple subgroups in a PO, or at least put FFS on the number of sub-groups. 2. A FFS bullet is needed on how to map sequences to one or a group of subgroups; 3. It was agreed in RAN1#105 that Physical-layer configuration(s) for paging early indication to the subgroups is subject to the same idle-mode reception bandwidth as CORESET-0 frequency span. Therefore, for the second sub-bullet, the multiple FDMed resources in a slot should be also in the same idle-mode reception bandwidth as CORESET-0 frequency span. Or maybe TDM is also needed to guarantee this. 4. For the last bullet, the whole sentence should not be as FFS considering it is required for PEI not to impact legacy UE functionality. A suggested revision is:   FFS: How the Physical-layer configuration(s) and sequence generation design can fulfil the requirement on ~~are subject to~~ no impact to initial access and RRM measurements of legacy UEs  **For Proposal 2-3:**  Similar comments on the last FFS bullet. |
| Nokia | On proposal 2-1 for PDCCH-based PEI;   * we are fine with point a), but we don’t think that point b) on applying code point based grouping with limiting the independent indication of groups (1st sub bullet on 4 bits) aligns very well with the design considered by RAN2. Hence, we would prefer to have up to 8 bits per PO for sub-group indication (i.e. don’t agree with point b) to limit to 4 bits).   On proposal 2-2 and 2-2;   * Like-wise for SSS- and TRS-based PEI, when considering the design we should ensure that we can identify the groups individually, up to 8 per PO. This could be clarified as FFS. * We should avoid the impact to legacy UEs (i.e. initial access/RRM or performance impact with cover code), so maybe related sub-bullets could be clarified, e.g. FFS how to ensure that there is no impact to IA and RRM.   We reached following conclusion in RAN1#105e: “Note : It is RAN1 understanding that Physical-layer configuration(s) for paging early indication to the subgroups is subject to the same idle-mode reception bandwidth as CORESET-0 frequency span”. Maybe this could be accounted in the FFS. |
| Nordic | Proposal 2-1 OK |
| Spreadtrum | Fine for Proposal 2-1 |
| Samsung | We think details of UE subgrouping in PEI can be postponed after confirmation of PEI L1 signal/channel design. We already discussed all the alternatives for each PEI candidate in last meeting. It’s sufficient for PEI down-selection at this stage.  For Proposal 2-1  We are not clear how the code-point is mapped to the subgroups in a PO. We need clarification to show the difference from bitmap based subgrouping and how it works.  For Proposal 2-3  It should be for CSI-RS based PEI. The last FFS point is common to all PEI candidates. BW restriction of CORESET-0 applies to all PEI candidates. If the system BW is restricted by configured CORESET#0 BW, the performance of all L1 signal/channel, including legacy paging PDCCH, PDSCH, will be impacted. The target SNR for PEI to achieve required reliability varies with respect to the system BW. Also, NW can always easily use empty REs to boots power if needed. So, the last FFS point is not needed. |
| CATT | We are OK to discuss further on how paging subgroup is carried by PEI candidates. The power saving gain of paging subgroup on PEI comparing to no paging subgroup with PEI is less than 2.3% from evaluation results in Figure 10 of CATT contribution in R1-2106983. Thus, we don’t think that we would need to make decision having paging subgroup indication at PEI for all candidates. |
| Intel | Similar view as Samsung. We also think there is not much value in capturing further details under each PEI candidate for sub-grouping indication at the moment, before deciding on signal/channel for PEI.  Regarding proposal 2-1, it is not clear why codepoint is considered, not bitmap. Also, what is the motivation to assume up to 4 bits payload? Sequence-based detection of PDCCH? If so, then what if the PDCCH-based PEI also indicates TRS availability?  Regarding proposal 2-3, we do not see the justification for excluding Alt2 given that PEI candidate selection is still open. Moreover, we have provided results which are captured in Observation table that Alt2 works and potentially has least overhead.  Also, agree with Samsung that last FFS bullet seems to apply to all PEI candidates and not specific to TRS/CSI-RS based PEI. Hence, it can be removed. |
| Qualcomm | Our evaluation shows a 2% further power saving gain with UE sub-grouping [R1-2107356]. UE subgrouping is not very critical compared to PEI itself. Given this, the discussion on UE subgrouping indication can be postponed after PEI design is down selected.  For the SSS, alternatives of proposal 2-3’s multiplexing methods also apply. For example, one SSS with orthogonal cover can also be used as PEI, and TDM can also be applied to multiplex multiple SSS. |
| ZTE, Sanechips | For proposal 2-1:  We agree that subgroups indication should be provided by PEI-only.  But for the mapping between PEI and sub-group, we think that bitmap is the simplest and most straightforward way, which has been agreed in the last meeting as the baseline solution. So we are wondering whether the proposed code point based solution is complementary to the agreed baseline or to agree something new. We are okay to consider the code point based solution on the top of the bitmap based solution. But it is unacceptable if the intention is to preclude bitmap based solution.  For proposal 2-2, 2-3:  (1) According to the observation agreed in RAN1#103, the sub-group information carried on the paging DCI provides negligible power saving gain. Therefore, the sub-group information should also be indicated by PEI-only.  (2)For the SSS-based PEI, initial access and RRM measurement should not be impacted. Hence, the “FFS” should be removed.  (3)Evaluations are needed to prove the sub-grouping carried by PEI has minimum impact on PEI detection performance.  (4) For the sub-bullet in proposal 2-3, we think it is clear that idle/inactive UE is not required to operate outside coreset-0. Hence, “FFS” should be removed. And CORESET 0 restriction is also applicable to SSS-like PEI. |
| Vivo | For proposal 2-2 and 2-3, it should align with proposal 2-1 for subgrouping indication method i.e., the three proposals should all adopt that subgroups indication provided is by PEI-only. Sub-grouping by paging PDCCH has been studied and the corresponding observation has been captured in the previous meetings. And it is shown that sub-grouping by paging PDCCH does not provide power saving gain.  Besides, regarding the subgrouping indication mapping, we have provide our solution in our contribution [R1-2106606]. The mapping method which can be applicable for all the proposals (i.e., proposal 2-1, 2-2, 2-3)  **Proposal 1: Adopt the sequence-based grouping method introduced in Rel-16 NB-IoT as described in Table 1. With this method, UE only needs to detect the following two sequences of PEI per PEI occasion, if sub-groups are configured.**   * **The sub-group specific sequence, to indicate only the sub-group which the UE belongs to receive paging, and** * **The common sequence, to indicate no less than two sub-groups to receive paging.**   With PDCCH PEI, based on codepoint based mapping, the similar approach can be applied to save PDCCH payload size. |
| Lenovo, Motorola Mobility | Fine with proposal 2-1 |
| Apple | Regarding the comments that subgroup indication should be discussed after PEI design is done, we disagree. We think subgroup indication carried in PEI provides good power saving gain, while this is not the case for subgroup indication carried in paging PDCCH. Therefore, we think it is an important aspect to consider.  **Proposal 2-1**  We are fine with bullet a). But for bullet b), as commented also by other companies, it should be clarified that the bitmap based indication is also supported. Also, is the intention of b) to support N+1 states for N subgroups? If yes, it can be directly formulated this way. If the intention is to allow RRC configuration of the states, the current proposal does not directly reflect it. Some clarification would be useful for us to understand what are the possible solutions on the table with the proposal.  **Proposal 2-2**  The first sub-bullet is a bit vague and leaves the design wide open, because how the mapping is done is not addressed. It would be good if this can be narrowed down. One example could be reuse NB-IoT design as vivo suggested.  For the first FFS, it is important that the bandwidth is limited to CORESET#0, which may greatly limit the extent of applying FDM.  For the second FFS, we do not think it should be jointly indicated with paging PDCCH. As shown by the simulation results from many companies, power saving from subgroup indication in paging PDCCH is minimal. Therefore, we should focus on carrying subgroup indication on PEI. This should be generally true for all the 3 options.  The third FFS should not be an FFS, because we had the agreement from last meeting already. Maybe the intention is to say “how to ensure”?  **Proposal 2-3**  We have the same comment on the first FFS as for P2-2.  The second FFS should not be FFS either, because we had the agreement from last meeting already. |
| CMCC | **Proposal 2-1:** We don’t not support to preclude the bitmap indication of UE sub-groups in PDCCH based PEI design. |
| Ericsson | Proposal 2-1 : OK with a). b) should be updated : “Up to N bits per DCI”. Apart from the addressing the subgrouping per PO, the PEI design should also facilitate TRS availability indication (as per WA from RAN1#105-e), addressing multiple POs using a single PEI, etc. So, more discussion would be needed.  For proposals 2-2 and 2-3, we don’t see need for further refinement (as a proposal). It is sufficient to move forward towards the selection of a single candidate. We also note Alt 1 of proposal 2-3 is not consistent with below agreement made in RAN1#102-e.  Agreements:   * New types/patterns of TRS/CSI-RS are not introduced specifically for idle/inactive mode UE. |
| DOCOMO | We support Proposal 2-1. |
| Panasonic | On 2-1 a), we think subgroup indication should be supported by both PEI and paging DCI, considering to support 8 subgroups and PEI would be separate UE features .  On 2-1 b), our proposal on wording is that **code-point and bitmapping based indication of one or more subgroups are supported, which is configured by SIB**. This should include the case of “one common indication to all subgroups”. Regarding the bit width, it is also up to SIB configuration.  On 2-2, we are okay.  On 2-3, we are okay. |
| Sony | We have already agreement on some details related to sub-grouping in the last meeting.Similar view as Intel and Samsung. We also think there is not much value in capturing further details under each PEI candidate for sub-grouping indication at the moment, before deciding on signal/channel for PEI.  Since the TRS/CSI-RS-based PEI and SSS-based PEI have commonalities both in terms of signal design and detection technique compared to the DCI-based PEI, they can be merged into a single sequence-based solution. This makes the down-selection list contain two candidate solutions, i.e., i) PDCCH-based PEI ii) sequenced-based PEI. We therefore propose to merge proposals 2-2 and 2-3 and consider them as a single proposal.  It is also not very clear why proposal 2-1 does not include the baseline agreed in the previous meeting saying “One bit in the DCI payload indicating one UE subgroup is supported”:   * For PDCCH-based PEI, subgroups in a PO are indicated by one PEI   + One bit in the DCI payload indicating one UE subgroup is supported     - **FFS**: Whether code-point based mapping is utilized, and, if so, how to map to the subgroups in a PO |
| LG | For proposal 2-1   * We are ok with the first sub-bullet (a) * Regarding sub-bullet (b), we have not been made enough discussion on benefits and necessity of code-point based mapping method. So, we prefer to deprioritize it. Additionally, we wonder if the bitmap based subgroup indication is supported by an agreement in the previous meeting; “One bit in the DCI payload indicating one UE subgroup is supported”.   For proposal 2-2 & 2-3   * Different multiplexing scheme may have different pros and cons. Some schemes may require additional resource for more UE subgroup identification, while some other schemes may sacrifices UE subgroup indication flexibility for saving resource overhead and UE complexity. Thus we do prefer to narrow down and capture the detail method for representing UE subgroup ID with sequence based PEI candidates. For example, we need information about how many sequence will be assigned to the one PEI resource, and whether the FDM/TDM is supported. * We do not prefer to support UE subgroup indication via paging PDCCH. According to observations in previous meetings, UE subgroup indication at a PO for a UE only shows marginal gain. Also it should be noted that reserved bits in a paging DCI can be used for other purposes, such as TRS availability indication.   For proposal 2-3   * It seems like the last FFS point is already captured in the agreement in the RAN1#105e meeting. So, it should be one of the design principles of PEI, not a FFS point. * For us, it seems like Alt 3 can cover Alt 1. Do we need to handle them separately? |

**Updated proposals for Phase\_2**

Thanks for companies’ valuable inputs. As per session chair’s guidance, identifying the remaining specification work for each PEI candidate design is one important step toward informed decision on PEI physical-layer channel/signal. In this regard, Proposals 2-1/2/3 are further updated to Proposals 2-1a/2a/3a as follows.

For Proposal 2-1a, the discussion can focus on whether code-point based subgroups indication mapping is included **in addition to bit-map based subgroups mapping (already agreed in RAN1#105-e)**.

For the benefit of code-point based mapping, it can reduce DCI bit number from 8 bits to 4 bits for indication 8 subgroups. Moreover, UE will only need to “match” 2 PDCCH outcomes for deciding whether it is indicated to monitor PO, which then allows UE to apply “sequence-matching” to detect PDCCH PEI and realize the benefits with sequence PEI, as verified in ZTE and MTK contributions.

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| **Subgroup indication mapping type** | **DCI to UE subgroups mapping for 8 UE subgroups** | **#PDCCH realizations  for UE to detect** |
| Bit-map | 1 bit per UE (sub)group; total 8 bits |  |
| Code-point | 1000: Wake up all (sub)groups | 2 |
| 0000: Wake up only 1st (sub)group  0001: Wake up only 2nd (sub)group  0010: Wake up only 3rd (sub)group  …  0111: Wake up only 8th (sub)group |

@Intel: If TRS indication is included there will multiply the “sequence-matching” candidate number e.g., by 4x with 2-bit TRS availability indication.

**Proposal 2-1a**

For PDCCH-based PEI,

1. Subgroups indication provided is by PEI-only
2. Include code-point based mapping, in addition to bit-map based mapping, for subgroups indication
   * N + 1 code-points for indicating N individual subgroups and one common indication to all subgroups when more than one subgroup is indicated.
   * ~~Up to 4 bits for maximum of 8 UE subgroups~~
   * ~~FFS: Detailed DCI content design~~

For Proposals 2-2a, it is updated to include more specific designs from proponents contributions. Further taking into account companies’ feedbacks, there looks less issue for 1 resource to indicate 1 subgroups but HW shows concern on how to indicate multiple subgroups in a PO. Further discussion can focus on whether to focus one simple solution for the design and reduce FFS.

**Proposal 2-2a**

For SSS-based PEI,

* One sequence is transmitted in one SSS PEI resource for indicating one subgroups in a PO or multiple subgroups in a PO
* FFS: How to map sequences to one or a group of subgroups
* FFS: One or multiple FDMed/TDMed resources in a slot are utilized for indicating up to 8 subgroups in a PO
* FFS: Subgroups indication provided is by PEI-only or jointly with paging PDCCH
* FFS: How the physical-layer configuration(s) and sequence generation design can fulfil the requirement on ~~are subject to~~ no impact to initial access and RRM measurements of legacy UEs
* FFS: How the physical-layer resource configuration(s) can fulfil the requirement on ~~are subject to~~ the same idle-mode reception bandwidth as CORESET-0 frequency span

For Proposal 2-3a, Ericsson quotes the following agreements in RAN1#102-e and states Alt-1 should be excluded:

|  |
| --- |
| Agreements:   * New types/patterns of TRS/CSI-RS are not introduced specifically for idle/inactive mode UE. |

Companies can further check whether we can further specify to one solution and reduce FFS.

Proposal 2-3

For TRS/CSI-RS-based PEI, further down-select one of the following two alternatives

* Alt 2: A set of TRS sequences indicating the subgroups with one selected sequence transmitting in one TRS resource
  + FFS: Sequence mapping design for supporting up to 8 subgroups per PO and combination of subgroups
  + Note: New types/patterns of TRS/CSI-RS are not introduced specifically for idle/inactive mode UE (Agreements in RAN1#102-e)
* Alt 3: Multiple TRS/CSI-RS resources FDMed/TDMed /CDMed in the same monitoring occasion where one TRS/CSI-RS resource indicates one subgroup
  + Reuse Rel-15/16 CSI-RS FDM/TDM/CDM patterns for supporting up to 8 subgroups per PO
* FFS: Subgroups indication provided is by PEI-only or jointly with paging PDCCH
* FFS: How the physical-layer resource configuration(s) can fulfil the requirement on ~~are subject to~~ the same idle-mode reception bandwidth as CORESET-0 frequency span

Companies please provide your further feedbacks on Proposals 2-1a/2a/3a in the table below.

Table 3: Companies’ feedbacks on Proposals 2-1a/2a/3a

|  |  |
| --- | --- |
| Company name | Companies’ views |
| Nordic | Regarding 2-1a: We do not support the updated proposal. Bitmap with 1 bit per configured sub-group is baseline. We do not think any compression is needed, but fine to keep FFS. If multiple sub-groups are under the same code-point, gNB should just configure one group? |
| Nokia | Proposal 2-1a: We are OK with the point a), but for point b) of having two mechanisms to configure the indication (sub-grouping and possibly others) would in our understanding imply that it is mandatory for the UE to support both mechanisms. Is this correct understanding? If this is dependent on the UE capability, it would not be possible to trigger all the UEs with same PEI, which would be highly undesirable. As a additional note, that in our understanding the option of supporting sub-grouping indication of multiple POs in a one PEI is possible and can still be considered (please see our comment to Proposal 4-3a).  For proposal 2-2a/2-3: Is the assumption that mapping multiple POs to PEI are not supported? As for further comments, I’ll come back later. |
| Samsung | **Proposal 2-1a:**   * For a), need to clarify it’s up to 8 subgroups * For b), code-point based mapping should be FFS. We are not conformable to confirm it yet. It doesn’t support to wake up 1< N < Nmax UE subgroups. Bitmap based is more flexible and simple. * More details need to be FFS. Proposal 4-3a is not needed.   + E.g. New DCI format, new RNTI   + Configuration of DCI format, e.g. payload length   **Proposal 2-2a/3a**   * For the last FFS point, it’ is irrelevant to UE subgroup indication, and also not needed.   + We already have agreement about “It is RAN1 understanding that Physical-layer configuration(s) for paging early indication to the subgroups is subject to the same idle-mode reception bandwidth as CORESET-0 frequency span.   + gNB can configure frequency resources, e.g. # of RBs for sequence based PEI up to CORESET-0 BW. No new design need FFS.   + It should be considered in the resources allocation for any PEI candidate. For PDCCH based PEI, the CORESET BW should not be larger than CORESET-0 BW.   + To sum up, we suggest to remove the following FFS.     - ~~FFS: How the physical-layer resource configuration(s) can fulfil the requirement on are subject to the same idle-mode reception bandwidth as CORESET-0 frequency span~~ * For FFS: subgroups indication provided is by PEI-only or jointly with paging PDCCH   + It should be whether or how. UE subgrouping in PEI can be considered, but whether or not to support it hasn’t been agreed yet. In our view, PEI is used mostly by NW when group paging rate is low, UE subgrouping in PEI is not needed. So we suggest to modify as follows: |
| Intel | Thanks for response and accommodating some suggestions.  We still think finalizing the PEI candidate selection is more important and would save this effort before capturing details of how sub-grouping indication can be conveyed. In last meeting, one or more options are already captured under each PEI candidates and we are not sure how further down selection without knowing the candidate (to be agreed upon) helps.  Nonetheless, few comments on the revised proposals.   * We think bitmap-based indication provides sufficient flexibility for PDCCH-based PEI as agreed in last meeting. We do not see why in addition to this, codepoint based signalling is needed? Since PDCCH based PEI could potentially include TRS availability indication and consequently, number of DCI sequences for matching would increase manifold, we are not sure whether expected benefit of sequence detection with limited UE complexity can be achieved. * For Proposals 2-2a, and Proposal 3a, last FFS bullet is not needed. Note captured in last RAN1 meeting is sufficient. “It is RAN1 understanding that Physical-layer configuration(s) for paging early indication to the subgroups is subject to the same idle-mode reception bandwidth as CORESET-0 frequency span” |
| Huawei, HiSilicon | **Proposal 2-1a:**  We are fine with it.  **Proposal 2-2a:**  We are fine with it. Regarding the added note. To resolve Nokia’s concern, maybe we can add FFS: one PEI associate with multiple POs.  **Proposal 2-3a:**  We are fine with it, and we agree Ericsson’s observation. To resolve Nokia’s concern, maybe we can add FFS: one PEI associate with multiple POs. Also, we do think the FFS regarding the bandwidth is needed because there are at least some companies show that the 24RB TRS pattern cannot fulfil the requirement of PEI according to the inputs in previous meetings. So, we are not sure whether TRS based PEI can work in case 24RB CORESET0 is configured. |
| IDCC | We think bitmap-based method is flexible and provides higher capacity. Codepoint based approach as exemplified here will reduce the capacity of PDCCH based PEI (capacity has been claimed to be an important advantage of this method). So, we support 2-1a (a) but not (b). Regarding the other proposals, we are ok. |
| CATT | For Proposal 2-3, We had introduced orthogonal cover of UL DM RS in LTE Rel-10 and did not consider it as new pattern/type of DMRS. Ericsson’s comment on Alt 1 as new type is not consistent with 3GPP convention. We would not agree any Proposals if Alt 1 of Proposal 2-3 is not included as one option. |
| OPPO | **For proposal 2-1a:**  We are fine with point a), but we don’t support the point b).   1. We have already agreed to support one bit indicating one UE sub-group for PDCCH-based PEI in RAN1#105. If we also support code-point based mapping for subgroup indication, **a new parameter indicated the type of mapping** must be introduced. It will need more specification work. 2. For the mapping between PEI and sub-group, bitmap is a simpler and more straightforward way. Though code-point can reduce the overhead, it will significantly affect the flexibility of sub-group indication. And it is hard to decide which case more than two subgroups (e.g. 1< N < Nmax) need to paging should be dropped. |
| Xiaomi | For Proposal 2-1a, we are fine for the bullet a), but we do not think we shall agree the b) way in this meeting, it can be put for FFS. |
| CMCC | For proposal 2-1a, if codepoint based indication is supported, how UE to differentiate two indication methods? Does gNB need configure the indication method, or define two DCI formats or RNTIs for UE blind decoding? |
| Apple | For Proposal 2-1a, we are fine with a), and also agree with some other companies that b) may not be necessary.  For Proposal 2-2a, (1) to make bigger steps and reduce the number of FFS points, can we use the codepoint approach in P2-1a for SSS-based PEI? It seems a very reasonable solution to us, and it has been used in NB-IoT already. (2) agree to add FFS on one PEI to multiple PO mapping as the current description does not support it.  We think the last FFS bullet should be kept in P2-2a/2-3a, especially given that FDM is being considered. |
| Lenovo/Motorola Mobility | For proposal 2-1a, agreeing on b) may not be essential for the feature (also not urgent). Can leave it as FFS. |
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# PEI Monitoring Occasion Design

Another important design topic is the monitoring occasion design, and companies’ views are collected in Table 3:

Table 4: Companies' views for PEI monitoring occasion design

|  |  |
| --- | --- |
| Company | Companies’ views |
| Huawei, HiSilicon | *Observation 25. As summarized in Table 1, For SSS-based PEI and TRS-based PEI, significant standard work needs to be introduced, including time, frequency and sequence/code resources and mapping rules , and new monitoring occasions needs to be defined, while PDCCH based PEI just needs little standard work.*  Table 1 Comparison of specification impact with respect to different PEI designs   |  |  |  |  | | --- | --- | --- | --- | |  | Information bearing/  Sub-grouping/multiple POs indication | Frequency resource allocation | Monitoring occasion | | PDCCH-based PEI | Directly DCI Bit mapping,  Little spec work | Reuse CORESET | Based on search space set | | TRS-based PEI | Sequence mapping definition;  Time/frequency resource allocation and mapping;  Common sequence definition;  Cover code design | May reuse NZP CSI-RS resource set | New design is required | | SSS-based PEI | Sequence mapping definition;  Time/frequency resource allocation and mapping;  Common sequence definition;  Cover code design | New resource allocation signaling | New design is required |   ***Proposal 2: The ZP-CSI-RS resources for the TRS-based PEI occasions associated with different sub-groups or different POs in the same SS burst period should be configured within the one ZP-CSI-RS resource set at most.***  ***Proposal 6: Considering there are different UEs in a cell, there can be multiple PEI occasions indicating the same PO.***  ***Proposal 7: A monitoring window and a small offset between the SS burst and the monitoring window can be specified for the PEI design to insure the power saving gain.***  ***Proposal 8: Existing CORESET0 or dedicated CORESET can be used for PDCCH-based PEI, and a common search space set is configured for DCI based PEI.*** |
| TCL | **Proposal 3: For TRS based PEI, subgroups in a PO can be indicated by One TRS sequence with orthogonal cover as PEI transmitted in the PEI monitoring occasion where one orthogonal cover of the PEI indicates one subgroup or combination of subgroups.** |
| ZTE | **Proposal 10: The PEI reception window is used to determine the PEI occasion, wherein PEI reception window can be configured by an offset between the start of PEI window and the associated PO, or a reference point and an offset between the start of PEI window and the reference point.** |
| vivo | Observation 3: Based on the sub-grouping method introduced in Rel-16 NB-IoT, the network only needs to transmit one certain sequence for each PEI occasion to indicate its associated PO(s).  Proposal 9: The configuration of PEI occasion should satisfy that the gap between PEI and the first indicated PO contains M SSB bursts, where the value of M can be 1, 2, 3 etc. |
| Spreadtrum |  |
| Sony | ***Proposal 5 – A window for PEI transmission/reception prior to PO is supported to avoid any blocking when other DL transmissions coincide with PEI.***  ***Proposal 6 – Signaling aspects on conveying the configuration of the PEI transmission/reception window and UE/network behavior on PEI reception/transmission are FFS.*** |
| Samsung | **Proposal 3: Support SIB based configuration of PEI, including**   * **a time offset, O, relative to start of an associated PO, to indicate start of PEI monitoring, and** * **a number of PEI monitoring occasions for multi-beam operation.** |
| CATT | ***Proposal 11: The sequence-based PEI configuration and procedure could be calculated by reference signal/channel, e.g., reusing the procedure of paging occasion computation for 38.304.*** |
| Transsion |  |
| Nordic | ***Proposal-3:*** *A dedicated PDCCH in dedicated search-space set contains:*   * *TRS validation bits, see our contribution in sub-agenda 8.7.1.2 for details* * *bitmap for up to 8 sub-groups to indicate wake-up or not in upcoming PO for each sub-group* * *define monitoring window before PO to monitor the dedicated search-space set for PEI, follow 2\_6 design principles.* |
| Lenovo, Motorola | **Proposal 1: Support repetition of PEI with multiple beams, where each PEI occasion is QCLed with one SSB of transmitted SSBs.**  **Proposal 2: A non-zero gap between the PEI and the corresponding PO or MO is configured for sequence based NR PEI.**  **Proposal 3: For PDCCH based PEI, Paging Power Saving (PPS)-PDCCH search space configuration can be signaled in SIB1 or in an RRC release message.**  **Proposal 4: A PDCCH carrying PEI is intended to a group of UEs associated with a set of paging frames. A size of the set of paging frames may be dependent on selected paging configuration parameter values.**  **Proposal 5: A PPS-PDCCH monitoring occasion(s) for a given PO may be configured based on a reference PF of the given PO (e.g. the earliest PF of a particular set of consecutive PFs associated with the given PO), e.g., before a start of a reference PF in a given paging cycle.** |
| OPPO | Proposal 1: One-to-one and one-to-many mapping between PEI and PO should be supported.  ***Proposal 2: Time offset parameters are configured for UE to determine a time duration before target PO where the UE starts and stop monitoring PEI.***  ***Proposal 3: Support N>=1 PEI monitoring occasions per PEI transmission, where each monitoring occasion is associated with a PDCCH monitoring occasion of the target PO.***  ***Proposal 7: Legacy PDCCH CSS set can be reused for paging early indication delivery to reduce resource overhead.*** |
| Qualcomm |  |
| CMCC |  |
| LG | Observation 5: A PEI occasion may need to consist of multiple monitoring occasions to support multi-beam operation.  **Proposal 4: PDCCH monitoring occasions for PEI are determined by PEI frame and PEI occasion**  **- PEI frame is determined by offset from the PF**  **- PEI occasion is configured within a PEI frame**  **- PDCCH monitoring occasions of PEI is either same as one for RMSI or configured by higher layer signal dedicated for the PEI** |
| MTK | Proposal 6: For PEI Monitoring Occasion (MO) determination, the following two steps are utilized   * **Broadcast potential MOs via a dedicated search space setting**   + **One PEI MO can contain multiple slots, accommodating beam sweeping**   + **Period of PEI MOs should be multiple of SS burst period**   + **Period of PEI MO should be no smaller than PO period** * **UE monitors the nearest MO subject to a configured minimum time gap (new RRC parameter) from UEs’ PO start to the end of PEI MO** |
| Intel |  |
| Panasonic |  |
| Apple |  |
| IDC |  |
| DoCoMo |  |
| Xiaomi |  |
| Ericsson | Observation 8 PEI transmissions should not be restricted to be in conjunction/adjacent to other transmission.  Observation 10 A one-to-many mapping scheme between a PEI and multiple POs can provide multiplexing gain and reduce system overhead compared to a one-to-one mapping scheme.  Observation 11 Irrespective of PEI format, from the UE power consumption perspective, at average 10% paging rate, the UE can at 90% of the time in idle mode immediately go back to deep sleep after PEI decoding regardless of PEI location with respect to PO.  **Proposal 7 PEI design supports associating one PEI DCI with multiple POs and/or paging groups.**  **Proposal 10 Search space for PEI PDCCH monitoring can be configured separately from or can be same as one of the existing search spaces configured for PDCCH monitoring in Idle/inactive.**  **Proposal 11 PO-specific configuration of the PEI includes an offset from PO ranging at least up to 3 SSBs prior to PO and includes a window of PEI monitoring occasions during which the UE searches for PEI.** |
| Nokia | **Observation:** *PDCCH-based EPI multiplexing with Connected Mode UEs is most straight forward, while with different mechanisms multiplexing of TRS-EPI and SSS-EPI with Connected mode UEs can be achieved, it is not as straight forward.*  **Proposal:** **Network should be able to configure the EPI to only sub-set of SSB/‘broadcast’ beams.**  **Proposal: A single EPI should be able to address multiple POs to reduce EPI (PDCCH) indication overhead.**  **Proposal: The monitoring occasions defined for PDCCH-EPI are defined by search space configuration. The paging search space (‘*pagingSearchSpace*’) configuration could be re-used for EPI.**  **Proposal: Define the reference location for EPI monitoring, EPI frame (EPI-F), based on offset to PF. Offset could be defined in radio frames.**  **Proposal: Define a PO specific offset (EPI-O) in relation to EPI monitoring reference location (EPI-F). Offset could be defined in symbols.**  **Proposal: Determine the valid PDCCH-EPI monitoring occasions from the search space configuration (e.g. ‘*pagingSearchSpace*’) based on monitoring occasion timing indicated by EPI-F and EPI-O and number of actually transmitted SSBs.** |
|  |  |

By the above, the following proposals are suggested:

Proposal 3-1

For PDCCH-based PEI,

* Determination of PEI monitoring occasion(s) is based on,
  + A search space configuration specifying the candidate monitoring occasions
    - The search space configuration can be dedicated for PEI or based on existing common search space configuration, e.g., *pagingSearchSpace*
      * FFS how to indicate the reference and include additional restriction if an existing common search space configuration is referred
  + A time gap before the start of UEs’ PO
    - FFS range and unit of the time gap
* UE monitors the nearest duration of the candidate monitoring occasion(s) specified by the search space configuration and subject to the time gap w.r.t. UEs’ PO

Proposal 3-2

For SSS-based PEI,

* Determination of PEI monitoring occasion(s) is based on,
  + A dedicated search space configuration specifying the candidate monitoring occasions
    - The configuration is also broadcasted to legacy/R15 UEs to exploit CORESET-wise rate-matching of legacy/R15 UEs
  + Resource FDM information if multiple PEIs are multiplexed in the same CORESET
    - FFS: resource FDM design and the association with the UE subgroups
  + A time gap before the start of UEs’ PO
    - FFS range and unit of the time gap
* UE monitors the associated time-frequency resource(s) in the nearest duration of the candidate monitoring occasion(s) specified by the search space configuration and subject to the time gap w.r..t UEs’ PO

Proposal 3-3

For TRS/CSI-RS-based PEI,

* Determination of PEI monitoring occasion(s) is based on,
  + A dedicated resource configuration specifying the candidate monitoring occasions
    - FFS: Necessary parameters
  + Resource FDM/CDM/TDM information if multiple PEIs are multiplexed in the same CORESET
    - FFS: resource FDM/CDM/TDM design and the association with the UE subgroups
  + A time gap before the start of UEs’ PO
    - FFS range and unit of the time gap
* UE monitors the associated time-frequency resource(s) in nearest duration of the candidate monitoring occasion(s) specified by the resource configuration and subject to the time gap w.r.t. UEs’ PO

Companies please provide your views/suggestions for the above proposals in the table below:

Table 5: Companies’ views/suggestions for Proposals 3-1, 2 and 3

|  |  |
| --- | --- |
| Company | Companies’ views |
| Huawei, HiSilicon | **For Proposal 3-1:**  It should be noted that in almost all the evaluations for power saving from proponents assumes PEI is located close to the SS burst(s) before the corresponding PO. One of the reason to introduce PEI is due to the uncontrollable PO location with respect to SSB, causing high power consumption due to pre-wake up and long light sleep state. If the PEI is still defined relative to the PO, it is still not guaranteed that the PEI is close to SS bursts, which cannot guarantee the benefit of PEI. Therefore, we have concerns on the bullet of “A time gap before the start of UEs’ PO”, and “the nearest duration subject to the time gap w.r.t. UEs’ PO”.  In our view, the monitoring occasion of PEIs should be defined by using a time gap relative to the SS burst(s) before the PO.  **For proposal 3-2:**   1. For SSS-based PEI, as discussed in our contribution, the CORESET-based resource sharing with PEI and PDCCH will significantly impact the configuration of CORESET/search space set for legacy UE, e.g. restrict the legacy UE to be scheduled in CORESET0 or restrict to configure the one additional CORESET as a non-interleaved CORESET overlapping with the bandwidth of CORESET0. This concern was also raised by other infrastructure vendors. Therefore the semi-static RB-level resource sharing should be considered as the baseline rather than CORESET-based resource sharing for SSS-based PEI. 2. Similar comment on the time gap as that for proposal 3-1.   **For proposal 3-3:**   1. Similar comment on CORESET based resource sharing. It should be based on semi-static RB-level resource.   Similar comment on the time gap as that for proposal 3-1. |
| Nokia | For proposal 3-1;   * A question to clarify the bullet regarding the time gap whether it covers two aspects; the minimum gap prior PO and the time offset prior PO? For time offset, we would prefer to consider offset to PF (from which the PEI monitoring corresponding to given PO can be addressed). Minimum gap can be further discussed. * The last sub bullet regarding the nearest duration is not fully clear to us; which duration is referred and nearest to what. It is not clear how this is interpreted in case of multiple beams (e.g. 8 or 64). This comment is general to all proposals. Thus this bullet would need further discussion.   On proposal 3-2;   * It might be good to clarify (or give examples/FFS) how the SS configuration is intended to be used for determining the SSS-PEI monitoring occasions (e.g. use of ‘*duration*’ and ‘*monitoringSymbolsWithinSlot*’) and how the frequency location is identified. * On the broadcasting the SS configuration to legacy UEs, is it correct understanding that this would refer to CONNECTED mode (legacy) UEs? If this is correct understanding and the intent is to facilitate multiplexing SSS-PEI and legacy user transmission. Firstly this seems to set some mandate for the network operation regarding the legacy UEs, and if this is for CONNECTED mode UEs, also dedicated signalling is an option. I.e. ‘configuration may be provided to…’?   On proposal 3-3;   * It seems that this design would be at least partially related to proposal 2-3 in Section 2, thus it might be best to try to progress that first. |
| Nordic | For P3-1   * UE monitors all candidate monitoring occasion(s) specified by the search space configuration and subject to the time window before UEs’ PO |
| Spreadtrum | For Proposal 3-1, we share the similar view as Huawei. It is beneficial that 1 PEI-PDCCH can be mapped to N POs. In this case, PEI-PDCCH can be configured very close to the 1st SS burst to achieve the additional gain. Therefore, the time gap could be before PF, or a time window with length of N paging cycles could be defined. |
| Samsung | We suggest to discuss monitoring occasion relative to associated PO first, i.e. slot position,. It can be common regardless of L1 signal/channel design, and is new. For the details within a slot, it can be determined after the L1 signal/channel design is confirmed. Many legacy rules in Rel-15/16 can be reused for all PEI candidates. |
| CATT | We had a contribution on the detailed monitoring occasions of PEI configuration in R1-2106985. The resource allocation of PEI could be derived similar to the paging occasion in TS38.304 with additional parameters by RRC or NAS signaling. |
| Intel | Monitoring occasions pattern with respect to start of PO can be discussed in a more general manner for all the PEI candidates, such as follows:  Proposal 3-x  For the PEI, determination of PEI monitoring occasion(s) is based on   * An offset/reference point with respect to the start of PO * A duration following the indicated offset/reference point which includes one or more monitoring occasions * A minimum time gap before the PO during which UE is not required to monitor the PEI * FFS, search space configuration, resource for PEI etc.   Also, it is not clear why CORESET multiplexing is assumed for SSS and TRS/CSI-RS based. We think more typical scenario is coexistence with PDSCH. |
| Qualcomm | PEI monitoring is closely tied with PO, it would be reasonable to assume a fixed timeline relationship between PEI and PO, i.e., PEI location should be defined with respect to the start of associated PO.  For SSS-based PEI, even though network can use CORESET to cover the SSS for rate matching to connected mode UEs, there is no need to define SSS-based PEI directly in form of CORESET to idle/inactive mode UEs. The SSS-based PEI configuration should also be based on resource monitoring occasion instead of SS set occasion.  Besides, both CSI-RS and SSS-based PEI can be configured as resources in a CORESET to the connected mode UE. This does not mean additional CORESET is used. Network can reuse CORESET#0 as bandwidth of PEI should be within CORESET #0. Network may need to use additional SS set to indicate the time domain location of PEI monitoring occasions. But since there can be up to 10 SS sets for the connected mode UE, the impact of this design is negligible. |
| ZTE, Sanechips | For proposal 3-1,  (1) When considering PEI (for both DCI-based PEI and sequence-based PEI) monitor occasion, the mapping between one PEI and multiple POs should be taken into account.  (2)Regarding the following bullet, it is appreciated to clarify what the “reference” refers to.   * FFS how to indicate the reference and include additional restriction if an existing common search space configuration is referred   For proposal 3-2,  It is appreciated to clarify how to use a dedicated search space configuration to specify the candidate MO. And same as proposal 3-3, necessary parameters are FFS.  Regarding the following bullet, we think it is commented by many other companies that the CORESET-wise rate matching for SSS-like is questionable considering UE’s capability of supporting CORESET and the resource mapping between PDCCH and SSS-like PEI.   * The configuration is also broadcasted to legacy/R15 UEs to exploit CORESET-wise rate-matching of legacy/R15 UEs |
| vivo | We agree with that the PEI monitoring occasion should be configured relative to the PO reception. However, we may have concern on that UE monitors the associated time-frequency resource(s) in the nearest duration of the candidate monitoring occasion(s) subject to the time gap w.r..t UEs’ PO. In our view, it is clearer to configure a PEI-offset relative to PO similar as PS-offset specified in R16 power saving WI for connected UE, so as to the UE can monitor the PEI MOs between the PEI-offset and the start time of PO reception. |
| Lenovo, Motorola Mobility | Regarding Proposal 3-1, we think that one PDCCH carrying PEI can be associated with multiple POs or more than one PF. Thus, PEI monitoring occasion(s) for a given PO can be determined based on a reference PF (or a reference PO) of the given PO (e.g. the earliest PF of a particular set of consecutive PFs associated with the given PO). For example, the PEI monitoring occasions for the given PO are the nearest candidate monitoring occasions specified by the search space configuration and subject to the time gap w.r.t. UE’s reference PF (or reference PO) in a given paging cycle.  Regarding proposal 3-2/3-3, for the sequence-based PEI, the time gap related to determining the PEI monitoring occasion(s) can take the multi-beam operation as a consideration. The time gap can be defined before the start of UEs’ PO or even before the corresponding MO of each beam in the PO. |
| Apple | For Proposal 3-1, would appreciate clarification on (1) the “reference” in the first FFS bullet; (2) “the nearest duration” in the last sub-bullet.  For Proposal 3-2, it is not clear to us why a search space configuration should be used. It would be more reasonable to configure the SSS resource itself. It is gNB’s choice to use search space set configuration to support coexistence with legacy signals/channels, but this should not impact how PEI is configured.  For all the proposals, it is not clear how to handle the beam sweeping for PEI. Is the intention to handle it in a similar way as paging monitoring? |
| CMCC | For proposal 3-1, we have similar views as companies to take into account one-to-many mapping between PEI and POs. In addition, we are not sure how to reuse *pagingSearchSpace,* since the PEI should always be monitored before PO. |
| Ericsson | For proposal 3-1,   1. First main bullet is OK if below updates are made    1. first FFS subbullet is simplified to “FFS : details, including any additional restrictions”    2. 2nd subbullet : delete UE’s in “A time gap before the start of the UE’s PO” 2. 2nd main bullet : This seems to be covered by first main bullet : “details of SS configuration including any additional restriction” and “the time gap”. It is also unclear what duration of candidate monitoring occasion(s) is referring to as well as what subject to the time gap wrt UEs’ PO means.   For proposals 3-2 and 3-3, similar comments as above apply. The text “*The configuration is also broadcasted to legacy/R15 UEs to exploit CORESET-wise rate-matching of legacy/R15 UEs*” seems to impose NW restriction and undue burden on legacy UEs and perhaps some clarification is helpful on this. For 3-2, clarification is needed on what search space configuration and candidate monitoring occasions refers to. |
| Panasonic | A common comment to 3-1/2/3 is that, it is better to clearly define the function of the gap that UE should monitor PEI before the range of the gap, which is the intention in our understanding. We think a time window could be a clearer term to use.  On 3-2, the first sub-sub-bullet on “The configuration is also broadcasted to legacy/R15 UEs…” is implementation in our understanding. It should be removed or to clarify it as "note".  On 3-3, we also do not see the reason why to use CORESET to describe the monitored resource. Rate matching can anyway handled by gNB using Rel.15 signaling. |
| Sony | It is not very clear why TRS-based proposal talks about “resource configuration” and the SSS-based proposal talks about “search-space” configuration. We agree with Intel that the monitoring occasions pattern with respect to start of PO can be discussed in a more general manner for all the PEI candidates, Signalling aspects on conveying the configuration of the PEI transmission/reception details and UE/network behavior on PEI reception/transmission can be discussed after finalizing PEI design. |
| LG | For proposal 3-1/3-2/3-3   * Regarding the sub-bullets on “a time gap”, we have similar view with Nokia. We prefer to consider the offset to PF, and prefer to keep this option.   Regarding the bullets on “the nearest duration”, we may need more discussion on this point. In our view, similar to the definition of PF and PO, PEI frame (offset to PF) and PEI occasion (search space configuration) would be enough for determining PEI monitoring occasions. |
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**Updated Proposals for Phase\_2 Discussion**

Thanks for companies’ valuable inputs on the determination of PEI monitoring occasions. In particular, thanks to Nokia, CATT and Lenovo, utilization of PF instead of PO can ease the specification. Also the design for SSS PEI and TRS/CSI-RS PEI can be merged in one proposal, although how to inform legacy UE for rate-matching will be very different. For PDCCH-based PEI, search space can be specifically utilized, therefore a different proposals based on search space is provided as well.

The proposals share some similarity with R16 WUS/DCP design, but the consideration of close placement of PEI to SS burst may induce another time offset to specify. Companies please check the following updated Proposals:

**Proposal 3-1a**

For PDCCH-based PEI,

* Determination of PEI monitoring occasion(s) is based on,
  + A search space configuration specifying periodic durations of the candidate monitoring occasions
    - The search space configuration can be dedicated for PEI or based on existing common search space configuration, e.g., *pagingSearchSpace*
      * FFS how to ~~indicate the reference and~~ include additional restriction if an existing common search space configuration is referenced
  + A minimum time offset before the start of UE’s PF
    - FFS range and unit of the minimum time offset
  + A maximum time offset between PEI monitoring occasion(s) and the start of the earlier and nearest SS burst
    - FFS range and unit of the maximum time offset
* UE monitors all candidate monitoring occasion(s) in the earlier and nearest duration to the start of UE’s PF and subject to the minimum time offset w.r.t. the start of UEs’ PF and the maximum time offset w.r.t. the start of the earlier and nearest SS burst

Although CORESET-based rate-matching is assumed for dynamic resource sharing of SSS-based PEI, the monitoring occasion determination can be separately specified. How to inform legacy UEs for rate-matching is captured as a FFS.

**Proposal 3-2a**

For SSS-based PEI or TRS/CSI-RS-based PEI,

* Determination of PEI monitoring occasion(s) is based on,
  + A dedicated resource configuration specifying periodic durations of the candidate monitoring occasions
    - FFS: Necessary parameters and how to inform legacy UEs for rate-matching
  + Resource FDM/CDM/TDM information if multiple PEIs are multiplexed ~~in the same CORESET~~
    - FFS: resource FDM/CDM/TDM design and the association with the UE subgroups
  + A minimum time offset before the start of UE’s PF
    - FFS range and unit of the minimum time offset
  + A maximum time offset between PEI monitoring occasion(s) and the start of the earlier and nearest SS burst
    - FFS range and unit of the maximum time offset
* UE monitors all candidate monitoring occasion(s) in the earlier and nearest duration to the start of UE’s PF and subject to the minimum time offset w.r.t. the start of UEs’ PF and the maximum time offset w.r.t. the start of the earlier and nearest SS burst

The following are specific response to companies’ comments:

@vivo: R16 WUS/DCP has the concept of minimum time gap (as a UE capability). For idle mode, it will be a network broadcast value. For realizing power saving gain, closeness to a SS burst should be restricted. Since PO allocation can have clustering allocation, a constant offset w.r.t. a PO cannot guarantee the closeness to a SS burst. In this regard, another maximum time offset w.r.t. SS burst is utilized. Given a minimum time gap, choosing the nearest duration of candidate monitoring occasions looks reasonable to confine additional paging delay, which then gives the suggested framework for determination of PEI monitoring occasion(s).

@ZTE @Lenovo @CMCC: The feasibility of indicating multiple POs is not precluded in the suggested framework.

@CMCC: Regarding reuse pagingSearchSpace, my understanding is to utilize CORESET in a previous PO (of another UE group) for carrying PEI for the PO of targeted UE group.

Since the determination of PEI monitoring occasions will induce RRC parameters, it is a high priority issue since RAN1 will start collecting initial RRC parameters. Companies’ please further provide your feedbacks on updated Proposal 3-1a/2a and see if we can specify the required RRC parameters.

Table 6: Companies’ feedbacks on Proposals 3-1a/2a

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| --- | --- |
| Company name | Companies’ views |
| Nordic | **Regarding 3-1a:**  Thanks for the updated wording, but I am still lost in what below sub-bullet is trying to say. Could it be said in more simple way and/or illustrated by a figure?   * UE monitors all candidate monitoring occasion(s) in the earlier and nearest duration to the start of UE’s PF and subject to the minimum time offset w.r.t. the start of UEs’ PF and the maximum time offset w.r.t. the start of the earlier and nearest SS burst   Is it trying to say that:   * UE monitors during a monitoring window * the window is at least minimum time offset before the start of UE’s PF * the window is located before one SSB burst that is earlier than PF |
| Nokia | Proposal 3-1a:  Firstly, like indicated in our paper the configuration of the time location of the PEI associated to a certain PO, could in our view be based on similar design/approach as we have for POs. Only new parameter needed would be the offset between PF and PEI frame. Thus, similar to PO definition, having, in addition to PF-to-PEI frame offset, having additional PO specific offsets between the PEI frame and PEI to indicate where the PDCCH-PEI monitoring occasions would start could be introduced (i.e. similar as ‘*firstPDCCH-MonitoringOccasionOfPO*’ but from the PEI-frame). Hence, one approach is to have multiple (hierarchical) time offsets where they can be specific to a PF or to a PO of a PF. Also if we consider a design to address the PEI time location, while minimum time offset value maybe needed, it might be clearer to separate this from the time location signal design. Thus we would propose following adjustments to the wording to make it more general in this respect (wo restricting different options):   * + A ~~minimum~~ time offset before the start of UE’s PF     - FFS range and unit of the minimum time offset, and number of time offsets     - FFS the minimum time offset value between PEI and PO   While I understand that it is preferable to close the PEI in close proximity of an SSB burst, similarly as for PO, to minimize the ‘active time’ it is good to understand that these time occasions are also in high demand also for other purposes. With multiplexing pattern 1, SIB1 delivery will also be located in close proximity of SSB burst. It may also be desirable to locate ROs to close proximity of SSBs, resulting a need of having UL symbols available, limiting the option of locating PEI(s) to the immediate proximity of SSB. After that being said, it would be useful if we are able to agree to some guidance/recommendation for the location of the PEI (in respect to SSB burst) to ensure good power saving gains. Thus, following change to the wording could be considered:   * + A ~~maximum~~ recommended time offset between PEI monitoring occasion(s) and the start of the earlier and nearest SS burst to ensure good power saving gain     - FFS range and unit of the maximum time offset   Regarding the last bullet, before agreeing that UE monitors all candidate locations, we probably should have better understanding of the definition of candidate locations. E.g. assuming ‘beam swept PEI’, is the intention to say that UE is required to monitor all PEI’s associated PO of the UE? Also, like discussed above, we would prefer to define the PDCCH-PEI monitoring occasions in a similar manner as for paging (as in 38.304) for sake of simplicity. While it could provide flexibility to the network by defining larger time window for PEI transmission, it might be preferable from UE perspective to try to limit the number of time occasions UE needs to monitor. Hence, at this point we are not supportive of the last bullet. Unfortunately, I’m not sure how to revise it with minimal changes before we have further alignment on the general approach. |
| Samsung | **Proposal 3-1a**   * We don’t agree that time offset should be determined relative to PF instead of PO. From UE perspective, UE has to determine the MO relative to start of PO anyway. To configure time offset relative to PO is the simplest solution. If not consensus, it should be FFS. * Also, the multi-beam operation should be FFS, e.g. # of PDCCH MOs, QCL assumptions determination.   **Proposal 3-2a**   * No new design for rate matching is needed. Also, we already agreed new types/patterns of TRS/CSI-RS are not introduced. Connected mode UE doesn’t need to distinguish RS for PEI or legacy TRS/CSI-RS resources. So, the following FFS point is not needed.   + - ~~FFS: Necessary parameters and how to inform legacy UEs for rate-matching~~     - ~~FFS: resource FDM/CDM/TDM design and the association with the UE subgroups~~ * Why we separate the discussion in proposal 3 for sequence based solutions, but merge here? * Same common about the time offset as for PDCCH based PEI, time offset relative to PO is much simpler solution.   In general, the time offsets to determine start and end of PEI monitoring occasion are common to all PEI, can discussed jointly in a separate preproposal. |
| Intel | Current proposals seem to be more complex than before and difficult to follow. Although PDCCH has a certain search space configuration from spec that can be reused, a common start and end time for monitoring occasions can be obtained for all the PEI candidates. We also agree with Samsung that offset with reference to PO makes more sense since the PEI would correspond to the next PO. We do not think reference to SSB is needed for determining the MOs. |
| Huawei, HiSilicon | **Proposal 3-1a**  We support Nordic’s update considering it would be clearer. It is not easy to understand why it is earlier and nearest.  We do think we need to make the PEI as more close to SSB as possible. Therefore, a maximum time gap relative to the end of SS burst is necessary. We are fine to define a minimum time offset relative to PF considering the PO is usually floating in time domain and may be very far away from the proceeding SSBs.  **Proposal 3-2a**  I think the monitoring occasions are different aspects from TRS/CSI-RS pattern. So, even no new pattern of TRS is introduced, there still needs to define monitoring occasions for TRS/SSS based PEI because the TRS/SSS shall never be blindly detected in legacy specification. |
| IDCC | We agree with Samsung that a reference to the corresponding PO is a more natural solution. It would be better if we could simplify and/or combine the proposals. We have the same confusion as Nordic. |
| CATT | The configuration of PEI monitoring occasions for DCI-based PEI and sequence-based PEI is different. For DCI-based PEI could be configured with a range of slots for PDCCH monitoring. However, sequence-based PEI needs to be indicated and derived at the exact slot. That is why we used the similar formula for paging occasion derivation for PEI monitoring occasion. Thus, proposal 2-a should have one offset value associated with paging occasion and not a range of slots as the potential PEI monitoring occasion. |
| OPPO | **Proposal 3-1a:**  We also agree that time offset should be determined relative to PO. And it is not easy to understand the “earlier and nearest” in 4th sub-bullet of the 1st bullet. The understanding of Huawei and Nordic is different in our standing, and we don’t think the maximum time offset should be between PEI and SS bursts. |
| OPPO2 | **Proposal 3-1a:**  We do not think it is necessary to introduce a maximum time offset between PEI monitoring occasion(s) and the start of the earlier and nearest SS burst. It is not clear which SS burst is the earlier and neatest one. Is it related to the PEI monitoring occasion(s)? Then the question is which one should UE determine first, PEI monitoring occasion(s) or SS burst? In Rel-16 power saving signal, the PDCCH MOs for DCI format 2-6 is related to PO. We prefer the similar mechanism.  The maximum time offset can be defined related to the target PO. It is configurable to make PEI monitoring occasion(s) close to a SS burst or before several number of SS bursts for earlier deep sleep if no PO is needed to monitor by PEI. If PEI indicates UE to monitor target PO, UE has the chance of further T/F tracking and AGC adjustment before target PO.  To summary, we propose that the maximum and minimum time offset between PEI monitoring occasion(s) and PO are defined and configurable, considering the time relationship between PEI monitoring occasion(s) and SS burst. |
| Xiaomi | We share the similar view with Huawei on Proposal 3-1a, so the current proposal is fine to us. |
| CMCC | For proposal 3-1a: If the PEI has one-to-one mapping with PO, it is straightforward way to use UE’s PO as the reference. But if one PEI used to indicate multiple POs in one PF, it makes sense to used PF as the reference which all UEs should considering the time offset between PEI and PF, i.e., the location of first PO in the PF. |
| Apple | For P3-1a/3-2a, we are also confused about the last two bullets regarding the PEI monitoring occasions. Some explanations on exactly how it could work (e.g. with an example) would be appreciated. We are still confused about the motivation for introducing max and min time offsets.  We also prefer to follow a similar approach as PO: configure a search space, define the first monitoring occasion, and then the monitoring occasions for all beams can be derived in a deterministic way. Exactly how to define the first monitoring occasion can be further discussed, which is related to the time offset between PEI and PO/PF, whether it should be close to SSB, etc. These can be left to FFS.  For P3-2a, it is not clear to us what “periodic durations” mean in the first sub-bullet. |
| Lenovo/Motorola Mobility | Unfortunately, the proposal 3-1a still excludes possibility that one PEI is associated with multiple PFs or multiple POs (please see the suggested modification in green highlighted. Note: the reference PF for UE can be UE’s PF). Also, we don’t think max time offset w.r.t. the earlier and nearest SS burst is necessary. The earlier and nearest set of monitoring occasions to the start of UE’s reference PF may be sufficient.  **Proposal 3-1a**  For PDCCH-based PEI,   * Determination of PEI monitoring occasion(s) is based on,   + A search space configuration specifying periodic durations of the candidate monitoring occasions     - The search space configuration can be dedicated for PEI or based on existing common search space configuration, e.g., *pagingSearchSpace*       * FFS how to ~~indicate the reference and~~ include additional restriction if an existing common search space configuration is referenced   + A minimum time offset before the start of UE’s reference PF     - FFS range and unit of the minimum time offset   + ~~A maximum time offset between PEI monitoring occasion(s) and the start of the earlier and nearest SS burst~~     - ~~FFS range and unit of the maximum time offset~~ * UE monitors all candidate monitoring occasion(s) in the earlier and nearest duration to the start of UE’s reference PF and subject to the minimum time offset w.r.t. the start of UEs’ reference PF ~~and the maximum time offset w.r.t. the start of the earlier and nearest SS burst~~   For sequence-based PEI, the minimum time offset before the start of UEs’ PO or before the corresponding MO of each beam in the PO can be defined. |
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# Remaining Design Details/Issues

In this section, other remaining design details/issues are collected and discussed:

Table 7: Companies' views on other remaining design details/issues

|  |  |
| --- | --- |
| Company | Companies’ views |
| Huawei, HiSilicon | ***Proposal 4: Both Behv-A and Behv-B are supported by Rel-17, which can be configurable by the network.***  ***Proposal 9: DCI format 2\_6 can be extended to transmit PEI for idle/inactive mode UEs.***  ***Proposal 10: The agreements and progress in RedCap need to be carefully considered in PEI discussion to ensure PEI utilization on RedCap UE, as required by RedCap WID.*** |
| TCL |  |
| ZTE | Observation 1: The advantages and disadvantages of Behv-A and Behv-B is summarized in Table 1.  Table 1 Summary of the advantages and disadvantages of Behv-A and Behv-B   |  |  |  | | --- | --- | --- | |  | **Advantages** | **Disadvantages** | | **Behv-A** | Resource overhead of PEI is relatively small when paging rate is low. | If UE misses the PEI with wake-up indication,   * both network and UEs associated with the same PEI or UE group consume more energy; * Cost more resources to re-transmit the PEI, paging DCI and paging PDSCH; * lead to the information loss and increase the latency of delivery of paging message; * resource overhead of PEI is significantly large when paging rate is high. | | **Behv-B** | * Resource overhead of PEI is relatively small when paging rate is high. * In an extreme case, the resource overhead can be reduced to, for example, 0. * No impact on the delivery of the paging message in the case of resource collision and PEI miss detection. | Resource overhead of PEI is high when paging rate is low. |   **Proposal 1: Behv-A and Behv-B should be configurable.**  **Proposal 4: The system information change and availability indication of periodic TRS can be conveyed by PEI.**  **Proposal 6: A PEI should be associated with multiple POs.**  **Proposal 7: The number of POs associated with one PEI should be configurable.**  **Proposal 8: Some legacy parameters can be reused to indicate the number of POs associated with one PEI.** |
| vivo | **Proposal 5: Only Behavior A should be adopted for UE behavior of PEI detection.**  **Proposal 6: Adopt that UE is not required to monitor the target PO if UE does not detect any PEI from all associated PEI MO(s) for the target PO.** |
| Spreadtrum |  |
| Sony |  |
| Samsung | **Proposal 6: Support only Behav-A for PEI for the benefit of low resource overhead.**  **Proposal 5: Merge RS-based PEI and PDCCH based PEI to a unified solution if necessary, considering**   * **common configuration of PEI monitoring occasions. and** * **no new physical layer signal/channel design.** |
| CATT | ***Proposal 1: For the evaluation and comparison of PEI candidate designs based on PDCCH, TRS/CSI-RS and SSS, Behv-A is supported.***   * ***Behv-A:***   + ***PEI indicates UE should monitor a PO if UE’s group/subgroup is paged***   + ***UE is not required to monitor a PO if UE does not detect PEI at all PEI occasion(s) for the PO*** |
| Transsion | ***Proposal 1: Both Behv-A and Behv-B should be supported and leave the selection to the network.***  ***Proposal 4: TRS availability indication should be carried by DCI-based PEI***  ***Proposal 5: PEI supports indicating the short message indicator .*** |
| Nordic | ***Observation-4****: If UE would be guaranteed wideband PDCCH DMRS within CORESET containing a search-space monitoring occasion for PEI, it would enable UE to obtain additional known synchronization signal, similarly as TRS and SSS offer.*  ***Proposal-1****: Consider introducing wide-band PDCCH DMRS transmitted in an entire CORESET configured by SIB1 or MIB during the early paging indication monitoring occasions to enable fine-synchronization based on known DMRS sequence as well as CRC based detection of PEI.* |
| Lenovo, Motorola | **Proposal 6: RAN1 further discusses DCI configuration information and RNTI for PPS-PDCCH.**  **Proposal 7: Study how to support Paging Early Indication for reduced capability UEs.** |
| OPPO | ***Proposal 5: Behv-A should be considered in PEI designs.***  ***Proposal 8: Reuse the existing DCI format or specify a new DCI format for paging early indication, if DCI-based indication is considered.*** |
| Qualcomm | Observation 4: Without multiple P-RNTIs, only one PDCCH based PEI can be transmitted in the same CCEs of the CORESET for idle/inactive UEs for the same PO.  **Proposal 3: Discuss the handling of collision between PEI and the other channels (UL symbol, DL broadcast channel including SIB, SIB PDCCH, SSB, idle/inactive TRS). No requirement for UE blind detection of the collision.**  **Proposal 5: Only support Behv-A for Rel-17 PEI design from the two UE behaviors identified in RAN1# 104-e.**  **Proposal 6: Transmit power of the PEI is configured as a power offset to the SSS in the PEI configuration.** |
| CMCC |  |
| LG | Observation 3: Once the SI change indication is transmitted, repetitions of SI change indication may occur within preceding modification period.  Observation 4: Informing short messages over the PEI avoids unnecessary UE wake ups at PO.  **Proposal 1: PEI should at least convey the information on UE sub-group indication and short message, and TRS/CSI-RS availability indication.**  **– FFS: UE group indication via PEI**  **Proposal 3: Introduce a new DCI format that conveys PEI information with smaller DCI bits than paging DCI.**  **- FFS: Reuse existing DCI format (e.g. DCI format 1\_0 with CRC scrambled by P-RNTI)** |
| MTK | Proposal 4: To merge the benefits of sequence PEI to PDCCH PEI, namely allowing simple sequence detection and tolerating larger CFO, the following alternatives can be considered:   * **Alt 1: Enable UE to detect PDCCH PEI via non-coherent sequence detection by including code-point based indication mapping to UE (sub)groups** * **Alt 2: Enable UE to detect DMRS of PDCCH PEI for whether to monitor PO by allowing one different DMRS scrambling ID from legacy PDCCH in the same CORESET**   Proposal 5: For PDCCH PEI, DCI format 2\_6 is extended with new content subject to P-RNTI. The following is the suggested content, depending on whether compact DCI format is configured (new RRC parameter)   |  |  |  | | --- | --- | --- | |  | **Normal DCI format** | **Compact DCI format** | | **PO/Subgroup indication** | **8 bits (one bit per PO/UE subgroup)** | **4 bits (code-point based mapping)** | | **TRS availability indication** | **2 bits** | **[1] bit** | | **Reserved bits** | **2 bits** | **[1] bit** | | **#DCI payload bits** | **12 bits** | **6 bits** |   **Proposal 7: To limit the PEI detection complexity, one single aggregation level is configured for monitoring PDCCH PEI (new RRC parameter)**  Proposal 8: Both Behv-A and Behv-B are supported. gNodeB configure one to apply (new RRC parameter)   * **Note: Behv-B is useful for PDCCH PEI coexistence with legacy PDCCH that is infrequent but of high priority (e.g. SI update or ETWS indication)** |
| Intel | **Proposal 2: Support Behv-A only as PEI functionality.**   * **Behv-A:**    + **PEI indicates UE should monitor a PO if UE’s group/subgroup is paged**   + **UE is not required to monitor a PO if UE does not detect PEI at all PEI occasion(s) for the PO** |
| Panasonic | **Proposal 2: Behv-A should be supported. If PEI is sent other than PDCCH region like sequence based design, Behv-B also should be selectively supported for the protection of URLLC.**  **Proposal 3: When UE is certain about the SIB configuration of PEI, if UE does not detect PEI, UE is not required to continue monitoring paging PDCCH in the PO after PEI.**  **Proposal 4: When UE is not certain about the SIB configuration of PEI, e.g. during SI modification period or before obtaining SIB configuration related to PEI and/or TRS/CSI-RS for time/frequency tracking availability status, UE should continue monitoring paging PDCCH in the PO after PEI.** |
| Apple | **Proposal 2: Adopt Behv-A, i.e.,**   1. **PEI indicates UE should monitor a PO if UE’s group/subgroup is paged.** 2. **UE is not required to monitor a PO if UE does not detect PEI at all PEI occasion(s) for the PO.** |
| IDC |  |
| DoCoMo | *Observation 1: If UE needs to monitor PO for SI change and/or ETWS in the case of configuring PEI, it causes additional UE power consumption.*  *Observation 2: Availability indication of TRS/CSI-RS for idle/inactive mode UE to acquire ACG and synchronization can be informed by DCI-based PEI.*  ***Proposal 1:*** ***It should be considered that ETWS and SI update is indicated via PEI.***  ***Proposal 2: Not only Behv-A but also Behv-B should be supported, which should be configured by the NW.***  ***Proposal 4: The following candidates can be considered as the information notified by PEI:***   * ***Whether or not UE wakes up at PO*** * ***Subgroup Information*** * ***Availability of TRS/CSI-RS for idle/inactive mode*** * ***legacy indication (ETWS, SI update)*** |
| Xiaomi |  |
| Ericsson | Observation 6 Use of reserved bits in paging DCI (as a PDCCH-PEI) in one PO as paging early indication for UEs in one or more groups in other POs can further reduce PEI signaling overhead.  Observation 7 As PEI is only monitored in RRC Idle/inactive states where only fallback DCI is used, a DCI based PEI does not impact DCI size budget of up to 4 for a cell.  **Proposal 5 In order to facilitate flexible content in PEI, the number of information bits conveyed by PEI is configurable between 1 and a maximum value PEImax (FFS on PEImax).**  **Proposal 6 For the PEI DCI, the RNTI used for CRC masking is configured via higher layers.**  **Proposal 8 PEI design supports higher-layer configuration of UE behavior wrt PEI detection/absence of PEI, i.e. whether UE follows Behv-A or Behv-B.**  **Proposal 9 RAN1 to discuss UE behavior w.r.t. PO PDCCH monitoring (e.g. to acquire ETWS/SI updates) even when UE determines that PEI indicates no paging in corresponding PO.**  **Proposal 12 PEI design should allow the use of reserved bits in paging DCI in one PO as paging early indication for UEs in one or more groups in other POs.** |
| Nokia | **Observation:** *Behv-A should be assumed as a baseline operation for EPI.*  **Proposal: Enable support of both Behv-A and Behv-B based on network configuration. Details would be for RAN2.** |
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From the above table, support of Behv-A/B looks of most interest. From UE perspective, UE always needs to monitor PEI occasions irrespective of Behv-A or Behv-B. The difference is mainly system flexibility. **From Panasonic, the use case with URLLC-like traffic looks a reasonable example, where PEI may be punctured due to high priority transmission, and Behv-B can be configured to PO avoid missing**. Since R17 paging enhancement solution should be **generic applicable to all NR use cases**, it is suggested that Behv-A/B can be up to network configuration. Companies please check the following proposal and provide your comment/suggestion in the following table, if available:

Proposal 4-1:

Both Behv-A and Behv-B are supported for paging early indication.

* Network configures one of Behv-A/B to be applied

Table 8: Companies' comments/suggestions on Proposal 4-1

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| --- | --- |
| Company | Companies’ views |
| Huawei, HiSilicon | Support. Behv-B is important for the commercialization of PEI. We also think Panasonic’s point is valid. |
| Nordic | P 4-1 We prefer only Behv-A . |
| Spreadtrum | Support |
| Samsung | We are not convinced to support Behv-B. According to the evaluation results, it requires too much resource overhead compared with Behav-A. |
| CATT | We have strong concern on supporting Behav-B. As we mentioned several times, UE could move around cells within registration area. The network would generally page UE to the latest camping cell first. If there is no response from UE, the network would page the neighboring cells of latest camping cell at next DRX cycle depending on each network’s paging strategy. There is high probability that the PEI would not be detected by UE in some DRX cycle since UE is not in the same cell when network paged. Thus, Behav-B would change the network paging strategy. We would object the support of Behv-B in the specification. |
| Intel | We support Behv-A only. We do not see motivation to support Behv-B, at least from power saving gain perspective. |
| Qualcomm | We support Behv-A but not Behv-B. In realistic paging rate, Behv-B won’t have any benefit but requires network to spend more resource/energy and more unnecessary implementation and power consumption of the UE. Note WUS for connected mode UE is different because a connected mode UE may need to wake up in every CDRX cycle. So WUS for NR Rel-16 cannot be used as the reference. A better reference should be NB-IoT WUS design which also only supports Behv-A. |
| ZTE, Sanechips | Agree.  Supporting Behv-B has following benefits:  (1) when other colliding signal/channel has higher priority, gNB has the flexibility to transmit other signal/channel without impact the delivery of paging message.  (2)In the high paging rate scenario, Behv-B requires less resource.  For Behv-A, if UE misses the PEI, it would cost more resource and energy for gNB to re-transmit the PEI and paging message in the next paging cycle, more energy for UE to detect the retransmitted PEI, and increase the latency of paging message. |
| vivo | We support BehavA only and not convinced the benefits for BehaveB. As clarified in our contribution [R1-2106606], the most obvious drawback of Behavior-B is that by adopting Behavior B, if a UE is not required to receive PO, the network shall always transmit PEI with no paging indication explicitly in order to save power. Moreover, the agreed per PO paging rate is 10%, which means the no paging rate is up to 90%. Hence, behaviour B does not provide beneficial either for power saving or resource overhead as our analysed and evaluated. |
| Lenovo, Motorola Mobility | Support |
| Apple | We support Behv-A because Behv-B causes unnecessary overhead and power consumption for the network. The overall PEI overhead with Behv-A is very small even in the worst case, so we do not think we need to worry much about PEI blocking other traffic. Note that PEI typically only occupies a small part of the carrier bandwidth, and urgent traffic can still be transmitted with the remaining bandwidth. |
| CMCC | Support |
| Ericsson | Support both Behv-A and Behv-B. It is important that PEI design includes tools such as configurable behavior (Behv-A and B) that help the NW minimize negative impact, especially in cases of higher paging rates, otherwise NW has no choice other than transmitting PEIs, thereby increasing NW energy consumption in order to guarantee paging performance. This is also aligned with the connected mode WUS design. |
| DOCOMO | We support this proposal.  As it was pointed out by some companies, in Behv-B, NW can have the flexibility to prioritize legacy channels/signals. For example, when the resource is full for legacy channels/signals and there is no room for PEI, NW can skip PEI transmission and UE just monitors a PO since UE does not detect PEI. When NW skip PEI in Behv-A, UE can’t receive paging DCI in PO and try to monitor PEI at the next paging cycle. |
| Panasonic | We think Behv-A and Behv-B should both be supported. Besides the network configuration of one of them, we think the UE behaviour in some cases should also be specified, e.g. system modification for the PEI or TRS. |
| Sony | We support Beh-A and therefore we do not support proposal 4-1.  It is true that from UE perspective and UE power saving, Beh-A and Beh-B have the same power saving gain BUT Resource overhead in Behv-A is much lower than the one in Behv-B since the PEI does not need to always be transmitted. By introducing a window for PEI transmission/reception prior to PO we can avoid any blocking when other DL transmissions coincide with PEI. |
| LG | We support proposal 4-1. |
|  |  |
|  |  |

Regarding PDCCH-based PEI, additional indications and DCI format design are also one identified topic. In particular, companies please check the following proposals and provide your comments/suggestions in the following table, if available.

Proposal 4-2:

For PDCCH-based PEI, the following indications can be configured in DCI in addition to subgroups indication:

* TRS availability
* SI update or ETWS
* FFS: Reserved bit(s) for future extension

Proposal 4-3:

For PDCCH-based PEI, the following DCI format can be configured to carry targeted indications:

* DCI format 2\_6 with P-RNTI
* DCI format 1\_0 with P-RNTI
  + Use of reserve bits for subgroups indication
  + FFS: How to avoid false paging for legacy UEs

Table 9: Companies' comments/suggestions on Proposals 4-2, 3

|  |  |
| --- | --- |
| Company | Companies’ views |
| Huawei, HiSilicon | **For proposal 4-2:**  We support proposal 4-2 in general. However, it is common understanding that the reserved bits can be used for future extension. So, maybe no need of the last bullet.  **For proposal 4-3:**   1. We are supportive on DCI format 2\_6. But we think the RNTI can be a new RNTI.   We are not sure whether we need to support DCI format 1\_0. DCI format 2\_6 can be configured with either small size or larger size. |
| Nokia | Regarding proposal 4-2,   * We are in principle fine with the intent of the proposal, with the clarification that the details of corresponding indication and procedures can be refined later. * For reserved bits for future use, there are various ways, of which one is that the DCI size and the field location information can be provided, allowing forward compatibility.   On proposal 4-3,   * It would be first good to clarify that CONNECTED mode UE is not expected/required to monitor PEI (i.e. we are not bound by the DCI size configuration limits). Once/if that is concluded, then it could be desirable to be able to select the PEI DCI size independent of DCI format 1\_0 size (e.g. smaller). Hence, having configurable DCI format could be preferable. It is not clear that two options are needed for DCI formats if we can configure the format. |
| Nordic | P 4-2 TRS better to be discussed in 8.7.1..2 AI . SI update OK  P 4-3 We do not prefer coupling of IDLE WUS with connected WUS, PEI should have DCI format of its own, but payload size could be aligned. Reusing reserved bits in Paging DCI is OK. |
| Spreadtrum | Support. Share the similar view as Huawei. |
| Samsung | Proposal 4-2 is unacceptable to us. Paging PDCCH already supports the indication for SI update or ETWS, and will support TRS availability too. No need to repeat the same functionality in PEI, especially another type of PDCCH. We should focus on the basic functionality we have discussed and evaluated so far. PEI indicates UE whether or not to monitor a PO is sufficient to achieve the power saving gain, no need to consider other indication content.  For proposal 4-3, it’s the next level details, which can be discussed after L1 signal/channel design is confirmed. |
| CATT | For Proposal 4-2, the TRS availability indication would be discussed in AI-8.7.1.2. We don’t support the SI update and ETWS in PEI since paging message would have clear indication on the purpose of paging or ETWS. PEI is used to indicate UE receiving Paging DCI and paging message/ETWS message.  For Proposal 4-3, we need to discuss whether P-RNTI could be reused for DCI-based PEI. Furthermore, we don’t agree to reuse DCI format 2\_6 as PEI since it will create ambiguity with Rel-16 DCP in CONNECTED mode. We could have new DCI format 2\_7 instead. |
| Intel | Do not agree proposal 4-2. We do not support duplicate functionality of paging DCI by PEI. Indication by Paging DCI for the considered contents seems sufficient. Since the common understanding is that network is not expected to send L1 availability indication frequently and typical paging probability is low, additional power saving gain of indication by PEI over paging DCI is not expected to be significant.  Proposal 4-3 can be postponed. We do not see how 2\_6 can be used, it would be a new DCI format in idle mode. Or, the intention here is to reuse the DCI format number? If it is format 1\_0, then PEI is serving as paging DCI? |
| Qualcomm | For proposal 4-2, we support TRS availability indication in paging PDCCH, and we do not think it is necessary for PEI to carry the TRS availability indication. But even though the PEI can carry TRS availability indication, both PDCCH and sequence/RS based designs can do this. Besides, we object SI update or ETWS in PEI for any PEI design option. Given this, we object proposal 4-2.  It is too early to discuss proposal 4-3. |
| ZTE, Sanechips | For proposal 4-2:  We support to use PEI to indicate information such as TRS availability, SI update, etc. to bring additional power saving benefits.  For proposal 4-3:  As the value of P-RNTI is fixed as FFFE (only one value according to 38.321), it is better that the RNTI for the DCI based PEI is new and configurable to avoid false paging. |
| Vivo | For proposal 4-2, we support TRS availability indication in paging PDCCH.  In the last meeting, support paging PDCCH for availability indication is taken as WA in AI8.7.1.2. For this meeting, we think it can be confirmed.   1. Support PEI for availability indication need to take PEI as prerequisite feature for idle TRS, we think it is not necessary. 2. The TRS availability may not change very frequently, thus indication by Paging DCI for the considered contents seems sufficient. |
| Lenovo, Motorola Mobility | Fine with Proposal 4-2.  For Proposal 4-3, we think RNTI should be discussed together with how to determine monitoring occasions and the max payload size of a DCI format. For example, the RNTI may be dependent on a reference PF (or a reference PO) which is used to determine monitoring occasions. |
| Apple | We are generally supportive of P4-2, except that the FFS point does not seem necessary.  For Proposal 4-3, we do not see why we need to reuse the existing DCI formats (or how we can reuse). We think it is more straightforward to define a new DCI format. |
| CMCC | Proposal 4-2: Support.  Proposal 4-3: Not support. Don’t know why to reuse existing DCI formats, since the indication in PEI are totally different from DCI format 2\_6 or DCI format 1\_0 with P-RNTI, it is straightforward to design a new DCI format. |
| Ericsson | Proposal 4-2 : support.  Proposal 4-3 : Not support –DCI format and RNTI should be configurable. Since DCI 2\_6 is used for connected mode UE, the motivation to consider it is unclear. |
| DOCOMO | For proposal 4-2, we are fine with this proposal. In particular, informing TRS availability by PEI is important to get best Power saving gain of additional TRS. |
| Panasonic | On 4-2, we are okay.  On 4-3, we share the concern of the false paging to the legacy UEs. We don't support to use DCI format 1\_0 with P-RNTI. |
| Sony | We do not support these proposals. These details need to be discussed after selecting the PEI design. |
| LG | For proposal 4-2   * We are fine with this proposal. If 12 bit DCI size is assumed and 8 bits in a PEI are used for UE subgroup indication, there are 4 remaining bits which can afford other functionalities. * If PEI can indicate TRS availability between the PEI and a corresponding PO, UE can use actual TRS transmission for paging reception. * If SI update and ETWS notification is not conveyed by PEI, UE should wake up at the PO and will expect PDSCH reception. Also, as we mentioned in our paper, gNB would repeat paging PDCCH to inform SI update and ETWS notification during a modification period. * Regarding the sub-bullet on reserved bit(s), we may need it for forward compatibility. Also, a configurable size of reserved bit(s) is preferred to reduce the unnecessary DCI overhead.   For proposal 4-3   * We are fine with DCI format with configurable size, so DCI format 2\_6 like design can be considered. * We are fine with considering DCI format 1\_0. For example if PO(s) occurs every frame, using PO for other UE group as PEI monitoring occasion could be considered. * Regarding RNTI values, we are generally fine with the proposal. But we are open to discuss further. |
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Finally companies are welcomed to provide suggested specification proposal(s) in the table below if any is missing in the above.

Table 10: Additional specification Proposals for PEI

|  |  |
| --- | --- |
| Company | Companies’ views |
| Huawei, HiSilicon | The interference from PEIs and legacy signals of neighbor cells needs to be evaluated and considered for TRS/SSS-based PEI. |
| CATT | We had shown PEI detection performance with the multi-sequence interference of sequence-based PEI in R1-2106983. The PEI performance and power saving gain of DCI-based PEI should be re-run with realistic evaluation assumption of at least 3 SSBs. |
| Intel | Maximum DCI Payload, whether DCI payload is configurable or not, impact on reliability for larger DCI payload sizes. |
| Qualcomm | Transmit power of PEI should be configured. Coexistence of PEI with idle/inactive TRS should be discussed. But both are not the priority before down selection of PEI design is done. |
| ZTE, Sanechips | The performance of PEI carrying sub-grouping information should be evaluated for SSS/TRS-based PEI. |
| LG | One PEI to multiple PO mapping can be considered. |
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|  |  |

**Updated Proposals for Phase\_2 Discussion**

Thanks for companies’ valable inputs. For collection of remaining issues, companies are welcomed to provide your inputs to the above table.

For Proposal 4-1, the following is the status from companies’ feedbacks:

Behv-A only (8): Nordic, Samsung, CATT, Intel, Qualcomm, vivo, Apple, Sony

Behv-A and Behv-B (configurable by network) (9): Huawei, Spreadtrum, ZTE, Lenovo, CMCC, Ericsson, DoCoMo, Panasonic, LG

Given that Behv-A is commonly supported while there are slight majority support on supporting Behv-B as well, we suggest to at least support Behv-A and keep FFS Behv-B:

**Proposal 4-1a:**

At least Behv-A for UE to monitor PEI for whether to monitor PO is supported.

* FFS: Whether Behv-B can be configured by network

For Proposal 4-2, since indication of TRS availability at least in PDCCH PEI is WA of A.I. 8.7.2, the following can be specified as well. Since there are 9 companies support inclusion of “SI update or ETWS”, keeping it as FFS should be a reasonable way forward:

**Proposal 4-2a:**

For PDCCH-based PEI, the following indications can be configured in DCI in addition to subgroups indication:

* TRS availability
* FFS: SI update or ETWS
* ~~FFS: Reserved bit(s) for future extension~~

For Proposal 4-3, DCI format is a necessary specification for PDCCH PEI. As per session chair’s guidance to identify the remaining specification efforts, the following update is suggested. In particular, to avoid ambiguity with R16 DCP in connected mode, a new DCI format is suggested. Utilization of DCI format 1\_0 with P\_RNTI is proposed by multiple companies and FFS is also reasonable WF to see whether it is beneficial to include. By the above the updated proposal is as follows:

**Proposal 4-3a**:

For PDCCH-based PEI, a new DCI format is supported for carrying targeted indications.

* FFS: DCI format 1\_0 with P-RNTI by use of reserve bits for subgroups indication or repurpose the bit fields without causing false paging to legacy UEs

Companies’ please check Proposals 4-1a/2a/3a and provide your feedbacks in the table below:

Table 11: Companies’ feedbacks on Proposal 4-1a/2a/3a

|  |  |
| --- | --- |
| Company | Companies’ views |
| Nordic | 4-1a OK , 4-2a should be taken as WA and 4-3a is OK |
| Nokia | Just a note that I forgot to provide comments regarding the behaviours for the first round, but our position would still be to support both and have NW configurability over Behv-A and Behv-B.  Proposal 4-1a: We are OK to take the intermediate step and support at least Behv-A and continue the discussion regarding Behv-B support.  Proposal 4-2a: We are OK with proposal and are supportive to consider further separate indication for ETWS/SI update to minimize the UE paging DCI monitoring. Like noted the possible procedures related to the SI reading in this context should be clarified.  Proposal 4-3a: Like noted, considering configurable DCI format to enable optimizing the DCI size would be preferable. It should be possible to configure separately a sub-group field corresponding to each PO associated to the given PEI. In addition, we could consider some more restricted maximum size for the PEI DCI size. As in our understanding CONNECTED mode UE is not expected/required to monitor PEI we are not restricted by the DCI size configuration limit (there is room in terms of budget 3+1). |
| Samsung | **Proposal 4-2a:**  The availability indication should be discussed in AI 8.7.1.2. We do not support it regardless of PEI candidate. No need to repeat the discussion in this AI.  **Proposal 4-3a:** this should be combined with Proposal 2-1a, since it’s also related to subgroups indication |
| Intel | Support Proposal 4-1a. Proposals 4-2a depends on progress of confirming WA in 8.7.1.2. Regarding Proposal 4-3a, it seems new DCI format is needed if PDCCH based PEI is supported. For both 4-2a/4-3a, correction is needed as follows:  For PDCCH-based PEI 🡪 For PDCCH-based PEI (if supported)  For 4-3a, we think FFS on DCI format 1\_0 may be an independent bullet, not as sub-bullet under new DCI format. Moreover, following FFS bullets are needed with regards to new DCI format.   * FFS: new or existing RNTI can be used * FFS: Whether payload can be configurable, maximum payload etc * FFS: Whether payload can be less than 12 bits, and corresponding processing |
| Huawei, HiSilicon | **Proposal 4-2a:**  Support. |
| IDCC | We are ok with 4-1a and 4-2a. Agree with Intel on 4-3a. |
| CATT | We are OK with proposals 4-1a. Proposal 4-2a on TRS availability indication should be discussed in AI-8.7.1.2. We agree with Intel’s revision on Proposal 4-3a |
| OPPO | We are OK with 4-1a and 4-3a. Proposal 4-2a on TRS availability indication can be discussed in AI-8.7.1.2. |
| Xiaomi | For 4-2a, at least TRS availability should be discussed in 8.7.1.2. |
| CMCC | We are fine with three proposals. |
| Apple | We support P4-1a and 4-2a.  On P4-3a, we support the main bullet, but the FFS bullet is a bit confusing. Is it about using paging PDCCH for subgroup indication? If yes, this should be discussed separately. If not, some clarification would be appreciated. |
| Lenovo/Motorola Mobility | Allowing a network to configure between Behv-A and Behv-B can balance between UE and network power saving and balance between resource utilization efficiency and UE power saving, depending on operating scenarios/conditions. Thus, we suggest the following modification:  **Proposal 4-1a:**  ~~At least~~ Behv-A for UE to monitor PEI for whether to monitor PO is supported as a default UE operation.   * ~~FFS: Whether~~ Behv-B can be configured by network   Fine with proposals 4-2a and 4-3a. |
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# Decision of PEI Physical-Layer Channel/Signal

In Table 1, companies’ suggestions on PEI decisions are collected:

Table 12: Companies’ suggestions on decision of PEI physical-layer channel/signal

|  |  |  |
| --- | --- | --- |
| Company | Suggested PEI channel/signal | Companies’ views |
| Huawei, HiSilicon | PDCCH | ***Proposal 5: Adopt DCI carried by PDCCH as the physical layer channel for PEI indication.*** |
| TCL | N/A |  |
| ZTE | PDCCH | Proposal 5: Adopt DCI-based PEI to reduce the paging reception for RRC idle/inactive state UE. |
| vivo | SSS or TRS | Proposal 8: Sequence (i.e., SSS-like or TRS-like) should be adopted for PEI design. |
| Spreadtrum | PDCCH | ***Proposal 4: PDCCH-based PEI is supported in R17.*** |
| Sony | SSS or TRS | ***Proposal 3 – Support sequence-based PEI as a paging enhancement scheme to reduce idle PO monitoring cost at the UE, as it has higher power saving gain and lower system overhead.***  ***Proposal 4 – Use sequence-based PEI as a paging enhancement scheme for UE sub-grouping to reduce overhearing and false-wake-up cost.*** |
| Samsung | CSI-RS or  CSI-RS + PDCCH | **Proposal 2: Support RS based PEI for better performance than PDCCH based PEI, including**   * **higher power saving gain,** * **lower resource overhead, and** * **no impact to Rel-15/16 UEs, especially on PDCCH blocking rate.**   **Proposal 5: Merge RS-based PEI and PDCCH based PEI to a unified solution if necessary, considering**   * **common configuration of PEI monitoring occasions. and** * **no new physical layer signal/channel design.** |
| CATT | TRS or SSS | Proposal 3: The sequence-based PEI should be adopted in Rel-17 for UE in IDLE/Inactive mode for UE power saving. |
| Transsion | PDCCH | ***Proposal 3: DCI-based PEI should be supported by R17.*** |
| Nordic | PDCCH | ***Proposal-1****: Consider introducing wide-band PDCCH DMRS transmitted in an entire CORESET configured by SIB1 or MIB during the early paging indication monitoring occasions to enable fine-synchronization based on known DMRS sequence as well as CRC based detection of PEI.*  ***Proposal-2:*** *Down-select PDCCH as PEI signal/channel.* |
| Lenovo, Motorola | PDCCH | **Proposal 3: For PDCCH based PEI, Paging Power Saving (PPS)-PDCCH search space configuration can be signaled in SIB1 or in an RRC release message.**  **Proposal 6: RAN1 further discusses DCI configuration information and RNTI for PPS-PDCCH.** |
| OPPO | PDCCH | ***Proposal 6: DCI-based PEI is preferred for paging early indication.*** |
| Qualcomm | SSS | **Proposal 7: Rel-17 PEI design is based on sequence**   * **Narrowband sequence such as SSS is preferred. Different SSS sequences can be multiplexed in the frequency domain in the same OFDM symbol** * **Availability of TRS at configured occasion(s) is indicated by paging PDCCH** * **How paging PDCCH and paging PDSCH are transmitted follows legacy rules but is not impacted by PEI** |
| CMCC | PDCCH | **Proposal 1. Support PDCCH-based PEI.** |
| LG | PDCCH | **Proposal 2: Support PDCCH based PEI.** |
| MTK | PDCCH | Proposal 1: PDCCH-based PEI is selected as PEI physical-layer channel/signal.  Proposal 4: To merge the benefits of sequence PEI to PDCCH PEI, namely allowing simple sequence detection and tolerating larger CFO, the following alternatives can be considered:   * **Alt 1: Enable UE to detect PDCCH PEI via non-coherent sequence detection by including code-point based indication mapping to UE (sub)groups** * **Alt 2: Enable UE to detect DMRS of PDCCH PEI for whether to monitor PO by allowing one different DMRS scrambling ID from legacy PDCCH in the same CORESET** |
| Intel | TRS or SSS | **Proposal 1: Support sequence-based PEI for Rel-17.**   * **FFS: TRS/CSI-RS based PEI or SSS-based PEI** |
| Panasonic | TBD | **Proposal 1: To firstly agree on functionalities of PEI and the number of bits supported by PEI, before agreeing on PDCCH, SSS or TRS/CSI-RS based design. If 5 or more bits are supported by PEI, where PEI is located close to SSB instead of each PO, PDCCH-based design should be taken. Otherwise, sequence based design should be taken.** |
| Apple | PDCCH | **Proposal 1: Use PDCCH to carry paging early indication.** |
| IDC | TRS or SSS | **Proposal 1: Sequence-based paging early indication is adopted for UE power saving in Rel-17.** |
| DoCoMo | PDCCH | ***Proposal 3: DCI-based PEI should be supported.*** |
| Xiaomi | PDCCH | ***Proposal 1: DCI-based PEI is preferred and can be carried in paging search space. For target UE group A’s PO for paging, its PEI can be located in another UE group B’s PO which is earlier in time domain.*** |
| Ericsson | PDCCH | Proposal 4 Physical layer design for PEI is based on PDCCH DCI. |
| Nokia | PDCCH | **Proposal:** **Base the EPI design on PDCCH/DCI.** |
|  |  |  |

From the above table, the following statistics can be checked:

|  |  |
| --- | --- |
| PDCCH (15) | HW, ZTE, Spreadtrum, Transsion, Nordic, Lenovo, OPPO, CMCC, LG, MTK, Apple, DoCoMo, Xiaomi, Ericsson, Nokia |
| Sequence (7) | * Either TRS or SSS (5): vivo, Sony, CATT, Intel, IDC * Specific (2): Samsung (CSI-RS), QC (SSS) |
| TBD (2) | TCL, Panasonic |

Based on companies’ detailed inputs (please see Appendix A), the following are major debate points:

1. When UE is not paged, whether can PDCCH-based PEI help UE to achieve minimum operations (serving cell measurement and PEI monitoring)?
2. When UE is paged, whether and how can sequence PEI be utilized for fine synchronization?
3. Whether can dynamic resource sharing with legacy/R15 UEs be always applied with sequence PEI?

Companies are encouraged to provide clarification/justification for resolving the debate points/conflicts in the following table:

Table 13: Companies clarification/justification for resolving the above debate points

|  |  |
| --- | --- |
| Company | Companies’ views |
| Huawei, Hisilicon | **For question a)：**  We think the answer is yes. SS burst(s) need to be received by UE for AGC and serving cell measurement. The number of SS burst(s) should be the same for all PEI candidates. This is common for all three PEI candidates. It was justified by many companies through simulation that PDCCH can be fulfil the PEI requirement after 1 SS burst reception. Therefore, when UE is not paged, PDCCH-based PEI can achieve minimum operations (serving cell measurement and PEI monitoring).  **For question b):**  We do not think the sequence based PEI can be utilized for fine synchronization. UE should not perform time/frequency tracking based on a signal/channel which is based on blind detection. Such a design has never been used in current NR specification, and has not been justified yet. Once the PEI is false detected considering low SINR scenario or neighbouring cell interference, UE shall perform T/F synchronization based on noise & interference and more T/F errors would be introduced. As a result more SS bursts are needed for the T/F synchronization of the subsequent DRX cycles. Both of the performance and power saving gain are impact.  **For question c):**  Dynamic resource sharing are hardly applied to sequence-based PEI. As discussed in our paper in RAN1#104bis~106:   * 1. Dynamic RB\*symbol level rate matching is not mandatory for legacy UE.   2. For TRS based PEI, the three AZP-CSI-RS resource sets are very limited, which needs to be used for CSI and other measurement purposes. No available AZP-CSI-RS resource set can be always allocated for PEI deployment.   3. CORESET-based dynamic resource sharing asks for dedicated CORESET or a shared non-interleaved CORESET on legacy UEs:   + If a dedicated CORESET is configured for PEI rate matching purpose for FR1, all the downlink traffic for the legacy UE has to be scheduled in CORESET0, which is too limited for downlink traffic scheduling, considering only one additional CORESET is supported by UE per BWP in addition to CORESET0 for FR1 based on UE capability #3-1.   + If a dedicated CORESET is configured for PEI rate matching purpose for FR2, one of the three CORESETs would be used for rate matching exclusively. The multi-beam operation will be limited and the downlink performance would be impact.   + If a shared CORESET is configured, a non-interleaved CORESET needs to be configured for sharing PEI. However, it should be noticed that IDLE mode UE shall just receive the bandwidth of MIB configured initial DL BWP, i.e. CORESET0 bandwidth. Therefore, such configuration requires that the CORESET for PEI occupies the same frequency domain as (or partial overlapped with) CORESET0, however, is configured in different symbols other than symbol 0~2 to avoid the impact on CORESET0 (CORESET0 is interleaved). This introduce the restriction on the configuration of the additional UE specific configured CORESET and will impact the scheduling flexibility scheduled by PDCCH in CORESET 0 since some symbols other than symbol0~2 needs to be avoided which have been used for CORESET for PEI.   Therefore, the resource overhead on sequence-based PEI based on dynamic resource sharing cannot be always applied. |
| Nordic | 1. TRS for RRM had no consensus, no need to re-discuss again for PEI 2. Sequence PEI can be utilized for synchronization. For example, a UE can firstly detect PDCCH and only after that use wideband DMRS for further synchronization. Alternatively, UE can blind detect first WB DMRS with rough synchronization and only then perform PDCCH detection. 3. We think that TRS cannot be placed on legacy or R17 UE CORESET or SSB and CORESET dynamic rate-matching is mandatory for R15 UEs, so the rate-matching is the most optimized for PDCCH. |
| Nokia | [Missed these on first round]  On point a), there should not be any difference between the candidates from serving cell monitoring.  Correspondingly on point b), as there is no guarantee of the ‘availability’of the sequence based PEI, thus in similar manner as discussed in context of TRS occasions, it would not seem possible to base the fine synchronisation solely to sequence based PEI.  For c, as discussed over past meetings, dynamic rate matching is not a mandatory feature thus cannot be relied. For TRS-PEI, use of aperiodic ZP-CSI-RS could be considered, but as these resources are intended for general aperiodic CSI-RS multiplexing the availability cannot be guaranteed and use would affect the overall flexibility of the deployment. Also TDM/FDM of TRS-PEI resources would be limited by the ZP-CSI-RS configuration(s). |
| Spreadtrum | 1. NR UE should perform RRM measurement for serving cell periodically, e.g. once per paging cycle. The minimum operation is processing one SS burst per paging cycle for PDCCH-based and sequence-based PEI both. For NB-IoT, sequence-based WUS has additional power saving gain since the RRM measurement relaxation for serving cell is assumed for low mobility use cases. NB-IoT UE can operate without synchronization and perform non-coherent WUS detection for several paging cycles (the number of paging cycles is dependent on the RRM measurement relaxation for serving cell). However, it is not true for NR UE. 2. NR UE is hard to utilize the sequence-based PEI for fine synchronization, since the sequence-based PEI is DTXed, and T/F tracking loop cannot rely a DTXed RS in current NR UE implementation. Recalling the discussion of AP-TRS in R15, it is general view that AP-TRS is just the additional RS on top of P-TRS, and this is specified as AP-TRS is present only when the same configuration of P-TRS is present. It means that NR UE should rely on the period RS for T/F tracking loop. 3. It is too optimistic. The dynamic rate matching by connected mode UE is not so realistic, since the RS for the connected mode UE could be based on C-DRX and beam directions of connected UE, which could not be aligned to the idle-mode sequence for PEI. |
| Samsung | For a), it doesn’t matter UE is paged or not, UE needs to process a number of SSBs before PDCCH-based PEI reception for synchronization and serving cell measurement. For the minimum operations for PDCCH based PEI, it should include synchronization, serving cell measurement and PEI monitoring. Synchronization is missing.  For b), yes, sequence based PEI can be used for synchronization. That’s the assumption we agreed on the same power model for PDCCH-based PEI and sequence based PEI in the first place; otherwise the power consumption for sequence based PEI should be much lower than PDCCH based PEI considering the low complexity correlation behaviour.  Since both synchronization and PEI detection are based on correlation between received data and pre-known sequence, UE can perform PEI detection and synchronization in terms of time/frequency offset estimation simultaneously within the monitoring occasion of PEI. In practice, UE just needs to conduct multiple trails of correction assuming different time/frequency offsets. When the maximum correction exceeds a predetermined threshold, the UE can claim detection of PEI and the corresponding time/frequency offsets are synchronization results, which can be used for paging PDCCH or PDSCH reception in next PO.  We have simulation results to show the synchronization performance of CSI-RS based and SSS based PEI in R1-2008175.  For c), NW has the flexibility to support dynamic resource sharing of sequence based PEI with legacy UEs in many ways. Dynamic RM is not always needed. |
| CATT | For (a), the low power correlator bank used for sequence-based PEI detection had been implemented at the UE for other purpose, such as cell search in the batch processing. The detection of sequence-based PEI would have smooth operation with/without paging message and consume very low power for any detection and achieve UE power saving gain. In contrary, the DCI-based PEI needs UE to turn on the whole RF and baseband processing and front-end signal processing in order to achieve coherent demodulation and Polar decoding. UE would barely have any power saving benefit of having DCI-based PEI if there is no paging message. Moreover, the additional operation of DCI-based PEI detection would prolong the paging time interval when UE is roaming around different cells.  For (b), the sequence-based PEI or RS signals had been assumed to be used for the detection, channel tracking and channel estimation since the study of NR in Rel-15. The SSB design and performance evaluation in Rel-15 had assumed the SSS is used for the detection of cell ID, channel track and channel estimation for PBCH. The additional DMRS used for PBCH channel estimation is because the BW of PBCH is wider than that of PSS/SSS. Thus, we don’t need to further discuss the feasibility of sequence-based PEI used for channel tracking and estimation since it was assumed in the NR design since Rel-15.  For c), we had shown the resource sharing and TRS-based PEI detection performance with legacy UE in R1-2106983. We also provide analysis of resource overhead of all PEI candidates. For DCI-based PEI, the CORESET resource configured for DCI-based PEI would be accounted as overhead if the CCEs are not used by other UEs even DCI-based PEI is not transmitted. However, sequence-based PEI could be used by PDSCH of other UE through rate matching. |
| Intel | Similar view as Samsung regarding bullet a) , b) above.  We do not see any fundamental feasibility issue for using TRS-based PEI for tracking. Even for receiving sync signals, UE would have to detect them during cell search and perform tracking as well. Hence, UE blind detection is not an issue as far as feasibility is concerned. As long as MDR is sufficiently low for a target FAR, there is no critical issue. More importantly, this is used as supplementary tracking signal after UE detects at least one SSB.  Regarding bullet c), previously agreed observations clearly capture that network has the tool to implement dynamic RM such as follows. Of course, it is not always necessary, and it is up to network whether to use it depending on coexisting signal/channels.   1. For coexistence with legacy PDSCH, dynamic resource sharing can be realized for all PEI candidates if PDSCH is scheduled by DCI format 1\_1    * For TRS/CSI-RS based PEI, RE-level rate matching can be realized for the PDSCH as per mandatory capability |
| Qualcomm | For a), it is highly dependent on UE implementation whether PDCCH can be used for RRM measurement. Depending on assessment of the implementation cost, a UE may or may not want to do this even in theory, the UE can do RRM measurement based on PDCCH PEI. The UE would need to first determine a PDCCH is detected, then re-encode the payload and calculate the RSRP as if the PDCCH is sequence. In this sense, a sequence-based PEI can make this much easier.  For b), similar to a), this would depend on UE implementation although in theory this can be done.  For c), yes. Both CSI-RS and SSS-based PEI can be configured as resources in a CORESET to the connected mode UE when different CSI-RS or SSS are FDM’ed/TDM’ed within the CORESET bandwidth and time duration. This does not mean additional CORESET has to be used. Network can reuse CORESET#0 as bandwidth of PEI should be within CORESET #0. Network may need to use additional SS set to indicate the time domain location of PEI monitoring occasions. But since there can be up to 10 SS sets for the connected mode UE, the impact of this design is negligible. |
| ZTE, Sanechips | 1. Yes, PDCCH based PEI can help UE to achieve the minimum operations. According to current spec, UE needs to measure SSB for serving cell measurement per paging cycle, hence, the frequency offset after UE wakes up should not be too large. According to the previous discussion, most companies think initial CFO is up to ±0.5ppm, which is a reasonable range. And under such a restriction, the performance impact of PDCCH based PEI is acceptable according to companies’ evaluations. 2. For Behv-B, the PEI is transmitted when the UE is not paged, in this case, the sequence PEI cannot be utilized for synchronization. For Behv-A, in the false alarming case when gNB doesn’t transmit PEI, but UE takes noise as PEI and use it for synchronization, it will degrade the synchronization performance of the entire system and more SSBs are needed for synchronization compensation in the next paging cycle. Therefore, we think it is problematic to use PEI for sync.   No. Firstly, supporting more than 2 CORESETs is an optional UE capability according to TS 38.306. Secondly, the maximum number of aperiodic *ZP-CSI-RS-ResourceSet(s)* configured per BWP is 3, which is very limited. What’s more, if the resource of sequence PEI overlaps with an interleaved CORESET, it will increase the PDCCH blocking rate or increase the paging latency. |
| vivo | For question a), the question itself is unclear for what is to achieve minimum operations? Can you clarify that?  For question b), we think it is no doubt that the sequence-based PEI itself such as SSS/TRS/CSI-RS can assist the RRM measurement or ACG adjustment or T/F tracking, since these is the one of the functions for SSS/TRS/CSI-RS. However, for PDCCH based PEI, it is not possible.  For question c),  It RAN1#105 meeting, it is agreed that  Agreement:  **Observation:**  Dynamically sharing PDCCH resource***s*** of Rel-15 UEs (whether or not this is an important aspect to consider for PEI is FFS)  …  We have analysis the system overhead for dynamically sharing and semi-static sharing in our contribution [R1-2106606], it is shown that at least from system overhead perspective, Dynamically sharing PDCCH resource is not an important aspects.  **Table 10: The resource overhead ratio to the overall system resource of the three PEI candidate designs by using different rate-matching methods.**   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | **PEI design** | **Rate matching methods** | **Baseline: resource overhead ratio for 100MHz/20MHz**  **PO and PEI mapping manner:**  **1 to 1 for sequence-based PEI;**  **1 to 1 for DCI based PEI;** | | **Resource overhead ratio for 100MHz/20MHz**  **PO and PEI mapping manner:**  **1 to 1 for sequence-based PEI;**  **2 to 1 for DCI based PEI;** | | | Behavior A | Behavior B | Behavior A | Behavior B | | **SSS like sequence for 2 symbols** | Dynamic rate matching | **0.0028%/0.014%** | **0.025%/0.125%** | **0.0028%/0.014%** | **0.025%/0.125%** | | Semi-static rate matching | **0.028%/0.14%** | **0.028%/0.14%** | **0.028%/0.14%** | **0.028%/0.14%** | | **TRS like sequence for 2 symbols** | Dynamic rate matching | **0.0031%/0.016%** | **0.028%/0.14%** | **0.0031%/0.016%** | **0.028%/0.14%** | | Semi-static rate matching | **0.031%/0.16%** | **0.031%/0.16%** | **0.031%/0.16%** | **0.031%/0.16%** | | **DCI for AL 8** | Dynamic rate matching | **0.0063%/0.032%** | **0.057%/0.285%** | **0.006%/0.03%** | **0.051%/0.26%** |   Dynamic resource sharing with legacy/R15 UEs can be always applied with sequence PEI. The answer is yes as quoted the agreements made in RAN1 #104bis and 105bis in the highlight parts as follow:  Agreement:  **Observation 1a:**  For the evaluation and comparison of PEI candidate designs, the following observations for coexistence with legacy PDSCH are identified:   1. For coexistence with legacy PDSCH, semi-static resouce sharing by configuring RB-symbol-level or RE-level rate-matching patterns covering PEI REs is supported for all PEI candidate designs. 2. For coexistence with legacy PDSCH, dynamic resource sharing can be realized for all PEI candidates if PDSCH is scheduled by DCI format 1\_1    * For PDCCH based PEI, CORESET-level rate matching can be realized for the PDSCH as per mandatory capability    * For SSS-based PEI, CORESET-level rate matching may be realized for the PDSCH as per mandatory capability, depending on the design of SSS-based PEI and UE capability regarding number of supported CORESETs    * For TRS/CSI-RS based PEI, RE-level rate matching can be realized for the PDSCH as per mandatory capability    * When PDSCH is not scheduled by DCI format 1\_1, it is up to gNB implementation whether and how PEI is transmitted in PDSCH resource   Agreement:  **Observation:**  Dynamically sharing PDCCH resource***s*** of Rel-15 UEs (whether or not this is an important aspect to consider for PEI is FFS)   * + For PDCCH-based PEI,     - PEI can dynamically share resources with PDCCH for Rel-15 UEs within a PDCCH CORESET at granularity of one or more candidates       * Exact number of multiplexed/impacted Rel-15 PDCCH candidates depends on AL used for PDCCH-based PEI and relative size of PDCCH CORESET, etc.   + For SSS-based PEI and for the case of partial overlap of CORESET and PEI     - For interleaved CORESET (such as CORESET#0), SSS-based PEI can dynamically share resources with PDCCH for Rel-15 UEs only at CORESET-level granularity     - For non-interleaved CORESET, SSS-based PEI can dynamically share resources with PDCCH for Rel-15 UEs within a PDCCH CORESET at granularity of one or more candidates       * Exact number of impacted Rel-15 PDCCH candidates depends on relative size and location of PDCCH CORESET, etc.   + For TRS/CSI-RS-based PEI and for the case of partial overlap of CORESET and PEI     - For interleaved CORESET (such as CORESET#0), TRS/CSI-RS-based PEI can dynamically share resources with PDCCH for Rel-15 UEs only at CORESET-level granularity     - For non-interleaved CORESET, TRS/CSI-RS-based can dynamically share resources with PDCCH for Rel-15 UEs within a PDCCH CORESETat candidate level granularity       * Exact number of impacted Rel-15 PDCCH candidates depends on CSI-RS mapping pattern, relative size and location of PDCCH CORESET, etc.) |
| Lenovo, Motorola Mobility | Regarding question a), when UE is not paged and accordingly if PEI is not transmitted, serving cell measurements will be done based SSB, irrespective of PEI schemes. |
| Apple | 1. Our assumption is that the UE monitors at least one SSB in each paging cycle, which can be used for serving cell measurement. Therefore, we think regardless of the options, it can be achieved. 2. Whether sequence-based PEI can be utilized for fine synchronization is UE implementation dependent. We have some concern on it because any false alarm would result in UE synchronizing based on invalid signal and may adjust the tracking loop in the wrong way. This can potentially take a long time to detect the wrong tracking loop and recover from it. 3. For dynamic sharing, we think PDCCH-based PEI is the most efficient from network perspective. |
| CMCC | a) Not sure if PEI can be used for serving cell measurement, does RAN4 needs define new measurement requirement? Since RAN4 only specifies SS-RSRP/RSRP for cell selection/reselection. |
| Ericsson | 1. We don’t see major differences between the candidates in regard to this – this is also observed based on power savings results from last meeting. 2. This can be up to UE implementation and any of the three candidates (including PDCCH-based) can be used.    * For TRS, only up to 2 bits are available for dynamic indication through DCI in each of those (“*Rate matching indicator*”/” *ZP CSI-RS trigger*”) and these are typically used for higher prioritized usage cases (rate-matching around connected mode TRS/CSI-RS transmissions, neighbor cell signals, etc.) than to rate-match around TRS-based PEI.    * For SSS, creating a fake coreset to make legacy/connected UEs rate-match around it is cumbersome. This is also infeasible in some cases where legacy UEs support limited number of Coresets that are used for regular scheduling.    * PDCCH-based PEI is most efficient as it can dynamically share resources within a Coreset, whereas the TRS/SSS-based PEI can only share the resources at Coreset-level granularity for the interleaved Coreset case, which would be more typical for Coreset0. |
| DOCOMO | For a), in our understanding, PDCCH based PEI can help UE to achieve the minimum operations.  No matter what kind of PEI, Idle/Inactive mode UE needs to receive at least one SSB for serving cell measurement per paging cycle. If UE receives one SSB and then PDCCH based PEI, the performance impact of PDCCH based PEI due to CFO that range [-0.5 0.5] ppm is acceptable. Thus, PDCCH-based PEI can achieve minimum operations. (That is, when UE is not paged, PDCCH-based PEI can inform UE of go-to-sleep) |
| Panasonic | As we proposed in our contribution, to firstly agree on functionalities of PEI and the number of bits supported by PEI, before agreeing on PDCCH, SSS or TRS/CSI-RS based design. If 5 or more bits are supported by PEI, where PEI is located close to SSB instead of each PO, PDCCH-based design could be taken. Otherwise, sequence based design should be taken.  One more point to check on the overhead is whether one PEI should cover one or multiple POs. For Behv-A, PEI can be skipped by gNB if no paging. So assuming one PDCCH PEI covers 10 POs, it has to be transmitted with probability of 1-0.9^10 = 0.65, assuming GPR = 0.1. However, for TRS-PEI only indicating for one PO, the overhead could be less considering the transmission is always with probability of 0.1. |
| Sony | On point a), there should not be any difference between the candidates from serving cell monitoring. When UE is not paged and accordingly if PEI is not transmitted, serving cell measurements will be done based SSB, irrespective of PEI schemes.  On point b) yes, sequence-based PEI can be used for synchronization. |
| LG | For (a) Yes. For the RRM measurement and AGC, and robust time/frequency tracking, all PEI candidates requires UE to monitor at least 1 SSB. Several observations from previous meetings shows that only 1 SSB is enough for decoding PDCCH based PEI. Additionally, for AGC and time/frequency tracking, the UE needs to turn on RF and baseband processing.  For (b) We think it is hard to guarantee utilizing time/frequency tracking with blinding detection.  For (c) In our view, it seems obvious that PDCCH based PEI has much more flexibility than sequence based PEI candidates. |
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| **Conclusion:**  To down-select one solution for PEI physical-layer channel/signal in RAN1 #106-e, using below as a starting point:   * PDCCH-based PEI * SSS-based PEI * TRS/CSI-RS-based PEI   Note: Additional details for each of the above 3 solutions are encouraged for more informed down-selection  Note: further refinement of the above list is possible, e.g., by merging/further splitting, depending on significance of the commonality and/or differences |

Given that the final decision is to down select to **one** physical channel/signal, companies are encouraged to provide views in Table 11 for the following questions:

1. What is your final suggestion PEI physical-layer channel/signal (one type)?
2. What is the distinguished benefit(s) of the other designs?
3. Is it possible to merge the benefit of the other designs to your supported PEI physical-layer channel/signal? The following are companies’ proposals for merging the benefits of different PEI designs for your reference:

* (Samsung) Network configuration between PDCCH PEI and RS PEI with common configuration of PEI MOs
* (Nordic) Introduce wideband PDCCH DMRS for PDCCH PEI for fine synchronization purpose
  + Effectively allow whole-band bundling 🡪 different from CORESET#0 setting (cannot be shared with legacy PDCCH of SI/P-RNTI)
* (MTK) Include compact code-point based indication mapping to UE (sub)groups so that UE can detect PDCCH PEI via non-coherent sequence detection
* (MTK) Include one different DMRS scrambling ID from legacy PDCCH so that UE can detect DMRS of PDCCH PEI for whether to monitor PO

Table 14: Companies' suggestion on the final PEI channel/signal and way forward

|  |  |  |
| --- | --- | --- |
| Company | Final one suggested channel/signal | Companies’ views |
| Huawei, HiSilicon | PDCCH-based PEI | The benefit(s) of PDCCH-based PEI are summarized as:   1. Sufficient bits to carry sub-group indication in PEI, which explores the most benefit of PEI feature for significant power saving gain. Besides, the DCI format can convey larger information, which can flexibly support for sub-group/multiple POs indication, TRS availability indication and other power saving related information, and is friendly for further enhancements 2. Dynamically share the resource of existing PDCCH and PDSCH as a transmission of PDCCH candidate, which consumes very low resource overhead. There is no co-existence issue of PDCCH based PEI, considering it reuses legacy PDCCH channel. 3. It can support both Behv-A and Behv-B to be friendlier for real deployment from network point of view. 4. By reusing Rel-16 PDCCH physical channel, minimize the impact on UE implementation and other existing channel/functionality of legacy UEs, e.g. cell search and RRM measurements. 5. Most mature and converged design with minimized specification impact among the three candidates.   We think it is not good to have multiple PEI designs supported in specification, which would increase UE implementation complexity. For the wideband PDCCH DMRS, it cannot be shared with CORESET0 resource, which may reduce the benefit of PDCCH based PEI. However, we are open to further discuss other options. |
| Nokia | PDCCH-based PEI | We have raised reasons for our preference in our paper, thus in brief the PDCCH based design in our view offers most feasible multiplexing with legacy/other users, most straight forward design and flexibility in terms payload. |
| Nordic | PDCCH-based PEI | The benefits based on our observations,   * + 1. PDCCH is the easiest for gNBs to deploy, this due to very well defined coexistence for PDCCH in R15     2. PDCCH is the most flexible and future compatible in terms of content     3. If PDCCH can be received with just single SSB cycle, then power saving is the same as for TRS/SSS   On the other hand, known RS with guaranteed BW could be beneficial for consequent PDSCH reception or even for PEI detection itself. Having separate scrambling is one possibility, however, this is too complex if detection has to be performed per each PDCCH candidate. From this point of view, wideband DMRS has better detection performance and lower complexity.  **Regarding Huawei comment:** Our understanding is that wideband DMRS can be used with CORESET#0 in transparent way for legacy users (despite CORESET#0 having NB-DMRS). However, only R17 UEs monitoring for PEI would assume that WB DMRS in whole CORESET are transmitted when monitoring for PEI. Moreover, it is known wideband NR PDCCH DMRS is R15 signal which has the same density at least in frequency domain as TRS. |
| Spreadtrum | PDCCH-based PEI | Benefit:   1. When 1 PDCCH-based PEI is mapping to N POs, the PDCCH-based PEI can be placed very close to the 1st SS burst to achieve the additional power saving gain. 2. Lower overhead in Behav-B. 3. More suitable for the semi-static resource sharing. Natively supporting the dynamic resource sharing between PDCCH candidates in a CORESET. 4. Not need to update UE firmware for sequence-based blind detection. The software update for PDCCH detection is enough. 5. More bits for subgrouping information, availability of additional TRS, SI update etc. 6. Early deployment, since there could be no much new test cases for PDCCH-based PEI.   Compromise:  The almost-zero wakeup receiver could be introduced in future release. It should be sequence-based receiver. |
| Samsung | Sequence based PEI | Sequence/RS based PEI has better performance than PDCCH-based PEI in all three performance aspects we evaluated:   * For power saving gain, sequence based solution achieves higher power saving gain duo to relaxed synchronization overhead based on SS bursts before and after PEI reception. * For resource overhead, PDCCH based PEI requires much higher minimum number of REs to achieve target reliability. * For coexistence, no issue and new handling is needed for any candidate. But dynamic resource sharing with PDSCH should be prioritized to avoid PDCCH blocking for R15/16 UEs, especially in CORESET#0 in idle mode. So, PDCCH based PEI has larger impact to legacy UEs than sequence based PEI.   For spec efforts, it depends on details we want to support.   * It’s no true that PDCCH based solution has the lowest spec efforts. PDCCH based PEI requires at least new DCI format design, and the configuration in terms CSS set, CORESET, PDCCH candidates, which are non-trivial. * For sequence based solution, the main spec efforts may be how to indicate UE subgroup indication. But we haven’t agreed to support that in PEI yet. UE subgrouping can be deprioritized in PEI design. Also, it can be supported in paging PDCCH. If time allows, we can further discuss it in PEI.   We think RS based PEI is sufficient. PDCCH DMRS can’t achieve the same performance as sequence based PEI. |
| CATT | Sequence-based PEI | Sequence-based PEI achieves better power saving gain and detection performance comparing to DCI-based PEI.  With proper design, sequence-based PEI could support up to 222 code points for additional functions, such as paging subgroup or subgroup combination indications without any performance degradation  The low power correlator bank for Sequence-based PEI detection has been implemented by UE for cell search batching processing. There is minimum cost of supporting sequence-based PEI  The sequence-based PEI is the proven technique for IDLE/Inactive UEs to achieve UE power saving, which is used by NB IoT.  All technical analysis showed sequence-based PEI is the better candidate comparing to DCI-based PEI. In particular, the power saving gain of introducing DCI-based PEI is negligible with realistic assumption of UE signal processing. Introducing DCI-based PEI would not have power saving benefit but increase the UE complexity. We might be better to have no PEI than to have DCI-based PEI. |
| Intel | Sequence-based PEI | We think sequence based PEI is clear winner, at least from the perspective of power saving gain and detection performance/resource overhead to meet certain MDR wrt a FAR.  Both PDCCH-based PEI and sequence-based PEI require specification efforts. To what extent depends on exact design of course. We suggest to reuse Rel-15 design/signal structure as much as possible to reduce the efforts. Simulation results show that payload necessary for basic PEI functionality and UE sub-group indication upto 8 can be supported by sequence based PEI design. Although PDCCH-based PEI may be more suitable to carry large information content, but that does not seem to be necessary to convey in a PEI.  We have concern on using PDCCH DMRS as sequence based PEI. It has not been evaluated, and hence feasibility (e.g., how many bits the PDCCH DMRS can convey and whether PDCCH decoding is always necessary for the UE), performance gain/overhead with respect to TRS/CSI-RS or SSS-based PEI is not clear. Moreover, merged solution or supporting both seems to be an overkill, since specification efforts would be significantly more. |
| Qualcomm | Sequence-based PEI | NB-IoT WUS design can be highly reused for NR idle/inactive mode PEI design. So in terms of spec efforts, sequence-based PEI design is simple. The detection of sequence-based PEI is much simpler. PDCCH-based PEI plus WB DMRS requires the UE to do both RS detection and PDCCH detection. The RS detection step itself is equivalent to sequence-based PEI. There is no need to put double efforts. So we do not think PDCCH-based PEI plus WB DMRS is the way to go. |
| ZTE, Sanechips | PDCCH-based PEI | 1&2 We support PDCCH-based PEI, considering the following benefits  (1)PDCCH-based PEI has almost the same power saving gain with SSS/TRS-based PEI.  (2)PDCCH-based PEI is more flexible to carry more information including sub-grouping information, TRS availability indication to provide additional power saving benefits. And it is easy to extend the usage for future enhancements.  (3)PDCCH-based PEI coexist with legacy PDCCH/PDSCH/other reference signal better. The resource collision rules can be directly reused for PDCCH based solution. While for SSS-like PEI or TRS-like PEI, we need to define new UE behaviors or restrict gNB scheduling in the case of resource collision.  (4) PDCCH-based PEI less standardization efforts which is important factor considering the limited TU. While for the SSS-like/TRS-like PEI, the solutions to carrying sub-grouping information, the sequence generation, resource mapping etc., should be considered, and also solutions to reduce impact on initial access, RRM measurement, neighbor cell interference are also needs to be discussed.  3, we don’t think a design of PDCCH PEI and RS PEI with common configuration of PEI MO is needed considering the excessive workload.  Comments on the sequence-based PEI: we need to down-select one from three candidates, not specify both SSS-based and TRS based PEI. |
| Apple | PDCCH-based PEI | This option has the smallest spec impact and has minimum impact on gNB/UE implementation. It also provides more efficient coexistence with legacy PDCCH/PDSCH.  There are a lot of design aspects to be considered for sequence-based design. The power saving gain is marginal based on our evaluation. |
| CMCC | PDCCH-based PEI | 1)High subgrouping indication capacity. Compared with TRS/CSI-RS or SSS based PEI, enough DCI bits, i.e., minimum 12bits can easily carrying subgrouping indication, and also can carrying TRS/CSI-RS availability information, ETWS, etc.  2)Easy to handle dynamic conscience with PDCCH resources of Rel-15 UEs.  3)Less remaining standard work effort. |
| Ericsson | PDCCH-based PEI | * readily supports link adaptation with flexible payload size support and resource usage, * is easy to support and configure multiple contents, * has lower standardization effort e.g. reuse existing WUS and PDCCH framework, including the ps-Wakeup functionality to support both BehvA and BehvB functionalities, * has less impact on UE and the NW both in terms of power, complexity, and consumed resources when multiple groups are addressed simultaneously and/or including various information elements, * has minimum impact on other ongoing/legacy user data traffic as PDCCH is easily multiplexed and/or rate-matched around * can readily support flexible one PEI-to-many PO mapping * is possible to extend in the future. |
| DOCOMO | PDCCH-based PEI | 1. Dynamically share the resource of existing PDCCH and PDSCH. In our understanding, considering the maximum number of aperiodic *ZP-CSI-RS-ResourceSet(s)* and support for more than 2 CORESETs is an optional UE capability, it is difficult that Dynamic resource sharing is applied to sequence-based PEI.  2. More extension (Sub-grouping, TRS availability and so on)  3. less impact on UE and the NW  4. less standard effort  Although we must deicide one PEI design, we are open to discuss for merging PEI-design．  As mentioned by ZTE, it is noted that we need to down-select one from three candidates, not specify both SSS-based and TRS based PEI. |
| Sony | Sequence-based PEI | The sequenced-based PEI has the lowest power consumption/highest power saving gain:  In *a sequence-based, i.e., TRS/CSI-RS based and SSS-based, PEI design* the UE does not need to do any synchronization prior to its PEI detection. The UE proceeds to read SSB and PO only if the sequence-based PEI is detected. Moreover, the structure of sequence-based PEI can also be used for synchronization purposes leading to a reduced number of SS bursts needed to achieve synchronization prior to PO for decoding of paging DCI and a paging message. When performing the energy analysis, the same number of SSB bursts before PEI and the characteristics of the different signal designs have not been considered. Since in the end achieving a certain detection performance with as small energy consumption as possible is the desired outcome the comparison should be made between schemes of equal performance rather than fixing any of the parameters.   * A simple correlation-based detection of sequenced-based PEI means that energy consumption when detecting sequence-based PEIs is lower than the energy consumption of the receiver when decoding/detecting PDCCH/DCI-based. This is not included in the current energy model. Since this energy difference has not been included in the energy model, sequence-based PEI in reality has a competitive advantage not visible in the current power saving gain comparisons. In other words, including lower power consumption in the power saving gain calculation when detecting sequence-based PEI will result in a higher power saving gain than those reported. |
| LG | PDCCH-based PEI | PDCCH based PEI has benefits from following aspects:   * Power saving gain among the candidates are quite comparable. * Bitmap based UE subgrouping can be provided * Additional information other than UE subgrouping can be provided * Existing specification, such as PDCCH, search space, and CORESET, can be reused. * More flexible dynamic sharing with legacy PDCCH/PDSCH * Forward compatibility |
| Nordic | Follow up | *Intel: We have concern on using PDCCH DMRS as sequence based PEI. It has not been evaluated, and hence feasibility (e.g., how many bits the PDCCH DMRS can convey and whether PDCCH decoding is always necessary for the UE), performance gain/overhead with respect to TRS/CSI-RS or SSS-based PEI is not clear. Moreover, merged solution or supporting both seems to be an overkill, since specification efforts would be significantly more.*  Response: The role of WB-DMRS is not to convey information, but be used as auxiliary known signal. It is up to UE implementation whether it wants to utilize or not. Specification efforts to provide WB DMRS with the PDCCH-based PEI are minor. In fact, PDCCH DMRS are part of PDCCH and thus it is one and only signal.  *QC: PDCCH-based PEI plus WB DMRS requires the UE to do both RS detection and PDCCH detection. The RS detection step itself is equivalent to sequence-based PEI. There is no need to put double efforts. So we do not think PDCCH-based PEI plus WB DMRS is the way to go.*  Response: It depends on number of subgroups and UE implementation, because for sequence-based RS, UE has to perform multiple sequence blind detection. DMRS sequence is just one irrespective of number of sub-groups. At the same time, if UE relies on PDCCH blind detection first which was shown to be robust to coarse synch, the WB DMRS are there and can be used by UE for fine synchronisation to receive paging.  **Overall:** We are also fine with PDCCH-based only approach, as stated before. However, we do not want to hear that PDCCH-based PEI cannot provide additional opportunity for synchronisation. |
| OPPO | PDCCH-based PEI | The benefit(s) of PDCCH-based PEI are summarized as:   * Much easier to use PEI to carry sub-group indication; * Each bit in PEI can indicate a subgroup, and can carrying TRS/CSI-RS availability information, ETWS, etc; * DCI-based PEI has much less spec impact and less gNB/UE implementation impact, it can mostly reuse the current specs on the PEI design itself and coexistence; * DCI-based PEI has better co-existence with other signal/channel, it can be transmitted in CORESET which can well co-exist with other channel/signal by nature according to the current spec.   It is good to just have one PEI design supported in specification. |
| Xiaomi | PDCCH-based PEI | PDCCH-based PEI is preferred at least for:   * The PDCCH-based PEI has the minimum impact on spec and gNB/UE implementation. * More information can be carried by PDCCH. |
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**Further discussion on key difference of PEI candidate designs**

* **P1**: SSS PEI or TRS/CSI-RS PEI can provide significantly better power saving gain because it can require less SS burst processing when UE is not paged

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| --- | --- |
| Company name | Comments |
| MTK | **There require the same amount of SS burst processing when UE is not paged for all PEI candidate designs, which is dominated by serving cell measurement and irrespective of PEI types.**  When UE is not paged, UE is still required to perform serving cell measurement every idle DRX cycle. As per RRM measurement accuracy requirement, coarse synchronization needs to be maintained by processing at least one SS burst every idle DRX cycle.    From the following contributions, the residue CFO **when one SS burst can be utilized for CFO compensation** can be confined within around [-0.5 0.5] ppm:   |  |  |  | | --- | --- | --- | | R1-2007869 (CATT) | R1-2008175 (Samsung) | R1-2008964 (MediaTek) | | Table 1 | Figure 4 | Figure 2 | | CFO can be reduced from  1 ppm to 0.6 ppm | Reduced CFO has  Mean < 0.15 ppm  STD < ~0.1 ppm | Reduced CFO has STD < 600 Hz,  corresponding to [-0.26 0.26] ppm uniform random CFO |     Since all companies’ evaluation results confirmed that all PEI candidate designs can comply with the mandatory performance requirement under [-0.5 0.5] ppm CFO condition, we thus see there require the same amount of SS burst processing when UE is not paged for all PEI candidate designs. |
| CATT | We don’t agree with MediaTek statement that the power consumption of front-end processing for PEI detection of different candidates are the same.   The difference of sequence-based PEI and DCI-based PEI is the non-coherent detection for sequence-based PEI and coherent detection of DCI-based PEI.   The analogy of sequence-based PEI detection vs DCI-based PEI detection is the SSB detection.   UE could detect PSS/SSS in low SINR with higher frequency error during the cell search for initial access or handover.   However, UE would might need more than one PSS/SSS detection to perform channel tracking and estimation before decoding the PBCH.   In addition, sequence-based PEI could be used for the PEI detection as well as channel tracking and estimation.   The sequence-based PEI would help UE in performing RRM measurements, which is not capable by DCI-based PEI.     The CFO error under +/- 0.5 ppm would require more than 1 SSB.   Moreover, some UE design might use low-power oscillator for further reducing power consumption during deep sleep.  The frequency drift with low-power oscillator after deep sleep could be much higher than 1 ppm and could be more than 10 ppm.      RAN4 LS in R1-2104170 also showed that it is required RS with 2 slot or 2 ms interval  in order to perform AGC and channel tracking.   Thus, 1 SSB assumption for detection of DCI-based PEI is not realistic. |
| Apple | We do not agree.  Comparing sequence-based PEI and PDCCH-based PEI, our assumption is that the UE needs to monitor at least one SSB in each paging cycle for serving cell measurement. And the residual CFO after SSB detection and serving cell measurement should be sufficiently small (<0.5ppm) to guarantee PDCCH decoding performance.  In this sense, the number of SSBs monitored by the UE is the same for sequence-based and PDCCH-based PEI when there is no paging.  Sequence-based PEI detection itself may consume less power compared to PDCCH-based PEI decoding because it is non-coherent detection using sequence correlation. But as we show in our contribution, this is only a very small part of overall power consumption of UE in idle/inactive state. So the overall power saving is marginal. |
| Qualcomm | For the sequence based PEI design (SSS, TRS, or CSI-RS), the benefit is UE can wake up a front end PEI detector and only if the PEI is detected, the main receiver will be activated. The wakeup receiver has very high power efficiency. For that, the PDCCH based PEI is not a good candidate as the Polar decoding itself is complicated enough to be not built in the front end. The current power model for idle/inactive mode is largely borrowed from connected power saving study which only reflects power consumption of individual operations (e.g., PDCCH detection, PDSCH decoding and RS processing) with the assumption that the UE is either activated entirely (even for PEI detection) or not activated. Based on this, we propose to adopt sequence based PEI because the PDCCH-based PEI does not help wakeup receiver design. With the assumption above, we agree that the power difference between PDCCH and sequence based PEI is not significant, and none of points (P1 - 4) is essential. |
| LG | We do not agree with P1.  Both PEI candidates require to monitor at least 1 SSB for RRM measurement and coarse synchronization. Several company already shows that residual CFO error after monitoring 1 SSB can afford PDCCH decoding.  Also it should be note that when there is no paging, sequence based PEI cannot be used for time/frequency tracking at all when Behv-A is assumed. So, UE cannot use sequence based PEI for helping RRM measurement. Nonetheless, we do not prefer assuming time/frequency tracking using a sequence with blind detection.  For the low SINR scenario, we believe that above table mentioned by MediaTek already covers the worst case scenario. Thus, we think the number of SSBs for PDCCH-only decoding can be assumed to be one regardless of the SINR scenario when it is  not paged.  From this perspectives, we see that there is no difference in terms of power saving efficiency among the PEI design candidates. |
| Samsung | SSS PEI or TRS/CSI-RS PEI can provide significantly better power saving gain because it can require less SS burst processing **no matter UE is paged or not.**   1. The synchronization accuracy requirement for serving cell RRM measurement is difference from the requirement for PDCCH reception. The coarse synchronization UE may achieve during serving cell RRM measurement is not enough for UE to decode PDCCH. For RRM measurement, UE only needs to locate the RS resources and measure the RSRP. Residual CFO can be large. However, for decoding PDCCH based on coherent detection, residual CFO matter a lot. 2. The simulation results cited by MTK are not the results from RRM measurement, but additional synchronization processing. UE can reuse the same SSB resources for measurement and synchronization. But UE needs to take extra power for synchronization in addition to the power consumed for RRM measurement. We have power model for these two activities. 3. For PDCCH-based PEI, UE needs to process at least one SSB burst for i) RRM measurement, and b) synchronization. The UE power consumption should be count the two parts. For companies relax synchronization performance for PDCCH compared with PDSCH, you relax the number of SSBs processed, not the synchronization process/algorithm per SSB. The so called “coarse synchronization” from RRM measurement doesn’t make sense for PDCCH decoding. 4. For sequence based PEI, UE only needs process one SSB bursts for RRM measurement. The sequence of PEI can be re-used for synchronization for paging PDCCH/PDSCH reception. If UE is not paged, i.e. UE doesn’t detect any PEI, no need to do the synchronization for paging PDCCH/PDSCH.     Based on the above facts.   * Sequence based PEI require less power consumption as it doesn’t need to do synchronization based on SSB to prepare for coherent detection of PDCCH/PDSCH. * However, for PDCCH-based PEI. It consumes higher power consumption due to the synchronization overhead for preparing the coherent detection of PDCCH of the PEI.   The difference is significant, as this happens every DRX cycle. It doesn’t matter UE is paged or not. |
| Huawei, HiSilicon | We don’t agree the P1.   1. The sequence based PEI cannot be used for serving cell measurement considering the sequence may or may not be transmitted and UE cannot know whether it moves out the cell or gNB does not transmit sequence based PEI; 2. IDLE/inactive mode UE anyway needs to receive at least one SS burst for serving cell measurement. In order to do serving cell measurement, time/frequency tracking is also needed to guarantee the serving cell measurement accuracy, which makes CFO sufficiently small (<0.5ppm). 3. PDCCH can be detected reliability within 0.5ppm CFO, which has been justified by link level simulations by a number companies including Huawei, HiSilicon, MTK, ZTE, Intel etc.   Based on above, we see the number of SS bursts required is the same for all three candidates. We don’t agree sequence based PEI can require less SS burst processing when UE is not paged.    BTW. Regarding CATT’s comments on RAN4 LS on the requirement of AGC, regardless how many SS bursts are required for AGC which is assumed, UE always need to finish AGC before the serving cell measurement. Therefore, they are the same for all PEI candidates. |
| vivo | As we mentioned in our contribution [R1-2106606], if a DCI-based PEI is introduced, UE always need to process one or more SSBs before it for correcting the frequency error. So, DCI-based PEI should be placed after one or more SSB bursts. However, for sequence-based PEI such as TRS-based PEI, it can assist the RRM measurement or ACG adjustment or T/F tracking, since this is one  of the main functions for TRS/CSI-RS. And such operation can be up to UE implementation. We would like not to restrict such UE implementation. Moreover, the detection performance and complexity of sequence-based PEI are all superior than DCI-based PEI.  In brief, compared to DCI-based PEI, adopting sequence-based PEI will bring more significant power saving gain no matter UE is paged or not, as per the aforementioned understanding. |
| ZTE, Sanechips | We don’t agree with the statement in P1.  (1)According to RAN4 requirement, idle/inactive state UE needs to performance serving cell measurement per paging cycle based on at least one SSB. Hence, the residual CFO after SSB processing should not be too large, otherwise the performance of serving cell measurement is impacted. Hence, we think [-0.5ppm, +0.5ppm] is a reasonable range for residual CFO, which is also assumed by most companies in the evaluations.    (2)Regarding the comment that “the sequence based PEI can be used to assist RRM measurement”, we think it should be noticed SSS/TRS based PEI is transmitted on-demand, which requires blind detection at UE side(different from the legacy TRS or TRS discussed in 8.7.1.2), it is clear that this not-always-on SSS/TRS based PEI can not used for AGC adjustment. Meanwhile, if gNB does not send the SSS/TRS-based PEI but FAR occurs, the UE would take noise as PEI and use it for synchronization, which will degrade the synchronization performance of the entire system and more SSBs are needed for synchronization compensation in the next paging cycle. Therefore, the SSS/TRS-based PEI cannot be used for AGC/sync.    (3)Regarding the comment that the initial CFO after UE wakes up can be higher in some cases, we think in the case of higher initial CFO, UE cannot reply on not-always-on SSS/TRS based PEI for AGC/sync/channel estimation, otherwise, the performance of AGC/sync/channel estimation would be significantly degraded if PEI is not transmitted, hence, UE needs to process more SSB (for example, 2 SSB) for AGC/sync and serving cell measurement, in this sense, the number of processed SSB is also determined by the requirement of serving cell measurement, which is the same for all the three PEI candidates.    (4)Moreover, according to our and MTK’s contribution, non-coherent detection can be also applied to the PDCCH based PEI. With non-coherent detection, the PDCCH based PEI has even better performance even with larger CFO.    (5)Regarding the comment that “the benefit of TRS/SSS based PEI is UE can wake up a front end PEI detector and only if the PEI is detected, the main receiver will be activated”, we need to notice that UE needs to perform SSB-based serving cell per paging cycle, which means UE still needs to turn on the main receiver for RRM measurement regardless of PEI detection. Hence, it is more power consuming to activate another dedicated receiver for PEI detection.    (6)The power of PEI detection (PDCCH based, SSS-based, or TRS based) is assumed to 50, which is slightly larger than the power of micro-sleep(45), there is almost no room to further reduce the power unit of PEI detection as it is cannot be more power efficient than sleep state . Moreover, according to Apple’s simulation results, the overall power consumed by PEI detection is quite small, the PS gain from PEI detection with a smaller power consumption is marginal. |
| Intel | We don’t think it can be guaranteed that after one SSB processing, residual CFO can be confined within +/- 0.5ppm (although we don’t think we have formally agreed on any such value). It depends on link condition, i.e., SNR. If we check SNR requirement to reach 1% BLER for PDSCH, we observe from companies contributions that SNR as low as -9dB/-10dB can be realized, depending on assumption of TB scaling (1 or 0.5) and CFO (whether 0ppm or 0.1ppm assumed). Hence, residual CFO that can be achievable at -6dB (such as used in MTK’s cited paper) may not hold for worse link condition. To this end, multiple SSB processing maybe needed so that input CFO remains tolerable when UE attempts to decode PDCCH.  Sequence based PEI has benefit in this regard since it can be detected with coarser sync condition that PDCCH, thereby reducing the required number of SSBs to be processed before PEI.  Since this operation is done before every paging cycle, then YES, meaningful power saving gain can be achieved with sequence based PEI compared to PDCCH based PEI. |
| Nokia | Not int our understanding. All of the designs require UE acquiring at least one SSB burst during the DRX cycle for serving cell evaluation purposes. From timeline perspective, to optimize IDLE power consumption it would seem most optimal to carry out this sufficient time prior PO, or PEI. Based on this SSB burst UE can also enhance it’s synchronisation if needed. This is based on the Rel-16 baseline assumption, where only 1 SSB burst is assumed for PDCCH and PDSCH detection before PO.  In our paper [R1-2108122] we evaluated this e.g. comparing the case when UE did not detect SSB prior TRS-PEI, and case when SSB was detected prior TRS-PEI. We also assumed that UE can use the SSB measurement prior PEI to refine the ‘best beam(s)’ information, and use this information to select the best PEI occasions/beams to monitor the PEI. Hence if UE does not measure SSB prior the PEI, UE would need to detect all PEI occasions (in all beams) to ensure that if can reliably detect the PEI. As discussed in Rel-15 for broadcast, that UE may choose the best monitoring occasion based on the serving cell measurements (i.e. receive in best beam). The end result is that omitting the SSB, due to the need of monitoring all PEI occasions, does not benefit the power saving. |
| Panasonic | We think SSS PEI or TRS/CSI-RS PEI can provide better power saving gain than PDCCH PEI. But how much significant would depend on the channel condition and requirement on the synchronization before PEI detection.  When UE is not paged, the power consumption is from:   * + a. PEI monitoring   + b. SSB burst processing, which consists of     - b.1 AGC and synchronization before detecting PEI     - b.2 RRM measurement   For part a, we see the difference between sequence-based and PDCCH based PEI on power consumption depends on the UE implementation of whether a separate low power module is used before UE fully wakes up. But from more general consideration, non-coherent sequence detection should outperforms coherent detection although the gain may not be dominating.  For part b, it contributes the majority of the power consumption.  On b.1, we think the required number of SSB burst to process is smaller in the statistic sense for sequence detection by peak correlation, which is the nature of non-coherent detection.  On b.2, we tend to agree that it should be same for both cases. It is also possible that the processing on b.2 can also save some operation for b.1. Vice versus. But the dominating factor can also be b.2, if it becomes the bottleneck in low SINR condition when the synchronization requirement lead to large number of SSB bursts to process, including the SSB from neighboring cells. Thus, anyway, the worst case may make the situation similar for both cases.  Therefore, we think in general, how much power saving gain for TRS/SSS-based PEI depends on the requirement corresponding to the number of SSB burst to process, e.g. whether one SSB burst is enough for PDCCH PEI detection in all cases. Or whether the same number of  SSB burst processing is always true for sequence detection and PDCCH detection. In a statistic sense, lower number of SSB burst processing is required for sequence based PEI. |
| Sony | Agree.  The  Sequence-based (SSS, TRS, or CSI-RS) PEI can provide better power saving gain compared to PDCCH-based approach independent of whether UE is paged or not.  A sequence-based PEI is detected non-coherently in contrast to PDDCH-based PEI which needs to be decoded/received coherently.  The UE proceeds to read SSB and PO *only if* the sequence-based PEI is detected. Moreover, the structure of sequence-based PEI can also be used for synchronization purposes leading to a reduced number of SS bursts needed to achieve synchronization prior to PO for decoding of paging DCI and a paging message.  Furthermore, a lower synchronization accuracy is needed for RRM measurement, such a coarse synchronization is not good enough for PDCCH decoding/reception.  Additionally, sequence-based PEI can help UE when performing RRM measurement. |
| Spreadtrum | We share the same view as MTK, Apple and LG. One SSB burst is needed for both two schemes. UE should perform T/F tracking, and serving cell RRM measurement. One SSB burst is enough for both two schemes. As observed by many companies, frequency error within [-0.5ppm, 0.5ppm] is enough for PEI detection. We are not sure about QC mentioned detection algorithm for sequence based PEI. Currently, only SSS is blindly detected, and UE should detect SSS by the baseband algorithm. I’m not sure about whether SSS can be detected by a front end PEI detector (means no baseband operation?) and whether it can meet the required MDR/FAR. Furthermore, in our power model, detection of PEI has the same power consumption for different schemes. Should we change the current power model. Moreover, the front end PEI detector seems the architecture for the very-low-power WUS receiver proposed in R18 workshop [RWS-210168]. We are open for it in the future release, and there could be a SI for the very-low-power WUS receiver. |
| IDCC | Agree. We think sequence based can help power saving by reducing the number of SSBs measured. We also acknowledge that the real gain will largely depend on link conditions. It has been shown that both PDCCH and sequence based PEI are robust to CFO of 0.5 ppm; but it is   not clear if 1 SSB will be sufficient to achieve this for PDCCH based PEI in all link conditions.  In addition, for PDSCH we will need lower CFO which means for PDCCH based PEI more than 1 SSB need to be processed. For sequence       based PEI, the PEI can be used for this purpose, also providing further opportunity for the UE to stay in sleep mode. |
| Nordic | Depending on paging cycle length, UE do not need to measure every paging cycle, also as part of RRM relaxations,  frequency of neighbour cell  measurements further drops, in paging cycles when RRM  measurements  are not needed, UE would benefit (in  terms of power consumption) from being able to detect PEI with less SSB. |
| Xiaomi | For current RRM requirements, at least one SSB is necessary  for serving cell evaluation purposes ; In addition, TRS for idle/inactive UE RRM is not agreed in the discussion in 8.7.1.2, because such sequence I may or may not be transmitted, **So we can’t say** SSS PEI or TRS/CSI-RS PEI can provide significantly better power saving gain on this aspect. |
| Ericsson | This is not the case according to the RAN1 observation (“*For the comparison of PEI candidate designs, the following table summarizes average power saving gains based on companies contributions, ….* ”)  on power saving gains from RAN1#105-e. |

* **P2**: SSS PEI or TRS/CSI-RS PEI can provide significantly better power saving gain because UE can use only PEI for fine synchronization before PO and reduce the wake up energy overhead when UE is paged:

|  |  |
| --- | --- |
| Company name | Comments |
| MTK | * Overall, the probability when UE is paged is small, i.e., 10% or even <2% when UE subgrouping is applied. Consequently, the  contributed difference in the averaged power consumption is also small. * PEI is not always available. Requiring PEI detection before utilizing it for fine synchronization can suffer FAR issue which causes UE to utilize noise/interference for the tracking loop. When UE needs to prioritize detection performance against poor channel condition, FAR will increase and can cause UE link failure. * For SSS PEI, effective CFO compensation will require multiple SSS symbols with time domain separation (similar as TRS). But such structure of multiple and separated SSS’s cannot match some CORESET#0 patterns for legacy UE to perform CORESET-wise rate-matching. This somehow requires static resource sharing with RB-symbol patterns and conflicts the claimed resource overhead benefit. * For TRS/CSI-RS PEI, the TRS/CSI-RS structure of 2 symbols in one slot only provides 288 RS REs. In a SSB, there can be 250 RS REs (PSS + SSS + PBCH DMRS), and we may only say one TRS/CSI-RS can replace one SSB. For the case of low SNR, we show, in Figure 2 of R1-2008964, there requires 3 SSBs (include 1 SSB before PEI and 2 SSBs between PEI and PO) for UE to reach 0.1 ppm CFO before PO. In this case, TRS/CSI-RS PEI of only 288 RS REs is not sufficient for fine synchronization. * **Suggestion on merging this benefit**: PEI to indicate connected-mode TRS for idle-mode UEs so that UE can utilize effective 4-symbol TRS and reduce wake-up overhead for all channel conditions. |
| CATT | The higher saving gain from sequence-based PEI is from low-power front processing for non-coherent detection comparing to that of DCI-based coherent detection.  This is fundamental of digital communication with lots of evidence in 2G/3G/4G LTE/5G NR system. |
| Apple | We do not agree.  It has been assumed by some companies that sequence-based PEI can replace one SSB for fine synchronization purpose. With this assumption, our analysis shows that there is only 1.6% extra power saving from sequence-based PEI.  We also have concern on using a signal that is blindly detected for synchronization. In case a false alarm happens, the UE would be using garbage signal for synchronization, and this may take some time for the UE to detect the error and recover from it. |
| LG | We do not agree with P2.  As pointed out by MediaTek and Apple, time/frequency tracking using a blind detected sequence can bring FAR issue. It is not only a matter of the same paging cycle, but UE link failure can be occurred due to the fake time/frequency result.  Also as we discussed in P1, all PEI candidates requires at least 1 SSB regardless it is paged or not. So all PEI candidates consumes same power for SSB monitoring when it is in normal SINR range. In case of low SINR scenario, UE shall monitor SSBs from both serving cell and neighbor cells for RRM measurements. Even if we assumed using sequence based PEI for time/frequency tracking, the overall power saving gain is very limited due to the inter-frequency RRM measurements. |
| Samsung | Yes, the sequence of PEI can be reused for synchronization before paging PDCCH/PDSCH reception. We provided detailed UE processing procedure for how to do in our contribution [R1-2106898], and we have simulation results to show the performance in [R1-2008175]. The RS resources is just similar as SSB, why there is any problem to reuse that?    For the power saving gain, it comes from two parts.   1. UE doesn’t have to wake up multiple time for PEI reception and paging PDCCH reception. They can be close in time domain. No big gap is needed. 2. No need to process additional SSB bursts between PEI and paging PDCCH for synchronization.   The gain increases with respect to increase of UE group paging rate. |
| Huawei, HiSilicon | We don’t agree P2.   1. Sequence based PEI needs to be blindly detected. A blindly detected signal has never been used in NR system for time/frequency tracking, and there is no related discussion/requirement/test in RAN4. If a false detection happens for the sequence based PEI, frequency/timing error shall be introduced impacting the performance and UE power consumption in subsequent DRX cycles. 2. In SS burst, the span of a SSB is 4 symbols. For SSS based PEI, it has two continuous symbols span, which cannot have the same time/frequency tracking performance as SSB even assuming the PEI is correctly detected. For TRS based PEI, the reception bandwidth of IDLE UE cannot be large than the frequency span of CORESET 0. In case of 24RB CORESET0, TRS based PEI cannot have the same time/frequency tracking performance as that of TRS pattern in connected mode within a wider bandwidth (usually e.g. 50 or 48RB) even assuming the PEI is correctly detected. 3. Sub-grouping indication is agreed to be supported in Rel-17, which can well control the paging wake-up rate of a UE to be much less than 10%, e.g. 1~2%. In this case, the contribution of power saving when UE is paged would be very marginal. Therefore, regardless whether sequence based PEI can replace SSB, there cannot be difference regarding the final power saving gain.   Based on the above reasons, we think sequence based PEI cannot replace SSB for time/frequency tracking, and there should be no sensible power saving difference considering sub-grouping indication is supported. |
| vivo | Sure. And the same interpretations for P1 as we analyzed in the previous table for P1. In addition, regarding the P2 itself, we think it is may misleading. Hence, we give our modification suggestion as follow:    **P2:** sequence-based PEI can provide significantly better power saving gain because UE can use ~~only~~ PEI for a lot of functions such as ~~fine~~ synchronization, T/F tracking, measurement, ACG adjustment before PO and reduce the wake up energy overhead when UE is paged. |
| ZTE, Sanechips | We don’t agree with the statement in P2.  (1)As we commented in P1, the PEI transmission is not always-on as SSB, UE needs to detect the SSS/TRS-based PEI by blind detection. If gNB does not send the SSS/TRS-based PEI but FAR occurs, the UE would take noise as PEI and use it for synchronization, which will degrade the synchronization performance of the entire system and more SSBs are needed for synchronization compensation in the next paging cycle.Therefore, the SSS/TRS-based PEI cannot provide the synchronization function.  (2)In an extremely idealistic case(which is questionable according to the above analysis), if SSS/TRS based PEI is used for sync, it can at most replace one SSB considering the number of REs of PEI and SSB. And according to our simulation results in Figure 3 in our contribution (R1-2106521), the additional power saving gain provided by the sequence-based PEI with synchronization function is marginal. The power saving gain from DCI-based PEI and sequence-based PEI is almost the same.  (3)The PEI can be configured with a small gap relative to SSB, so that the UE doesn’t have to wake up multiple time to detect SSB and PEI. Therefore, the power saving gain from DCI-based PEI and sequence-based PEI still almost the same. |
| Intel | First things first, something has never been assumed in NR so far is an unfortunate statement. In every release, we try to introduce new functionality if it is useful. PEI is also a new concept in idle mode, never considered in NR before. Even then,  the statement by Huawei ” A blindly detected signal has never been used in NR system for time/frequency tracking” is inaccurate. How does UE perform initial cell search? UE will perform detection of PSS/SSS and based on that it tries to perform tracking. UE needs to look for all three PSSs at a certain carrier frequency. Hence, the functionality to perform detection and then tracking is there. Similarly, with regards to using sequence based PEI, we do not see any fundamental feasibility issue for using it for tracking, i.e., UE blind detection is not necessarily a deterrent, as long as sufficiently low MDR can be achieved for a low target FAR. Contributions have shown how robust MDR performance for sequence PEI is for a given target FAR 1%. Hence, based on the characteristics of the signal design (such as for TRS or SSS-based PEI), using it for tracking is possible.    If PDCCH based PEI is used, it is expected that one or more further SSB processing is needed between PEI and PO, so that PDSCH can be detected with low CFO such as 0.1ppm or less. Based on the above, if sequence based PEI is used for tracking, need for further SSB processing can be avoided and PEI can be located much closer to the PO. This allows the UE to be in deep sleep longer.    So, YES, higher power saving gain can be achieved if sequence based PEI is used even when UE is paged, and the margin depends on paging rate. |
| Nokia | This benefit, if any would heavily depend on the paging probability. Via UE sub-grouping, especially if it can be used to the full extent, would reduce the need for the UE to monitor PO significantly.  As noted by other companies, using PEI for fine synchronisation would require blind detection of the said resources, thus in order to ensure reliable T/F-tracking estimate, the detection threshold would need to be increased. Also as we raised in answer to P1, based on the serving cell evaluation it carried out prior PO, UE could identify the best beams, and further focus the SSB monitoring in subsequent burst e.g. to fewer best SSBs, thereby reducing the power consumption prior the PO. We think that this would be a reasonable thing to do, if UE aims to minimize the IDLE mode power consumption even without PEI.  We do agree that PEI design can be made to inform UE the L1 availability, enabling the use of TRS occasions (if present) without any blind detection requirement. Thus we see that this would be also an important factor to consider, if we want to facilitate the UE power saving as whole. We showed in paper [R1-2108023] the cost of not having PEI to carry indication for the TRS availability and assuming that PEI is used to trigger UE monitoring of the PO to acquire updates on said information.  Table 2 Energy saving loss for L1 availability indication (only) in paging DCI as compared to the availability indication being included in the PEI. All numbers in %.   |  |  |  |  | | --- | --- | --- | --- | | **L1 availability indication probability** | **Low SINR** | **Medium SINR** | **High SINR** | | **20 %** | -11.4 | -7.6 | -4.9 | | **40 %** | -22.7 | -15.2 | -9.8 | | **60 %** | -34.1 | -22.8 | -14.6 | |
| Panasonic | How much power saving gain in this case should depend on the detailed design of TRS/SSS PEI, e.g. how many symbols/slots to use, the location of the PEI, and etc. When UE is paged, we think this is not the dominating case for conclusion. |
| Sony | Agree.  The  Sequence-based (SSS, TRS, or CSI-RS) PEI can provide better power saving gain compared to PDCCH-based approach since it is detected non-coherently in contrast to PDDCH-based PEI which is decoded coherently.  It can also be used for synchronization purposes leading to a reduced number of SS bursts needed to achieve synchronization prior to PO for decoding of paging DCI and a paging message. |
| Spreadtrum | We share the same view as MTK, Apple and LG. The sequence-based PEI cannot used for the fine T/F tracking.  For SSS based PEI, the fine frequency tracking with multiple SSS symbols. The multiple SSS symbols have issue of resource sharing with CORESET#0.  For TRS/CSI-RS based PEI, the time-domain non-coherent detection may not be feasible, since with other non-zero-power subcarriers in between the CSI-RS REs UE should select the CSI-RS REs in time domain. The frequency-domain non-coherent detection may not be feasible too, since the frequency error provides the large interference, as mentioned in Huawei’s contribution [R1-2106479]. |
| IDCC | We agree that sequence based PEI can be used for synchronization. |
| Nordic | We  agree that known signal  can be used further for synchronisation purpose.  Of course Idle TRS could do the same job, but at expanse of additional overhead.  Also we assume that such signal could replace reception of 1SSB. On the other hand, if PDCCH is detected, it becomes also known signal.  However, known signal should be preferably stable in size, such as  SSS, TRS or Wideband PDCCH DMRS |
| Xiaomi | Do not agree  Even if  SSS PEI or TRS/CSI-RS PEI can provide some power saving gain for it can be used fine synchronization when UE is paged,  the normalized power saving gain is not obvious for the following reasons, one is the probability of UE is paged is assuming to be 10%, the other is SSB may still need to for RRM measurement.  We think it does not make sense to compare the power saving gain on the condition when UE is paged. |
| Ericsson | This is not the case according to the observation on power saving gains from RAN1#105-e. The gain (if any) would be limited to the case when UE is paged, which depends on the paging probability which would be low e.g. 1%. |

* **P3**: SSS PEI or TRS/CSI-RS PEI can provide significantly better power saving gain because processing SSS PEI or TRS/CSI-RS PEI has significantly less power consumption than processing PDCCH

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| --- | --- |
| Company name | Comments |
| MTK | **There is little difference from the agreed power consumption model**  From the agreed power consumption model, PDCCH-only processing has **the same power** value as SSB/CSI-RS processing. Since detection of sequence PEI has similar correlation-based operation as serving-cell measurement and synchronization is also assumed with sequence PEI, the power value of sequence PEI processing will be the same as PDCCH PEI processing according to the agreed power consumption model.   |  |  |  | | --- | --- | --- | | * Power State | Relative Power  (FR1 reference from TR ~~84~~38.840) | Relative Power  (Idle/inactive-mode operation with reception bandwidth 20 MHz) | | Deep Sleep (PDS) | 1 | 1 | | Light Sleep (PLS) | 20 | 20 | | Micro sleep (PMS) | 45 | 45 | | PDCCH-only (PPDCCH) | 100 | 50Note | | PDCCH + PDSCH (PPDCCH+PDSCH) | 300 | 120 | | PDSCH-only (PPDSCH) | 280 | 112 | | SSB/CSI-RS proc. (PSSB) | 100 (synchronization or serving cell measurement) | 50 | |
| CATT | The higher saving gain from sequence-based PEI is from low-power front processing for non-coherent detection comparing to that of DCI-based coherent detection.  This is fundamental of digital communication with lots of evidence in 2G/3G/4G LTE/5G NR system. |
| Apple | We do not agree.  As MTK pointed out, our current power consumption model cannot capture the potential power consumption difference between PDCCH decoding and sequence detection.  Practically speaking, we should expect less power consumption for sequence-based PEI, and the extent of saving is implementation dependent. However, for idle/inactive UEs, the power UE spends on PEI detection is a small portion of total UE power consumption (~3% for low SINR UEs), and the saving from sequence-based PEI is just a portion of this, which is marginal. |
| LG | We do not agree with P3.  As described in the agreed power consumption model above, it is assumed that power consumption for PDCCH-only decoding is 50 and power consumption for Micro sleep is 45. It is obvious that power consumption for sequence based PEI cannot be smaller than that for the micro sleep state. Even if we assumed some value between 45 and 50 for sequence based PEI, only the marginal power saving gain can be expected.  On the other hand, we have not been consider the power saving efficiency from the additional power saving information, such as TRS availability and SI update/ETWS notification. In our view, if power saving gain from the UE subgrouping is similar among PEI candidates, the benefits of the additional information should be considered. |
| Samsung | For sure.   1. The power model we agreed is very bad, it doesn’t reflect the real implementation complexity. 2. We assume the same power model for SSB and RS based PEI. So, that should reflect the fact that RS based PEI can be used for synchronization purpose. For SSB burst, we assume 2ms duration, where more than one SSB per slot. It should be same for RS based PEI, i.e more than one MOs per slot. However, UE only needs to process one MO after beam-sweeping based serving cell measurement. The power consumption for detecting RS based PEI should be at least half smaller than PDCCH based PEI even we use current power model. But even from Samsung, we forget to take this into consideration in our simulation. But, I still want to point it out. |
| Huawei, HiSilicon | We don’t agree P3.   1. According to the agreement listed by MTK, the power consumption of SSB processing is similar as PDCCH-only. It is not correct to say sequence processing have significantly less power consumption than processing PDCCH. I need to also mention that this model was reviewed and agreed again at the beginning of R17 for IDLE mode UE, which was agreed by all companies. 2. Some companies mentioned front processing can have lower power consumption. However, it is not clear on whether the so-called front processing can have the same coverage/sensitivity as main receiver, and without significant impact on the paging latency considering they may need time to switch on the main receiver. Also, it seems these companies also propose to use sequence based PEI for time/frequency tracking before paging PDSCH, and the serving cell measurement anyway needs to be performed. If AGC, time/frequency tracking and RRM measurement needs to be done anyway, I don’t see there would be much difference regarding the main receiver and this frond receiver. |
| vivo | As per the agreed power consumption model quoted by MTK, it is true that PDCCH-only processing has the same power value as SSB/CSI-RS processing. But we share the same view as Qualcomm on the power consumption model. With the aid of a front-end receiver, a potential benefit might be obtained by sequence-based PEI, but this cannot be reflected by using the current power model for idle/inactive mode.  Although the current power model does not reflect such fact, we provide some analysis for the RF front end receiver in [R1-2106609](file:///C:\Users\11048224\AppData\Local\Docs\R1-2106609.zip), which shows it is more power efficient. |
| ZTE, Sanechips | We don’t agree with the statement in P3.   (1)As we commented in P1, the power of PDCCH / SSB / TRS detection is assumed to 50, which is slightly larger than the power of micro-sleep(45), there is almost no room to further reduce the power unit of PEI detection as it is cannot be more power efficient than sleep state . Moreover, according to Apple’s simulation results, the overall power consumed by PEI detection is quite small, the power saving gain from PEI detection with a smaller power consumption is marginal.    (2)Meanwhile, the non-coherent detection can be also applied to PDCCH based PEI, which can achieve same power consumption with SSS/TRS based PEI.    (3)On the other hand, if it is assumed that the SSS/TRS based PE can be used for other functionalities(which is questionable according to the above analysis), such as AGC/sync adjustment, it is also questionable whether low-power state can be assumed for PEI detection with such complicated functionalities. For example, if a low-power receiver is used for PEI detection, the adjusted AGC/sync can be only applicable to this low-power receiver. If the PEI indicates wake-up, UE needs to turn on the main receiver, which requires additional AGC/sync operations. Hence, the low-power state PEI detection with complicated functionalities seems self-contradictory. |
| Intel | We think it is quite clear that power consumption model missed the potential energy consumption difference of coherent and non-coherent detection. Apple, Qualcomm, CATT have clarified this above. In real world, certainly lower complexity receiver is expected to result in power saving gain. To what extent, it is up to implementation. |
| Nokia | The benefit, if any would be very negligible. Based on our evaluations, the portion of PEI power consumption of the power consumption (with paging probability of 10%) is between 3% to 1.5%, depending on the assumed SINR. It would not seem to be able to result significant power saving even if assumed to be reduced to 0 (from 50). |
| Panasonic | On this part, we would like to firstly listen to the UE and modem vendors’ view as this is deeply related to implementation. |
| Sony | Agree.  A simple correlation-based detection of sequenced-based PEI means that energy consumption when detecting sequence-based PEIs is lower than the energy consumption of the receiver in its full operation when decoding/detecting PDCCH/DCI-based.  This is **not included** in the current energy model. Since this energy difference has not been included in the energy model, sequence-based PEI in reality has a competitive advantage not visible in the current power saving gain comparisons |
| Spreadtrum | We share the same view as MTK, Apple and LG. The power consumption for sequence-based PEI and PDCCH-based PEI are the same in current power model.  If the new detection algorithm, like front-end based detection, it could be discussed in very-low-power WUS receiver the future SI. In our mind, currently all blind-detection algorithms in UE side is based on baseband algorithm. It is too early or premature to commercialize the new architecture at UE side. If we rush into it, it may not be really deployed in commercial network. |
| IDCC | Agree. We think the agreed model cannot capture this difference. The actual gain will depend on the specific implementation. |
| Nordic | It depends on implementation and thus hard to conclude. |
| Xiaomi | t’s true by some specific implementation, sequence based PEI detection can have power saving gain than the current PDCCH detection, but we see no consensus among companies even among chipset companies. |
| Ericsson | This is not the case according to the agreed UE power consumption model, and according to the observation from RAN1#105-e, which were made based on the agreed UE power consumption model. |

* **P4**: SSS PEI or TRS/CSI-RS PEI can provide significantly less resource overhead by guaranteed dynamic resource sharing with legacy UEs

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| Company name | Comments |
| MTK | **Not really.**  According to the agreement, for resource sharing with PDSCH of legacy UE for TRS/CSI-RS PEI, it is only guaranteed for PDSCH scheduled by DCI format 1\_1. For the case PDSCH not scheduled by DCI format 1\_1, there can be network implementation that cannot avoid transmitting PEI in the PDSCH, and the legacy UE will be impacted due to treating PEI REs as PDSCH REs. Due to the impact to legacy UEs, such network can only apply static resource sharing for TRS PEI  If sequence PEI is to share CORESET#0 of legacy UEs, the resource sharing granularity is only CORESET-level. Since CORESET#0 has 576 REs or 1152 REs, the resulting resource overhead will be no smaller than PDCCH PEI |
| CATT | In order to achieve same detection performance, sequence based PEI would require less REs comparing to DCI-based PEI even with the frequency error.   The detail analysis has been shown in R1-2106983 |
| Apple | We do not agree.  The overhead comparison depends on too many factors, such as the assumptions on coexisting mechanism with the legacy signals, subgrouping, PEI-to-PO mapping.  Objectively speaking, there are cases where sequence-based PEI has less resource overhead, and there are also cases where PDCCH-based PEI has less resource overhead.  In addition, our calculation shows that the overall PEI overhead is very small, so it does not need to be a determining factor here. |
| LG | We do not agree with P4  We would like to emphasize that we should focus on coexistence with other signal/channel, and number of REs itself is not meaningful without consideration on coexistence.  In case of PDCCH-based PEI, gNB can select AL and existing coexistence strategies can be reused without any further standard work. Meanwhile, in case of sequence based PEI, resource overhead per PEI transmission cannot be controlled by gNB and it may require additional standard work to guarantee coexistence with legacy signal/channels. |
| Samsung | Definitely.   1. It’s obvious that the required RS resource per PEI transmission for sequence based is smaller than PDCCH based. As PDCCH based transmit >12 bits payload+24CRC bits. 2. Dynamic resource sharing should not be an issue for any of the PEI candidate. gNB has many way to achieve that, it’s not a new issue. In the simplest case, gNB can schedule PDSCH and PEI in different OFDM symbols. And do power boosting for PEI to reuse any unused REs per symbol. 3. Multi-beam operation should be taken into consideration for resource overhead.    1. The difference linearly increased with respect to the number of MOs needed.    2. In addition, UE has flexibility to use wider beam for sequence based PEI as it’s based on non-coherent detection and it doesn’t necessary need to be QCLed with a SSB. |
| Huawei, HiSilicon | We don’t agree P4.   1. We are discussing the resource overhead, which should consider the coexistence and whether the resource can share with legacy signal/channel of legacy UEs. We cannot use the link level results to compare resource overhead. I think we have discussed this and made related agreements already. 2. In order to support multiplexing of PEIs of different sub-groups, FDM/TDM of PEI resources are proposed by related proponents. Also, according to the analysis from network vendors’ contribution, it would be difficult to configure CORESET or A-ZP-CSI-RS source set for the purpose of PEI rate matching or sharing. In this sense, semi-static RB-symbol level rate matching would be the choice for sequence based PEI in deployment. 3. PDCCH based PEI can associate with multiple POs and also indicating sub-grouping information, which can well reduce the resource overhead. In our view, the PDCCH based PEI have lower resource overhead when multiple POs are associated. 4. PDCCH based PEI can well support behv.B, which can enable gNB to well balance resource overhead and power saving gain. |
| vivo | Firstly, in our point of view, the resource overhead and coexistence are not the critical factors for the final decision on PEI physical-layer channel/signal, compared to performance and power saving. According to our contribution [R1-2106606], Table 9 and Table 10 gave plenty of calculations for the comparison of the resource overhead difference between PEI designs, by using different rate-matching methods. Accordingly, in term of resource overhead for per PEI occasion and per PO, SSS-like sequence-based PEI will consume the least resource, TRS-like sequence-based PEI followed and DCI-based PEI comes last. Last but only least, it has be proven that the difference of between DCI-based PEI and sequence-based PEI in the proportion of resource overhead to the overall system resource is negligible, no matter adopting dynamic rate-matching or semi-static rate-matching method. |
| ZTE, Sanechips | We don’t agree with the statement in P4.  (1)According to the agreed observation, the dynamic resource sharing depends on the co-existence with other signal/channel. For example, the whole interleaved CORESET of legacy PDCCH would be blocked if SSS/TRS based PEI is collided with legacy PEI. Considering the limited numbers of CORESET supported by UE, dynamic resource sharing of SSS/TRS based PEI cannot be guaranteed in the implementation.  (2)Besides, if non-coherent detection is assumed for PDCCH based PEI, the required AL can be reduced.  (3)Moreover, the occupied resource is also determined by many other factors, such as sub-groups per PO, number of PO indicated by PEI, etc, considering all these factors, PDCCH based PEI requires less resource than SSS/TRS based PEI. |
| Intel | According to MDR and resource overhead observation table, it seems to the case that per PEI occasion, sequence based PEI results in lower resource overhead than PDCCH based PEI when 1 PEI to 1 PO association is assumed. Overall impact on system resources depends on paging rate.  Regarding coexistence, as repeated multiple times, network has the necessary tool to realize dynamic resource sharing whenever needed. Agreed observations made it clear already. |
| Nokia | Now we tend to agree with the point made by vivo that the absolute number level the values are small. However, like raised several meetings ago, important thing is not just that there is a method, it also matters how feasibly that method can be applied without restricting the operation. I.e. multiplexing with CONNECTED mode UEs, semi-static RB-symbol level RM would seem to be only practical option.  One additional aspect companies have not considered is the fact that TRS- and SSS-PEI cannot feasibly be multiplexed to slots where any broadcast information needs to be sent. The IDLE UEs do not assume any rate matching based e.g. on ZP-CSI-RS over the PDSCH resources (also the scheduling is done via DCI 1\_0). Correspondingly, it is not possible to configure additional SS set to ‘puncture’ holes to the transmission for TRS- or SSS-PEI transmission.  In my understanding one of the methods considered in RAN1#104bis-e or RAN1#105e would not enable transmitting TRS- nor SSS-PEI in conjunction with broadcast PDSCH. Now in multibeam systems, such as at FR2, it is also likely that the whole slot would be sent to same direction (to enable FDM’ed unicast data transmission with broadcast information). Hence, with TRS- or SSS-PEI would also further restricting the scheduler flexibility in spatial domain in FR2. |
| Panasonic | We agree on this point if small information bits is assumed, e.g. no more than 4 bits.  Basically, two aspects need to be separately discussed. One is resource overhead caused just by the physical channel design. The other one is the possible waste due to coexistence with legacy UEs.  From the channel design perspective, by looking at the typical cases, our observation is that the overhead situation should be **(a) sequence-based PEI covering one PO < (b) PDCCH-based PEI covering one PO < (c) PDCCH-based PEI covering multiple POs**. For Behv-A, the overhead will increase dramatically with more POs to indicate by one PEI, due to fact that even if one of the PO is positive, the whole PEI needs to be transmitted. Assuming one PDCCH PEI covers 10 POs, it has to be transmitted with probability of 1-0.9^10 = 0.65, assuming GPR = 0.1. However, for PEI only indicating for one PO, the overhead could be less considering the transmission is always with probability of 0.1.  On the coexistence aspect, we see same possible but not essential issue for both cases and gNB needs to carefully manage the scheduling. This has been discussed for quite long time. And we believe the difference even if exists, is not decisive to possible conclusion on overhead comparison and the adopted PEI design. |
| Sony | Agree.  Dynamic resource sharing should not be an issue for any of the PEI candidate.  gNB handle this for instance by introducing a window for PEI transmission/reception prior to PO is supported to avoid any blocking when other DL transmissions coincide with PEI.    NOTE: We consider  the resource overhead and coexistence are not the main design criteria. The main design criteria should be **performance and power saving gain**. |
| Spreadtrum | We share the same view as MTK, Apple and LG. If the new signal in the idle-mode, the dynamic resource sharing w.r.t. the legacy UE is not so realistic. Using the connected-mode resource to cover the idle-mode new signal is too tricky. We don’t think the connected-mode resource allocation, C-DRX timing and beam transmission should consider too much about the idle-mod new signal. The new PDCCH in the idle mode is more friendly network to allocate resource. In some cases, network can send the new PDCCH in PO resource, which is transparent to the connected-mode UE and idle-mode UE. |
| IDCC | We agree with Vivo that the absolute overhead is small. Regarding the relative overhead, the final number will depend on UE group                 multiplexing method and whether one PEI is associated to multiple POs. |
| Nordic | It depends on assumption of PDCCH AL sufficient for detection, there were different results among companies. However, we think that key KPI is how easy it is to deploy PEI in the existing systems. It is clear that  CORESET#0 resources are already there and can be reused only on whole CORESET granularity for PDSCH,  and cannot be used for any other signal.   In other words, CORESET#0 partially unused capacity can be used for PEI basically for free. |
| Xiaomi | P4 depends on some assumptions for consensus, e.g. Is the overhead of PEI a critical factor for the PEI decision？ how many information bits we may need in the PEI design?  So, this may be a low priority aspect for online discussion. |
| Ericsson | PDCCH-based PEI is most efficient as it can dynamically share resources within a Coreset, whereas the TRS/SSS-based PEI can only share the resources at Coreset-level granularity for the interleaved case, which is less efficient than PDCCH based PEI. |

From the above companies’ inputs, the following summaries are collected.

First, regarding UE power saving gain comparison (related to P1 – P3):

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| **Discussion Point 1**: SSS PEI or TRS/CSI-RS PEI can provide significantly better power saving gain because it can require less SS burst processing when UE is not paged |
| **Agree (7)**: CATT, Qualcomm, Samsung, vivo, Intel, Sony, IDCC  **Disagree (9)**: MTK, Apple, LG, Huawei, ZTE, Nokia, Spreadtrum, Xiaomi, Ericsson  **Neutral (2)**: Panasonic, Nordic |
| **Key arguments:**   * Serving-cell measurement can also provide synchronization for PEI detection * PEI cannot be used for measurement or synchronization since it is not transmitted when UE is not paged |

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| **Discussion Point 2**: SSS PEI or TRS/CSI-RS PEI can provide significantly better power saving gain because UE can use only PEI for fine synchronization before PO and reduce the wake up energy overhead when UE is paged |
| **Agree (6)**: CATT, Samsung, vivo, Intel, Sony, IDCC  **Disagree (9)**: MTK, Apple, LG, Huawei, ZTE, Nokia, Spreadtrum, Xiaomi, Ericsson  **Neutral (2)**: Panasonic, Nordic |
| **Key arguments:**   * The power saving gain difference of reduced SSB processing when UE is paged is subject to UE paging rate (10% per PO; ~1.3% with 8 UE subgroups per PO) * No consensus on the amount of reduced SSB processing before PO by RS PEI processing * FAR of PEI may impact the time/frequency tracking loop |

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| **Discussion Point 3:** SSS PEI or TRS/CSI-RS PEI can provide significantly better power saving gain because processing SSS PEI or TRS/CSI-RS PEI has significantly less power consumption than processing PDCCH |
| **Agree (6)**: CATT, Samsung, vivo, Intel, Sony, IDCC  **Disagree (8)**: MTK, Apple, LG, Huawei, ZTE, Nokia, Spreadtrum, Ericsson  **Neutral (3)**: Panasonic, Nordic, Xiaomi |
| **Key arguments:**   * RAN1 agreed power consumption model cannot show noticeable difference between PDCCH processing and SSS or TRS/CSI-RS processing  |  |  |  | | --- | --- | --- | | * Power State | Relative Power  (FR1 reference from TR ~~84~~38.840) | Relative Power  (Idle/inactive-mode operation with reception bandwidth 20 MHz) | | Deep Sleep (PDS) | 1 | 1 | | Light Sleep (PLS) | 20 | 20 | | Micro sleep (PMS) | 45 | 45 | | PDCCH-only (PPDCCH) | 100 | 50Note | | PDCCH + PDSCH (PPDCCH+PDSCH) | 300 | 120 | | PDSCH-only (PPDSCH) | 280 | 112 | | SSB/CSI-RS proc. (PSSB) | 100 (synchronization or serving cell measurement) | 50 | |

And, regarding the resource overhead,

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| --- |
| **Discussion Point 4:** SSS PEI or TRS/CSI-RS PEI can provide significantly less resource overhead by guaranteed dynamic resource sharing with legacy UEs |
| **Agree (5)**: CATT, Samsung, vivo, Intel, Sony  **Disagree (8)**: MTK, Apple, Huawei, ZTE, Nokia, Spreadtrum, Nordic, Ericsson  **Neutral (3)**: Panasonic, IDCC, Xiaomi |
| **Key argument:**   * System-level consideration and link-level consideration show different resource overhead requirements * Considering available multiplexing schemes supported by legacy UEs and minimum impact to system operation/scheduling, multiple infra-vendors suggest static resource sharing with legacy UEs for SSS PEI and TRS/CSI-RS PEI. |

Accordingly, the following 3 possible conclusions are suggested:

**Possible conclusion 1**:

* For the evaluations of PEI candidate designs, it is implicitly assumed that the following RS processing can also provide synchronization:
  + Processing of SSB for serving-cell measurement
  + Detection of multi-symbol SSS PEI when transmitted
  + Detection of TRS/CSI-RS PEI when transmitted
  + Note: SSS PEI is assumed to reuse the SSS structure as in legacy SSB
  + Note: Multiple companies show concern on the impact to time/frequency tracking if the detection of PEI results in a false alarm
* Given serving-cell measurement is required for every idle DRX cycle, UE is required to process at least one SSB, regardless whether PEI is present or not.
* Based on RAN1 agreed power consumption model for idle/inactive-mode UEs, the power consumption of processing one SSB and additional PEI detection is comparable for all PEI candidate designs.

Possible conclusion 2

* RAN1 has no consensus on which PEI candidate design can provide significantly lower average resource overhead than the others, considering link-level performance requirement and minimum impact to system operations with legacy UEs

Possible conclusion 3

For the decided PEI physical-layer channel/signal, FFS whether and how to achieve the following:

* Allowing UE to apply simplified processing for PEI detection
* Minimization of average resource overhead

**Since there is less support on Possible conclusions 2 and 3, companies are encouraged to provide views/suggestions on Possible conclusion 1 in the table below:**

Table : Companies’ views on Possible Conclusion 1

|  |  |
| --- | --- |
| Company | Companies’ views on Possible Conclusion 1 |
| LG | LG support the **Possible Conclusion 1**  We believe that the proposed possible conclusion is reasonable and can be useful information for our decisions. |
| Samsung | For the first bullet, it doesn’t help understand the performance difference among PEI candidates. We think the facts assumed an individual PEI candidate is more useful to reflect performance difference. In this sense, we think following facts are more important and can be captured.   * Additional SSBs processing is required after PDCCH based PEI detection at least for medium/poor channel when UE is paged * The power consumption of processing serving cell measurement may be different, depending on whether or not to use synchronization from serving cell measurement for PEI reception.   For the second bullet, as we commented before, it’s not acceptable to us.   * Per chairman’s guidance in the last GTW, our understanding is that conclusion doesn’t necessary to be limited by evaluations. The power model we agreed for PEI detection is very rough. It’s worth discussing and capturing all the useful information to compare the performance difference. The power consumption for sequence based PEI detection should be less than PDCCH based PEI detection in practice, as the processing overhead for PDCCH reception (including channel estimation, demodulation, channel decoding, etc ) and sequence detection (correlation) is totally not in the same level. * Even based on current channel mode, the power consumption of PEI detection can be different due to the processing duration. We agree the power model for sequence based PEI to be same as SSB. Then similar MO duration should be considered for sequence based PEI, where at least 2 MOs per slot. For PDCCH based PEI, it’s same as paging PDCCH, where one MO per slot. So the detection power consumption for sequence based PEI should be at least half less than PDCCH based PEI. |
| Huawei, HiSilicon | We support the **Possible Conclusion 1.**  some comments on *Samsung’s comments:*  *Additional SSBs processing is required after PDCCH based PEI detection at least for medium/poor channel when UE is paged*  Huawei, HiSilicon: We don’t agree. The SSS based PEI and TRS based PEI may provide synchronization when transmitted. However, it is not reliably known that the PEI is transmitted or not. It would be also possible that the UE falsely detect the sequence, e.g. falsely detect sequence A for an individual group to a common sequence. In this case, the UE cannot reliably rely on the (falsely) detected sequence for synchronization before PO reception. Furthermore, the SSS based PEI has less REs compared with PSS+SSS+DMRS of PBCH and shorter span of symbols than a SSB, it cannot say a SS based PEI can replace a SSB for time/frequency tracking. Similarly, 24RB TRS has less REs than a SSB. We think for all three PEI candidates, the required SS bursts are the same before PO.  *The power consumption of processing serving cell measurement may be different, depending on whether or not to use synchronization from serving cell measurement for PEI reception.*  Huawei, HiSilicon: serving cell measurement shall be always done regardless which PEI is utilized or whether PEI is there. I need to point out serving cell measurement itself includes time/frequency tracking to obtain the RSRP measurement. As shown by Samsung’s results, PDCCH can be detected reliably within 0.5ppm. The synchronization for RSRP measurement is already sufficient for the detection of PDCCH. There  is no “(PSSB + Pintra\_meas)\*0.85” claimed by Samsung.  *Per chairman’s guidance in the last GTW, our understanding is that conclusion doesn’t necessary to be limited by evaluations. The power model we agreed for PEI detection is very rough. It’s worth discussing and capturing all the useful information to compare the performance difference. The power consumption for sequence based PEI detection should be less than PDCCH based PEI detection in practice, as the processing overhead for PDCCH reception (including channel estimation, demodulation, channel decoding, etc ) and sequence detection (correlation) is totally not in the same level.*  Huawei, HiSilicon: The power model was reviewed at the beginning in Rel-17 for IDLE mode UE and agreed by all the companies. We should be based on the agreement for further discussion. As we explained in the first round, there is no big difference on the power consumption level.  *Even based on current channel mode, the power consumption of PEI detection can be different due to the processing duration. We agree the power model for sequence based PEI to be same as SSB. Then similar MO duration should be considered for sequence based PEI, where at least 2 MOs per slot. For PDCCH based PEI, it’s same as paging PDCCH, where one MO per slot. So the detection power consumption for sequence based PEI should be at least half less than PDCCH based PEI.*  Huawei, HiSilicon: we can’t agree this comment from Samsung. We haven’t agree the monitoring occasions of sequence based PEI and PDCCH based PEI. PDCCH based PEI can have search space set configuration and can also support multiple MO’s in one slot. |
| Apple | We support the proposed conclusion 1. |
| Spreadtrum | We support the Possible conclusion 1 drafted by FL.   * Given serving-cell measurement is required for every idle DRX cycle, UE is required to process at least one SSB, regardless whether PEI is present or not.   We support the above observation and share the similar view as Huawei. As shown in our contribution [R1-2106708], ~~we don’t~~ think PEI cannot be used for RRM measurement.   * Based on RAN1 agreed power consumption model for idle/inactive-mode UEs, the power consumption of processing one SSB and one additional PEI detection is comparable for all PEI candidate designs.   We support the above observation and share the similar view as Huawei. In addition, for statement from Samsung, (PSSB + Pintra\_meas)\*0.85 or Pintra\_meas, we think if the power model is (PSSB + Pintra\_meas)\*0.85, it means we consider the “double work” for synchronization and RRM measurement, if the power model is Pintra\_meas, it means we consider the “single work” for synchronization and RRM measurement. Anyway, the power model is the same for all PEI schemes. |
| CATT | This proposal is technically incorrect in concluding that the power consumption of channel processing in preparation of non-coherent detection and coherent detection is the same.   RAN4 LS in R1-2104170 already identify that RS for AGC and channel tracking needs to be 2 ms or 2 slots apart, which is not in a SSB.  RAN1 could not re-invent the engineer and defy against Physics. |
| Intel | **Regarding first bullet:**  Is it assumed that 1 SSB is being used for both AGC and serving cell measurement? If AGC is assumed, then we need two?  **Also, is the intention that first bullet applies regardless of PEI candidate? This needs to be clarified.**  Let’s focus on the SSB that can be used for serving cell measurement because if AGC processing would be common anyways if assumed. In our view, tracking achieved by that SSB may not be enough to ensure low CFO to detect PDCCH because of the following reasons:   * When UE comes out of deep sleep, UE may need to prepare for worst case as link condition maybe unknown. Hence, UE would need to wake up a bit early to process multiple SSBs. The worst case timeline would be different depending on PEI candidate design, e.g., it would be shorter if sequence based PEI is also assumed to help in tracking and given the fact that it is more robust to coarse CFO. * If we observe the PDSCH 1% BLER points, we have seen that operating SNR points can be much lower, close to -10dB. Since achievable residual CFO depends on link condition, certainly tracking based on 1 SSB may not be enough for PDCCH detection.   To this end, we think following bullet is more accurate and should replace the above:   * **The required number of SSBs processing before detecting PDCCH based PEI can be more than sequence based PEI (e.g., SSS or TRS/CSI-RS based) PEI, where the latter is assumed to aid in tracking.**   Regarding using sequence based PEI for tracking, again there is no feasibility issue. FAR target was assumed to be 1% or below during initial access study. For PEI, the MDR results also assumed that. MDR of sequence based PEI was shown to be quite robust at the operating SNR point at FAR 1% by quite a few companies.  **Regarding second bullet:**  That table did not take into account receiver energy consumption difference that could occur between coherent and non-coherent detection. Since this is based on  UE implementation, it may be difficult to come up with a model and possibly the reason why it was overlooked in Rel16. However, that should not change the fact that low complexity correlation based detection would typically require less power consumption than full-fledged PDCCH polar decoding, and the table is used as excuse to bypass this fact just because it is not visible in the table from the power model. |
| ZTE, Sanechips | We support conclusion 1.  As to the RAN4 LS, as we commented before, if more RSs are required for ACG and tracking, it is common for all PEI candidates, hence, the required number of processed SSB should be the same for all PEI candidates.    As to Samsung’s comment that “The power consumption of processing serving cell measurement may be different, depending on whether or not to use synchronization from serving cell measurement for PEI reception.” **We think there is a similar issue for SSS/TRS-based PEI, if the transmitted SSS/TRS-based PEI is used for sync, it consumes more power.**Therefore, the PDCCH based PEI should save more power than SSS/TRS-based PEI. Meanwhile, only then transmitted  SSS/TRS-based PEI can be used for sync. When SSS/TRS-based PEI is not transmitted, UE use the noise for sync, the synchronization performance would be degraded. In summary, the SSS/TRS-based PEI is more power consuming and also have negative impact on synchronization performance.  Considering the above factors, the required SSS is the same for PDCCH based PEI and SSS/TRS-based PEI to guarantee the performance of paging DCI and message.    As to the comment that “Then similar MO duration should be considered for sequence based PEI, where at least 2 MOs per slot. For PDCCH based PEI, it’s same as paging PDCCH, where one MO per slot. So the detection power consumption for sequence based PEI should be at least half less than PDCCH based PEI.”, more than 2MO per slot is used for SSS/TRS-based based PEI, the power consumption of SSS/TRS-based PEI is also increased due to the increased MO, and new pattern with more standardization workload is needed. While for PDCCH based PEI, the MO is determined by the search space set configuration, the MO per slot is can be flexibly configured according to the current spec.    Moreover, according to our simulation results, non-coherent detection can be also applied to PDCCH based PEI. In this case, the processing requirements are exactly the same for PDCCH based PEI and SSS/TRS-based PEI. |
| LG - 2 | We have similar view with MediaTek, Huawei, Apple, Spreadtrum, and ZTE.  Regarding power consumption for non-coherent detection,  As we mentioned before, we assume that the UE in a micro sleep state, where no monitoring is performed, requires 45 units of power. Even the UE performing non-coherent detection requires more than this baseline power unit. In general, UE power consumption is proportional to the BW. However, when BW is small, we think that power consumption of the UE will be biased by the baseline power consumption.  Regarding power consumption for the time/frequency tracking during the RRM measurement,  We share similar view with several companies that power consumption model for RRM measurement already reflects the impact from the time/frequency tracking. On the other hand, if power consumption due to the time/frequency tracking is a larger than we assumed, additional power consumption for sequence based PEI due to the time/frequency tracking shall be considered as well. It seems like there is no company who support time/frequency tracking while assuming additional power consumption by the additional UE behavior.  Anyway, proposed conclusion from FL seems quite straight forward and reasonable since it is quite general idea that have been assumed in NR and Rel-17 power saving item so far. |
| SONY | We do not support the possible conclusion 1. The sequence-based PEI has the lowest power consumption/highest power saving gain:   * In this conclusion, the same number of SSB bursts before PEI has been assumed for all PEI designs which basically means the characteristics of the different signal designs have not been considered.   A simple correlation-based detection of sequenced-based PEI means that energy consumption when detecting sequence-based PEIs is lower than the energy consumption of the receiver when decoding/detecting PDCCH/DCI-based. This is not included in the current energy model/energy analysis and therefore not in the conclusion. |
| vivo | For the first sub-bullet:  As we pointed out in the last round discussion for possible conclusion 1, there will be some difference between PDCCH-based PEI and sequence-based PEI for the requirement number of SSB detection. In some bad coverage case, at least 2 SSBs rather than at least one SSB will be required by PDCCH detection aiming for fine sync, T/F tracking and serving cell measurement. Whereas for sequence-based PEI, as the conclusion endorsed during the online meeting, due to the sequence itself can be used for sync, only one SSB is needed even in the same bad coverage case.  For the second sub-bullet:  In our views, there should be some power consumption difference between (PSSB + Pintra\_meas) and Pintra\_meas i.e., (PSSB + Pintra\_meas) > Pintra\_meas. However, we haven’t such power model so far to capture such differences. But it is technical sounding that some differences exists. |
| OPPO | We support the conclusion 1.  The sequence based PEI is not always transmitted. And it is also possible that the UE falsely detect the sequence, it is not a good choice to replace a SSB with sequence based PEI for time/frequency tracking. We think it can be assumed the same SSB number regardless of PEI candidate. |
| Xiaomi | We agree the Possible Conclusion 1  If sequence base PEI is always transmitted, then the power saving gain is better. However, it is not and therefore UE can’t assume using PEI regardless of false detection, so the two sub bullet are true. |
| Nokia | We support conclusion 1  Firstly liked discussed extensively in the agenda 8.7.1.2, serving cell evaluations should be based on SSB. Thus I don’t think we need to consider this aspect for the second time.  Like noted by others, in SL, 1 symbol is reserved for AGC in conditions where the expected signal level change can be much faster. Thus settling AGC in the SSB should not be any issue.  On the need of SSBs after the PEI (between PEI and PO) for synchronizing for paging reception; assuming e.g. two slot TRS could result reduced need to receive SSBs for T/F synchronization for detection of the PO (paging message), but this would only apply when UE needs to monitor paging. Accounting the option to feasibly support paging sub-grouping to full extent with PDCCH-based PEI and the option to have additional information also (like L1 availability) we don’t think this gives any actual benefit for the sequence based PEI. |
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With the offline and online discussion (GTW on 8/20 UTC), the following conclusion is made:

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| Conclusion   * For the evaluation of PEI candidate designs (for which observations made in previous RAN1 meetings), it was implicitly assumed by companies that the following processing can also provide synchronization:   + Processing of SSB(s) of each DRX cycle for serving-cell measurement   + Detection of multi-symbol SSS PEI (s)when transmitted   + Detection of TRS/CSI-RS PEI(s) when transmitted   Note: SSS PEI is assumed to reuse the SSS structure as in legacy SSB |

Now the group continue discussing whether further conclusion/observation can be made before the final decision target on next GTW (potentially on 8/25 UTC).

# Summary

For this meeting, down-selecting one solution for PEI physical-layer channel/signal is targeted:

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| **Conclusion:**  To down-select one solution for PEI physical-layer channel/signal in RAN1 #106-e, using below as a starting point:   * PDCCH-based PEI * SSS-based PEI * TRS/CSI-RS-based PEI   Note: Additional details for each of the above 3 solutions are encouraged for more informed down-selection  Note: further refinement of the above list is possible, e.g., by merging/further splitting, depending on significance of the commonality and/or differences |

In Appendix B, there summarize all available agreements and observations related to the PEI candidate designs from the previous RAN1 meetings. In Section 5, there extensively collect companies’ views on comparing the candidates.

Additionally, RAN1 agrees the following in this meeting:

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| Conclusion   * For the evaluation of PEI candidate designs (for which observations made in previous RAN1 meetings), it was implicitly assumed by companies that the following processing can also provide synchronization:   + Processing of SSB(s) of each DRX cycle for serving-cell measurement   + Detection of multi-symbol SSS PEI (s)when transmitted   + Detection of TRS/CSI-RS PEI(s) when transmitted   Note: SSS PEI is assumed to reuse the SSS structure as in legacy SSB |

RAN1 is currently discussing the potential conclusion below, but the decision is expected to be made no matter further conclusion can be achieved or not:

**Possible Conclusion 1**

For the evaluation of PEI candidate designs (for which observations made in previous RAN1 meetings), the following were implicitly assumed:

* Given serving-cell measurement is required for every idle DRX cycle, regardless whether PEI is present or not, additional SSB processing may not be required before PEI detection, which depends on UE implementation.
* If UE is indicated to monitor PO, less SSB processing may be required for SSS PEI or TRS/CSI-RS PEI than PDCCH PEI after PEI detection and before PO reception, which depends on UE implementation.
  + The difference in average UE power consumption is subject to UE paging probability with PEI.
* Based on RAN1 agreed power consumption model for idle/inactive-mode UEs, the power consumption of processing one SSB and one additional PEI detection is comparable for all PEI candidate designs.

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| * Power State | Relative Power  (FR1 reference from TR ~~84~~38.840) | Relative Power  (Idle/inactive-mode operation with reception bandwidth 20 MHz) |
| Deep Sleep (PDS) | 1 | 1 |
| Light Sleep (PLS) | 20 | 20 |
| Micro sleep (PMS) | 45 | 45 |
| PDCCH-only (PPDCCH) | 100 | 50Note |
| PDCCH + PDSCH (PPDCCH+PDSCH) | 300 | 120 |
| PDSCH-only (PPDSCH) | 280 | 112 |
| SSB/CSI-RS proc. (PSSB) | 100 (synchronization or serving cell measurement) | 50 |

To assist the decision, RAN1 also identified the following potential proposals for the PEI candidate designs, which can be useful for understanding the remaining specification effort for each candidate design. RAN1 will come back to the necessary proposals after the decision on PEI physical-layer channel/signal.

**Proposal 2-1a**

For PDCCH-based PEI (if supported), subgroups indication provided is by PEI only.

**Proposal 2-2a**

For SSS-based PEI (if supported),

* One sequence is transmitted in one SSS PEI resource for indicating a PO or multiple subgroups in a PO
* FFS: How to map sequences to one or a group of subgroups
* FFS: One or multiple FDMed/TDMed resources in a slot are utilized for indicating up to 8 subgroups in a PO
* FFS: Whether and how subgroups indication is provided by PEI
* FFS: How the physical-layer configuration(s) and sequence generation design can fulfil the requirement on no impact to initial access and RRM measurements of legacy UEs

**Proposal 2-3a**

For TRS/CSI-RS-based PEI (if supported), further down-select one of the following two alternatives

* Alt 1: One TRS sequence with orthogonal cover as PEI transmitted in the PEI monitoring occasion where one orthogonal cover of the PEI indicates one subgroup or combination of subgroups
* Alt 2: A set of TRS sequences indicating the subgroups with one selected sequence transmitting in one TRS resource
  + FFS: Sequence mapping design for supporting up to 8 subgroups per PO and combination of subgroups
* Alt 3: Multiple TRS/CSI-RS resources FDMed/TDMed /CDMed in the same monitoring occasion where one TRS/CSI-RS resource indicates one subgroup
  + Reuse Rel-15/16 CSI-RS FDM/TDM/CDM patterns for supporting up to 8 subgroups per PO
* FFS: Whether and how subgroups indication is provided by PEI

**Proposal 3-1a**

For PDCCH-based PEI (if supported),

* Determination of PEI monitoring occasion(s) is based on at least the following:
  + A search space configuration specifying periodic durations of the candidate monitoring occasions
    - The search space configuration can be dedicated for PEI or based on existing common search space configuration, e.g., *pagingSearchSpace*
      * FFS: How to include additional restriction if an existing common search space configuration is referenced
  + A minimum time offset befoe UE’s PO or PF
    - FFS range and granularity of the time offset, e.g., in unit of symbol, slot or frame
  + FFS: A maximum time offset between PEI monitoring occasion(s) and the start of the earlier and nearest SS burst for ensuring UE power saving gain

**Proposal 3-2a**

For SSS-based PEI or TRS/CSI-RS-based PEI (if supported),

* Determination of PEI monitoring occasion(s) is based on at least the following:
  + A dedicated resource configuration specifying periodic durations of the candidate monitoring occasions
    - FFS: Detail parameters
    - FFS: Configuration of an offset with respect to PO to indicate start of monitoring occasions
  + Resource FDM/CDM/TDM information if multiple PEIs are multiplexed
  + A minimum time offset before UE’s PO or PF
    - FFS range and granularity of the time offset, e.g., in unit of symbol, slot or frame
  + FFS: A maximum time offset between PEI monitoring occasion(s) and UE’s PO or the start of the earlier and nearest SS burst for ensuring UE power saving gain
  + Note : It is RAN1 understanding that the resource configuration for paging early indication is subject to the same idle-mode reception bandwidth as CORESET-0 frequency span

**Proposal 4-1a:**

At least Behv-A for UE to monitor PEI for whether to monitor PO is supported.

* FFS: Whether Behv-B is also supported, subject to that only one of Behv-A and Behv-B is configured by network.

# Reference

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2. R1-2106143, “Summary of Paging Enhancements”, Moderator (MediaTek), RAN1 #105-e
3. R2-2104356, “Reply LS on UE Sub-grouping for Paging Enhancement,” RAN2, MediaTek, RAN2 #113-bis-e; as R1-2104229 for RAN1 #105-e
4. R1-2009801, “LS on Paging Enhancement”, RAN1 to RAN2, RAN1 #103-e
5. R1-2106479, “Paging enhancements for UE power saving in IDLE/inactive mode”, Huawei, HiSilicon
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10. R1-2106775, “Discussion on paging enhancements”, Transsion Holdings
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13. R1-2106983, “Paging enhancement for UE power saving”, CATT
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22. R1-2107599, “On Paging Enhancements for UE Power Saving”, Intel Corporation
23. R1-2107622, “On paging enhancement”, Panasonic
24. R1-2107750, “Paging enhancements for idle/inactive-mode UE”, Apple
25. R1-2107806, “Paging enhancements for UE power saving”, InterDigital, Inc.
26. R1-2107869, “Discussion on paging enhancement”, NTT DOCOMO, INC.
27. R1-2107932, “Potential paging enhancements for power saving”, Xiaomi
28. R1-2107998, “Design of Paging Enhancements”, Ericsson
29. R1-2108122, “On paging enhancements for UE power saving”, Nokia, Nokia Shanghai Bell
30. Companies’ views from all submitted contributions

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| Company | Companies’ views |
| Huawei, HiSilicon | *Observation 1. PDCCH-based PEI can fully support coexistence with the legacy PDCCH CORESET at granularity of one or more candidates.*  *Observation 2. It would significantly restrict UE scheduling in CORESET 0, if a dedicated CORESET is configured for dynamic rate matching of SSS-based PEI, considering legacy UE mandatorily support only one additional CORESET in addition to CORESET0 in a BWP in FR1.*  *Observation 3. It impacts multi-beam operation of downlink traffic for FR2, if one dedicated CORESET is configured for the dynamic rate matching of SSS based PEI.*  *Observation 4. A non-interleaved CORESET for sharing with SSS-based PEI needs to be configured with the same frequency domain as (or partial overlapped with) CORESET0 in the symbols other than symbol 0~2, which restricts the gNB configuration of UE specific CORESET and impact scheduling flexibility scheduled by PDCCH in CORESET 0.*  *Observation 5. PDSCH scheduled by DCI format 1\_0 cannot be dynamic rate matched by TRS-based PEI.*  *Observation 6. It would significantly restrict UE scheduling in CORESET 0, if a dedicated CORESET is configured for dynamic rate matching of TRS-based PEI, considering legacy UE mandatorily support only one additional CORESET in addition to CORESET0 in a BWP in FR1.*  *Observation 7. It impacts multi-beam operation of downlink traffic for FR2, if one dedicated CORESET is configured for the dynamic rate matching of TRS based PEI.*  *Observation 8. A non-interleaved CORESET for sharing TRS-based PEI needs to be configured with the same frequency domain as (or partial overlapped with) CORESET0 in the symbols other than symbol 0~2, which restricts the gNB configuration of UE specific CORESET and impact scheduling flexibility scheduled by PDCCH in CORESET 0.*  *Observation 9. Power boosted the TRS-based PEI would impact the PDSCH performance, and the power for PDSCH REs in the same symbols of PEI will be reduced.*  *Observation 10. Several SS bursts are required to perform serving cell for IDLE mode UE, which can also be used for time-frequency tracking before the PEI detection in idle/inactive mode, regardless which PEI candidate is used.*  *Observation 11. The false detection of SSS-based/TRS-based PEI presence would introduce more time and frequency error before the next paging cycle if blindly detected SSS-based/TRS-based PEI is used for time and frequency tracking.*  *Observation 12. The detection performance of TRS-based PEI is impacted by the adjacent PDSCH REs in the same symbols of PEI, if the number of SS bursts were reduced before the reception of TRS based PEI .*  *Observation 13. PDCCH-based PEI can support to indicate 8 sub-groups per PO with little standard work, and the payload can be used for sub-group indication and associated with multiple POs flexibly.*  *Observation 14. More standard effort would be needed, e.g. new time-frequency allocation and sequence/cover code mapping and required RAN1 simulation and RAN4 requirement, to support sub-grouping indication if SSS-based/TRS-based PEI is adopted.*  *Observation 15. It is common issue for all three PEI candidates to associate PEI transmission(s) near a SS burst to the different POs during a SS burst period after the PEI transmission.*  *Observation 16. One PEI associating with multiple POs can save the resource overhead for PEI and does not introduce additional paging delay or power saving consumption.*  *Observation 17. The 48RB TRS-based PEI cannot work when the bandwidth of CORESET0 is 24RB and the 24RB TRS-based PEI cannot fulfil the link level performance requirement when the bandwidth of CORESET0 is 24RB according to observation 2a in RAN1#104bis-e.*  *Observation 18. To support deployment in 24RB initial downlink BWP, the SSS-based PEI with single-sequence CDM2 requires complex time resource allocation.*  *Observation 19. PDDCH-based PEI can work in both the configuration of Behv-A and Behv-B.*  *Observation 20. The SSS-based PEI has impact on the legacy cell search procedure and cell ID planning.*  *Observation 21. TRS-/SSS- based PEI may be interfered by PEIs and legacy signals of neighbor cells.*  *Observation 22. PDCCH-based PEI can be flexibly configured to carry PEI indication, sub-group indication, short message and other power saving functionalities, e.g. the availability indication of assistance TRS.*  *Observation 23. Sequence-based PEI signals is not suitable to support the indication of short message.*  *Observation 24. Sequence-based PEI signals is not suitable to support other power related information, e.g. assistance TRS availability indication*  *Observation 25. As summarized in Table 1, For SSS-based PEI and TRS-based PEI, significant standard work needs to be introduced, including time, frequency and sequence/code resources and mapping rules , and new monitoring occasions needs to be defined, while PDCCH based PEI just needs little standard work.*  Table 1 Comparison of specification impact with respect to different PEI designs   |  |  |  |  | | --- | --- | --- | --- | |  | Information bearing/  Sub-grouping/multiple POs indication | Frequency resource allocation | Monitoring occasion | | PDCCH-based PEI | Directly DCI Bit mapping,  Little spec work | Reuse CORESET | Based on search space set | | TRS-based PEI | Sequence mapping definition;  Time/frequency resource allocation and mapping;  Common sequence definition;  Cover code design | May reuse NZP CSI-RS resource set | New design is required | | SSS-based PEI | Sequence mapping definition;  Time/frequency resource allocation and mapping;  Common sequence definition;  Cover code design | New resource allocation signaling | New design is required |   ***Proposal 1: At most one aperiodic ZP-CSI-RS resource set can be utilized on legacy UE for rate matching purpose of PEI considering Rel-15 only supports up to 3 aperiodic ZP-CSI-RS resource sets per BWP.***  ***Proposal 2: The ZP-CSI-RS resources for the TRS-based PEI occasions associated with different sub-groups or different POs in the same SS burst period should be configured within the one ZP-CSI-RS resource set at most.***  ***Proposal 3: SSS-based/TRS-based cannot be used for time-frequency tracking.***  ***Proposal 4: Both Behv-A and Behv-B are supported by Rel-17, which can be configurable by the network.***  ***Proposal 5: Adopt DCI carried by PDCCH as the physical layer channel for PEI indication.***  ***Proposal 6: Considering there are different UEs in a cell, there can be multiple PEI occasions indicating the same PO.***  ***Proposal 7: A monitoring window and a small offset between the SS burst and the monitoring window can be specified for the PEI design to insure the power saving gain.***  ***Proposal 8: Existing CORESET0 or dedicated CORESET can be used for PDCCH-based PEI, and a common search space set is configured for DCI based PEI.***  ***Proposal 9: DCI format 2\_6 can be extended to transmit PEI for idle/inactive mode UEs.***  ***Proposal 10: The agreements and progress in RedCap need to be carefully considered in PEI discussion to ensure PEI utilization on RedCap UE, as required by RedCap WID.*** |
| TCL | *Observation 1: Different cdm types of size 8, i.e. cdm8-FD2-TD4, cdm8-FD4-TD2, cdm-FD8-TD and cdm-FD-TD8, and its orthogonal covers may create diverse unique indication codes for each subgroup indication in a PO.*  **Proposal 1: In PDCCH based PEI, code-points can also be utilized to map subgroups in a PO. The payload size of code-points can be design according to the number of PO configured in a PF.**  **Proposal 2: For SSS based PEI, one to one sequence mapping and/or a common sequence mapping to 8 subgroups of UEs in a PO can be considered.**  **Proposal 3: For TRS based PEI, subgroups in a PO can be indicated by One TRS sequence with orthogonal cover as PEI transmitted in the PEI monitoring occasion where one orthogonal cover of the PEI indicates one subgroup or combination of subgroups.** |
| ZTE | Observation 1: The advantages and disadvantages of Behv-A and Behv-B is summarized in Table 1.  Table 1 Summary of the advantages and disadvantages of Behv-A and Behv-B   |  |  |  | | --- | --- | --- | |  | **Advantages** | **Disadvantages** | | **Behv-A** | Resource overhead of PEI is relatively small when paging rate is low. | If UE misses the PEI with wake-up indication,   * both network and UEs associated with the same PEI or UE group consume more energy; * Cost more resources to re-transmit the PEI, paging DCI and paging PDSCH; * lead to the information loss and increase the latency of delivery of paging message; * resource overhead of PEI is significantly large when paging rate is high. | | **Behv-B** | * Resource overhead of PEI is relatively small when paging rate is high. * In an extreme case, the resource overhead can be reduced to, for example, 0. * No impact on the delivery of the paging message in the case of resource collision and PEI miss detection. | Resource overhead of PEI is high when paging rate is low. |   Observation 2: For Behv-A, a two-symbol TRS-like PEI or SSS-like PEI with FAR=1% fulfills the performance required by the paging PDSCH without scaling. For Behv-B, a two-symbol TRS-like PEI or SSS-like PEI with FAR=0.1% fulfills the performance required by the paging PDSCH without scaling.  Observation 3: For both Behv-A and Behv-B, sequence-based PEI (both TRS-like PEI and SSS-like PEI) needs more than two symbols to fulfill the JMDR performance requirement when the paging PDSCH is configured with TB scaling 0.5.  Observation 4: For Behv-A/B and SCL decoding, DCI-based PEI with AL 4 fulfills the performance required by paging PDSCH without TB scaling; DCI-based PEI with AL 8 fulfills the performance required by paging PDSCH with TB scaling=0.5.  Observation 5: For Behv-A/B and ML decoding, DCI-based PEI with AL 2 fulfills the performance requirement of paging PDSCH with TB scaling 1 and DCI-based PEI with AL 4 fulfills the performance requirement of paging PDSCH with TB scaling 0.5.  Observation 6: DCI-based PEI with AL adaptation provides more flexibility and better coverage.  Observation 7: The payload size of DCI based PEI can be flexibly configured without exceeding the 3+1 DCI size budget.  Observation 8: When the information bits of the DCI based PEI are reduced, the MDR performance of DCI based PEI is further improved. The MDR performance of DCI-based PEI with AL 2 carrying no more than 6 information bits is better than that of the two-symbol TRS-like PEI.  Observation 9: The MDR performance of DCI-based PEI is almost unchanged when the CFO is up to 1ppm.  Observation 10: For SSS-like PEI and TRS-like PEI, UE behavior is not defined in Rel-15/16 specification for the coexistence with SSB.  Observation 11: SSS-like PEI may impact the initial access procedure and neighbor cell measurement of the legacy UEs.  Observation 12: TRS-like PEI is not a good choice for the power consumption of idle/inactive mode UE due to  the large bandwidth.  Observation 13: To co-exist with other signals/channels, the mechanisms in the current specifications can be reused for DCI-based PEI. However, new mechanisms are needed for sequence-based PEI to resolve the resource collision with other signals/channels.  Observation 14: Based on the above analysis, it can be concluded that   * the power saving gain will be decreased if the PEI location is not properly configured; * the power saving gain caused by unreasonable configurations should not be used as a reference; * if the number of UE subgroup in one PO is 1, the power saving gain is 9.3% ~ 22.5% when two SSBs are processed before PO; the power saving gain is 13.2% ~ 31.4% when three SSBs are processed before PO.   Observation 15: The power saving gain of DCI-based PEI and sequence-based PEI is almost the same even the capacity limitation of sequence-based PEI is not considered and sequence-based PEI with synchronization function is assumed.  Observation 16: Whether the sequence-based PEI can provide the synchronization function and replace SSB or not is questionable considering the following factors.   * If gNB does not send the sequence-based PEI but FAR occurs, UE would take noise as PEI for synchronization; * The modules for PEI processing and paging DCI/PDSCH can be different in the implementation. The corrected synchronization accuracy may not be sufficient for paging DCI and PDSCH decoding.   Observation 17: If the on-demand (instead of always-on) sequence-based PEI is used for synchronization without justification, it will impact the correction of synchronization and paging performance, and increase more UE energy.  Observation 18: If the sub-grouping information is carried on the paging PDCCH, the power saving gain is negligible.  Observation 19: For DCI-based PEI, one PEI associated with multiple POs will not degrade the UE power saving gain.  Observation 20: It will decrease power saving gain if TRS-like PEI generated by sequence with orthogonal cover is used to indicate a combination of subgroups.  Observation 21: The detection performance will be degraded if   * the resources TRS-like PEI and legacy TRS are shared; or, * TRS sequence with orthogonal cover is used to indicate sub-grouping information.   Observation 22: When multiple PEI sequences are used to implement multiple PO/sub-group indication, the detection performance of sequence-based PEI will be deteriorated due to the increased FAR and correlation between the multiple sequences.  Observation 23: For sequence based PEI associated with multiple POs/sub-groups,   * for Alt-1, if PEI with orthogonal cover is used, the UE power saving gain or the detection performance will decrease; * for Alt-2, if PEI is generated by different sequences, the performance of sequence-based PEI will be deteriorated with the increased blind detection； * for Alt-3, if TDM or FDM technique is used for sequence-based PEI, the resource overhead will be multiplied.   Observation 24: For sequence-based PEI associated with multiple POs or sub-groups, Alt 3 (TDM or FDM) are considered.  Observation 25: When sub-grouping is considered, the DCI-based PEI can provide larger power saving gain than sequence-based PEI.  Observation 26: DCI based-PEI occupies less resources for both Behv-A and Behv-B.  Observation 27: Compared with sequence-based PEI, DCI-based PEI has less workload.  Observation 28: Multi-beam based transmission should be considered for PEI, and the QCL information of the PEI should be associated with an SSB.  **Proposal 1: Behv-A and Behv-B should be configurable.**  **Proposal 2: For SSS-like PEI and TRS-like PEI, semi-static RB-symbol-level rate matching pattern should be used for the coexistence with legacy PDSCH and PDCCH.**  **Proposal 3: The sub-grouping information should be indicated by PEI.**  **Proposal 4: The system information change and availability indication of periodic TRS can be conveyed by PEI.**  **Proposal 5: Adopt DCI-based PEI to reduce the paging reception for RRC idle/inactive state UE.**  **Proposal 6: A PEI should be associated with multiple POs.**  **Proposal 7: The number of POs associated with one PEI should be configurable.**  **Proposal 8: Some legacy parameters can be reused to indicate the number of POs associated with one PEI.**  **Proposal 9: For DCI-based PEI, bitmap can be used to indicate the sub-grouping information.**  **Proposal 10: The PEI reception window is used to determine the PEI occasion, wherein PEI reception window can be configured by an offset between the start of PEI window and the associated PO, or a reference point and an offset between the start of PEI window and the reference point.** |
| vivo | Observation 1: Sub-grouping method introduced in Rel-16 NB-IoT can save the number of candidate sequences by defining a “common sequence” representing the case that no less than two sub-groups need to be paged.  Observation 2: The additional false alarm rate and power consumption caused by the common sequence is marginal.  Observation 3: Based on the sub-grouping method introduced in Rel-16 NB-IoT, the network only needs to transmit one certain sequence for each PEI occasion to indicate its associated PO(s).  Observation 4: Up to 5.01% or 9.36% additional power saving gain can be achieved by introducing the sub-grouping paging indication carried by PEI-only when the per PO paging rate is 10% or 20% respectively.  Observation 5: When per PO paging rate is higher than 50%, there is almost no or even negative power saving gain for High SINR case and Medium SINR case.  Observation 6: Behavior B will consume 64.6%~80% more PEI resources than Behavior A when assuming the same power saving gain achieved by Behavior A/B when PO rate is 10%.  Observation 7: Behavior B will result in more power consumption than Behavior A, and it is even worse compared with baseline paging scheme, when assuming its resource overhead is the same as that of Behavior A.  Observation 8: For Behavior B, the network shall guarantee the probability of sending PEI with go to sleep indication is larger than 79%, otherwise there is no power saving benefit to configure PEI for idle/inactive UE.  Observation 9: Sequence-based PEI can be well co-existed with legacy signals/channels.  Observation 10: Performance of sequence-based PEI will not degrade with the increasing of number of subgroups, if a common sequence is introduced to wake up no less than two sub-groups.  Observation 11: If the DCI size of DCI based-PEI is less DCI format 1-0/0-0, UE need to decode two DCI size in idle state. If the DCI size of DCI based-PEI is aligned with DCI format 1-0/0-0, the performance of DCI-based PEI is less reliable.  Observation 12: The performance of SSS-like based PEI and TRS-like based PEI outperforms that of DCI-based PEI.  Observation 13: Up to 14.68% more power saving gain can be achieved by using sequence-based PEI, compared with DCI-based PEI.  Observation 14: Sequence-based PEI is superior to DCI-based PEI in terms of power saving gain, compared to baseline paging scheme.  Observation 15: In term of resource overhead for per PEI occasion and per PO, SSS-like sequence-based PEI will consume the least resource, TRS-like sequence-based PEI followed and DCI-based PEI comes last.  Observation 16: The difference of between DCI-based PEI and sequence-based PEI in the proportion of resource overhead to the overall system resource is negligible, no matter adopting dynamic rate-matching or semi-static rate-matching method.  Observation 17: Compared to performance and power saving, the resource overhead and coexistence are not the critical factors for the final decision on PEI physical-layer channel/signal.  Observation 18: TRS/CSI-RS availability indication through PEI is not unified solution since PEI and TRS/CSI-RS for idle/inactive UEs are decoupled features for UE power saving.  **Proposal 1: Adopt the sequence-based grouping method introduced in Rel-16 NB-IoT as described in Table 1. With this method, UE only needs to detect the following two sequences of PEI per PEI occasion, if sub-groups are configured.**   * **The sub-group specific sequence, to indicate only the sub-group which the UE belongs to receive paging, and** * **The common sequence, to indicate no less than two sub-groups to receive paging.**   Proposal 2: Sub-grouping indication only carried in PEI should be supported for paging enhancement.  Proposal 3: The sub-grouping indication by using paging PDCCH should be excluded. And reply the LS sending from RAN2 as follow:   * **From RAN1 perspective, the sub-grouping indication by using paging PDCCH should not be supported.**   **Proposal 4: PEI makes no power saving benefit in the case of per PO paging rate is higher than 50%.**  **Proposal 5: Only Behavior A should be adopted for UE behavior of PEI detection.**  **Proposal 6: Adopt that UE is not required to monitor the target PO if UE does not detect any PEI from all associated PEI MO(s) for the target PO.**  Proposal 7: Capture the power saving gain results given in Table 8-b for the comparison of PEI candidate designs.  **Proposal 8: Sequence (i.e., SSS-like or TRS-like) should be adopted for PEI design.**  Proposal 9: The configuration of PEI occasion should satisfy that the gap between PEI and the first indicated PO contains M SSB bursts, where the value of M can be 1, 2, 3 etc.  **Proposal 10: Defer the discussion for whether TRS/CSI-RS availability indication can be carried by PEI until the PEI candidate design is settled.** |
| Spreadtrum | ***Proposal 1: For evaluation purpose, it is assumed that PEI cannot be RS for T/F tracking.***  ***Proposal 2: For evaluation purpose, it is assumed that PEI cannot be RS for RRM measurement.***  ***Proposal 3: For evaluation purpose, it is assumed that UE should perform RRM measurement for the serving cell per paging cycle.***  ***Proposal 4: PDCCH-based PEI is supported in R17.***  **Table 2: Comparison among the schemes of PEI**   |  |  |  |  | | --- | --- | --- | --- | |  | **PDCCH-based PEI** | **SSS-based PEI** | **TRS/CSI-RS-based PEI** | | Power saving gain without UE subgrouping | Similar;  Gap b/w the 1st SS burst and PEI can be shortened (e.g. 1 PEI-PDCCH mapping to N groups) to achieve additional gain | Similar | Similar | | Power saving gain with UE subgrouping | Similar;  Potential larger gain due to more bits for UE subgrouping | Similar | Similar | | Resource overhead | Similar (Behv-A);  Small (Behv-B) | Similar (Behv-A);  Large (Behv-B) | Similar (Behv-A);  Large (Behv-B) | | Resource sharing | Similar for dynamic sharing;  Better for semi-static sharing | Similar for dynamic sharing | Similar for dynamic sharing | | Complexity of receiver | Medium (coherent receiver) | Low (time-domain non-coherent receiver) | High (frequency-domain non-coherent receiver) | |
| Sony | *Observation 1 – The cost of transition from/to deep sleep as well as synchronization cost are dominant sources of power/energy consumption.*  *Observation 2 – The TRS/CSI-RS-based and SSS-based PEI designs have significant commonality since they both are sequence-based signal designs and non-coherent detection/correlation is used for their detection.*  *Observation 3 – Sequence-based PEI fulfils the condition that paging enhancement schemes should avoid the UE unnecessarily transitioning from/to deep sleep and from/to synchronization states, when there is no paging for target UE.*  *Observation 4 – Since the energy difference between different receiver types, for DCI-based and sequence-based PEIs detection, has not been included in the energy model, sequence-based PEI in reality has a competitive advantage not visible in the current power saving gain comparisons.*  *Observation 5 – Resource overhead when sub-grouping is indicated through sequence-based PEI is lower than the one in DCI-based PEI.*  *Observation 6 - There is a certain probability that PEI transmission may potentially collide with DL transmission to a legacy UE or DL transmission of existing signals/channels to other UEs.*  *Observation 7 – The use of sequence-based early paging indicator is also beneficial for the FR2 case since the UE does not need to monitor a wider bandwidth for its paging detection.*  ***Proposal 1 – Paging enhancement schemes should avoid the UE unnecessarily transitioning from/to sleep states and from/to synchronization states.***  ***Proposal 2 – When making decisions on down-selection of the solution, support to compare calculated power saving gains based on the characteristics of different signal designs (and NOT based on assuming the same number of SSB before PEIs).***  ***Proposal 3 – Support sequence-based PEI as a paging enhancement scheme to reduce idle PO monitoring cost at the UE, as it has higher power saving gain and lower system overhead.***  ***Proposal 4 – Use sequence-based PEI as a paging enhancement scheme for UE sub-grouping to reduce overhearing and false-wake-up cost.***  ***Proposal 5 – A window for PEI transmission/reception prior to PO is supported to avoid any blocking when other DL transmissions coincide with PEI.***  ***Proposal 6 – Signaling aspects on conveying the configuration of the PEI transmission/reception window and UE/network behavior on PEI reception/transmission are FFS.***  ***Proposal 7 - Use sequence-based early paging indicator with sub-grouping for paging enhancement for FR2 operation.*** |
| Samsung | **Observation 1:** Potential specification efforts needed for the three PEI candidates are:   * PDCCH based PEI: a new DCI format, new CSS set, and CORESET/PDCCH candidate determination * SSS-based PEI: sequence generation to avoid impact to SSB detection, and sequence mapping for UE subgroup indication * CSI-RS/TRS based solution: method for UE subgroup indication if not reusing Rel-15/16 CSI-RS FDM/TDM/CDM patterns.   **Observation 2:** CSI-RS/TRS based PEI requires lowest specification efforts to achieve basic functionality of PEI.  **Observation 3:** RS based PEI can be used for synchronization in idle/inactive mode.  **Observation 4:** RS based PEI achieves higher power saving gain than PDCCH based PEI, due to reduced synchronization overhead on SS bursts reception before and after PEI monitoring occasions.  **Observation 5:** UE subgroup indication has no impact to UE power consumption on PEI reception regardless of physical layer signal/channel design of the PEI.  **Observation 6:** PDCCH based PEI requires much larger (~2X larger) resource overhead than RS-based PEI, especially TRS/CSI-RS based PEI.  **Observation 7:** For multi-beam operation in idle mode, gNB has flexibility to configure less number of reception occasions for RS based PEI to reduce resource overhead, due to non-coherent detection characteristics of RS based PEI.  **Observation 8:** No new gNB handling is expected to support coexistence of PEI with legacy PDCCH or PDSCH.  **Observation 9:** Coexistence with PDSCH is better than coexistence with PDCCH to avoid PDCCH blocking for Rel-15/16 UEs.  **Observation 10:** Behav-B requires much larger (9x larger @ group paging rate = 10%) resource overhead than Behav-A.  **Observation 11:** UE subgroup indication achieves limited PSG (e.g. < 2%) for most use cases when paging group rate is not high, such as the baseline of 10%.  **Observation 12:** There are 14 reserved bits in legacy paging PDCCH that can be used for UE subgroups per PO without additional resource overhead.  **Proposal 1: To down-select PEI physical layer signal/channel for best performance, including**   * **highest power saving gain,** * **low resource overhead, and** * **no impact to legacy Rel-15/16 UEs.**   **Proposal 2: Support RS based PEI for better performance than PDCCH based PEI, including**   * **higher power saving gain,** * **lower resource overhead, and** * **no impact to Rel-15/16 UEs, especially on PDCCH blocking rate.**   **Proposal 3: Support SIB based configuration of PEI, including**   * **a time offset, O, relative to start of an associated PO, to indicate start of PEI monitoring, and** * **a number of PEI monitoring occasions for multi-beam operation.**   **Proposal 4: Further study reusing Rel-15 configuration of physical layer signal/channel for determining time/frequency resource allocation of PEI.**  **Proposal 5: Merge RS-based PEI and PDCCH based PEI to a unified solution if necessary, considering**   * **common configuration of PEI monitoring occasions. and** * **no new physical layer signal/channel design.**   **Proposal 6: Support only Behav-A for PEI for the benefit of low resource overhead.**  **Proposal 7: Deprioritize UE subgroup indication in PEI due to the limited power saving gain and increased resource overhead.**  **Proposal 8: Support paging PDCCH for UE subgrouping indication for the benefit of no additional resource overhead.** |
| CATT | *Observation 1: For behavior-B, UE expects to receive PEI at every PO to determine whether to wake up or go back to sleep. If PEI is not detected by UE, UE falls back to proceed with the legacy paging procedure.*  *Observation 2: Sequence-based PEI shows better detection performance than that of DCI-based PEI regardless of joint MDR of Alt 1 or MDR of Alt 2.*  *Observation 3: Sequence-based PEI could provide more power saving gains than DCI-based PEI.*  *Observation 4: DCI-based PEI or sequence-based PEI can coexist with dynamic resource sharing with PDSCH used by legacy UE if it is scheduled by DCI format 1\_1 or Rel-17 UEs.*  *Observation 5: DCI-based PEI or sequence-based PEI can share resource well with PDCCH for Rel-15 UE.*  *Observation 6: Resource sharing of TRS used by legacy UE and TRS-based PEI allows TRS-based PEI without additional resources.*  *Observation 7: The resource overhead of sequence-based PEI is not greater than that of DCI-based PEI when sub-grouping is not considered for one PO associated with one PEI.*  *Observation 8: Introducing sub-grouping in sequence-based PEI can bring 30.19%~31.73% and 1.2%~2.21% power saving gain compare to Rel-16 paging and sequence-based PEI respectively.*  *Observation 9: With the increase of the number of sub-group, the gain of power saving gain is tending flat.*  *Observation 10: To support sequence-based PEI with sub-grouping, the power saving gain of option 1 relative to option 2 is negligible.*   * *Option 1: Multiple sub-grouping PEI can be transmitted in a resource.* * *Option 2: Single sequence is transmitted in a resource.*   *Observation 11: The resource overhead of sequence-based PEI is not greater than that of DCI-based PEI when sub-grouping is supported.*  *Observation 12: When one PEI indicates multiple POs, no matter behavior-A or behavior-B, the TRS-based PEI could maintain the same performance but the DCI-based PEI detection performance is degraded.*  *Observation 13: For supporting sequence-based PEI associated with multiple POs and sub-grouping, if no more than one sequence is transmitted in a resource at a given time, the false alarm probability is acceptable.*  *Observation 14: The resource overhead of sequence-based PEI is smaller than that of DCI-based PEI when sub-grouping and multiple POs associated with one sequence-based PEI are supported.*  *Observation 15: If sub-grouping is supported, the sequence-based PEI is better than DCI-based PEI from detection performance, power saving gain, coexistence and resource overhead views.*  ***Proposal 1: For the evaluation and comparison of PEI candidate designs based on PDCCH, TRS/CSI-RS and SSS, Behv-A is supported.***   * ***Behv-A:***   + ***PEI indicates UE should monitor a PO if UE’s group/subgroup is paged***   + ***UE is not required to monitor a PO if UE does not detect PEI at all PEI occasion(s) for the PO***   ***Proposal 2: The sequence-based PEI can co-exist well with existing channels and signals.***  ***Proposal 3: The sequence-based PEI should be adopted in Rel-17 for UE in IDLE/Inactive mode for UE power saving.***  ***Proposal 4: The number of code points generated from multi-segment orthogonal cover is up to 222 to indicate either or all paging subgroup/subgroup combination, paging occasions/occasions combination, and TRS/CSI-RS resource availability indication with the same detection performance.***  ***Proposal 5: Sub-grouping is indicated in sequence-based PEI.***  ***Proposal 6: For TRS/CSI-RS-based PEI, subgroups in a PO can be indicated by the combination of Alt1 and Alt2.***   * + ***Alt 1: One TRS sequence with orthogonal cover as PEI transmitted in the PEI monitoring occasion where one orthogonal cover of the PEI indicates one subgroup or combination of subgroups***   + ***Alt 2: A set of TRS sequences indicating the subgroups with one selected sequence transmitting in one TRS resource***   ***Proposal 7: For one-to-one mapping between PEI and PO, the cover code index of sequence-based PEI is related to sub-group number allocated by CN or randomization.***  ***Proposal 8: Whether to support multiple POs associated with one PEI need further study, taking into account the following factors:***   * ***PEI overheads.*** * ***PEI detection performance.*** * ***Power saving gains between different POs associated with one PEI.*** * ***The benefit of multiple POs associated with one PEI.***   ***Proposal 9：One-to-one mapping between PEI and PO is taken as baseline.***  ***Proposal 10: If one-to-N between PEI and PO is supported, the cover code index of sequence-based PEI is related to sub-group number and PO\_index.***  ***Proposal 11: The sequence-based PEI configuration and procedure could be calculated by reference signal/channel, e.g., reusing the procedure of paging occasion computation for 38.304.***  ***Proposal 12: For IDLE/Inactive mode, multiple beams of PEI should be supported.***  ***Proposal 13: For IDLE/Inactive mode, the spatial channel property of PEI is QCLed with the beams of SSB corresponding to paging PDCCH/PDSCH.*** |
| Transsion | ***Proposal 1: Both Behv-A and Behv-B should be supported and leave the selection to the network.***  ***Proposal 2: Subgrouping indication should be carried by PEI***  ***Proposal 3: DCI-based PEI should be supported by R17.***  ***Proposal 4: TRS availability indication should be carried by DCI-based PEI***  ***Proposal 5: PEI supports indicating the short message indicator .***  ***Proposal 6: One PEI associated with multiple POs should be supported by RAN1.***  ***Proposal 7: Supporting Multiple beams of PEI***  ***Proposal 8: Supporting setting a PEI detection time window*** |
| Nordic | ***Observation 1:*** *If no specification change is adopted in R17, TRS based PEI could not be configured in symbols where CORESET#0 or Common control resource set is present for R17 UE.*  **Observation-2:** *From PEI candidates*, *finding resources for TRS-based PEI is the most challenging for gNB, since gNB must avoid collisions with common CORESET(s) and SSB(s) in initial DL BWP.*  ***Observation-3:*** *Conclusion on feasibility of reception of PDCCH with only single SSB for cell-edge UEs is needed to be able to down-select PEI signal/channel.*  ***Observation-4****: If UE would be guaranteed wideband PDCCH DMRS within CORESET containing a search-space monitoring occasion for PEI, it would enable UE to obtain additional known synchronization signal, similarly as TRS and SSS offer.*  ***Proposal-1****: Consider introducing wide-band PDCCH DMRS transmitted in an entire CORESET configured by SIB1 or MIB during the early paging indication monitoring occasions to enable fine-synchronization based on known DMRS sequence as well as CRC based detection of PEI.*  ***Observation-5:*** *PEI should support the case where paging PDSCH is in different frame than paging early indication.*  ***Observation-6:*** *Gains from sub-grouping are having large variance among companies and depend on group paging rate. Specification effort to support sub-grouping is the lowest for PDCCH based PEI.*  ***Proposal-2:*** *Down-select PDCCH as PEI signal/channel.*  ***Proposal-3:*** *A dedicated PDCCH in dedicated search-space set contains:*   * *TRS validation bits, see our contribution in sub-agenda 8.7.1.2 for details* * *bitmap for up to 8 sub-groups to indicate wake-up or not in upcoming PO for each sub-group* * *define monitoring window before PO to monitor the dedicated search-space set for PEI, follow 2\_6 design principles.* |
| Lenovo, Motorola | **Proposal 1: Support repetition of PEI with multiple beams, where each PEI occasion is QCLed with one SSB of transmitted SSBs.**  **Proposal 2: A non-zero gap between the PEI and the corresponding PO or MO is configured for sequence based NR PEI.**  **Proposal 3: For PDCCH based PEI, Paging Power Saving (PPS)-PDCCH search space configuration can be signaled in SIB1 or in an RRC release message.**  **Proposal 4: A PDCCH carrying PEI is intended to a group of UEs associated with a set of paging frames. A size of the set of paging frames may be dependent on selected paging configuration parameter values.**  **Proposal 5: A PPS-PDCCH monitoring occasion(s) for a given PO may be configured based on a reference PF of the given PO (e.g. the earliest PF of a particular set of consecutive PFs associated with the given PO), e.g., before a start of a reference PF in a given paging cycle.**  **Proposal 6: RAN1 further discusses DCI configuration information and RNTI for PPS-PDCCH.**  **Proposal 7: Study how to support Paging Early Indication for reduced capability UEs.** |
| OPPO | *Observation 1: The beam sweeping of PEI transmission requires large resource overhead.*  *Observation 2: Reusing legacy PDCCH CSS set for PEI delivery has no backward compatibility issue.*  Proposal 1: One-to-one and one-to-many mapping between PEI and PO should be supported.  ***Proposal 2: Time offset parameters are configured for UE to determine a time duration before target PO where the UE starts and stop monitoring PEI.***  ***Proposal 3: Support N>=1 PEI monitoring occasions per PEI transmission, where each monitoring occasion is associated with a PDCCH monitoring occasion of the target PO.***  ***Proposal 4: The sub-grouping indication is supported by PEI, while sub-grouping indication by paging PDCCH is not supported.***  ***Proposal 5: Behv-A should be considered in PEI designs.***  ***Proposal 6: DCI-based PEI is preferred for paging early indication.***  ***Proposal 7: Legacy PDCCH CSS set can be reused for paging early indication delivery to reduce resource overhead.***  ***Proposal 8: Reuse the existing DCI format or specify a new DCI format for paging early indication, if DCI-based indication is considered.*** |
| Qualcomm | Observation 1: UE sub-groups can be indicated by   * Paging PDCCH   + Unused bits and/or reserved bits of the DCI, this includes cross-slot scheduling based paging PDCCH as PEI * PDCCH based PEI   + DCI field bits * RS or sequence-based PEI   + Different sequences, these sequences can be transmitted in different sets of RBs and symbols.   Observation 2: Regarding power saving gain for idle and inactive mode UEs   * Optimal location of PEI transmission can be different for different SINR conditions * Optimal location of PEI transmission can be different for PDCCH-based and RS/sequence-based PEI due to potential different requirement of time and frequency synchronization and AGC accuracy. PDCCH-based PEI may have lower power saving gain than RS/sequence-based PEI * When UE sub-grouping is adopted, it provides about 2% additional power saving gain.   Observation 3:   * At CINR = -6dB, PDCCH, RS and SSS based PEIs all have a MDR much lower than 〖10〗^(-3) and hence nearly no impact to the joint paging PDCCH and PEI detection performance * None of PDCCH, RS or SSS based PEIs is sensitive to CFO up to 0.5ppm * SSS based PEI has better future compatibility for even higher power saving gain if the PEI is processed by narrow band front end processor.   Observation 4: Without multiple P-RNTIs, only one PDCCH based PEI can be transmitted in the same CCEs of the CORESET for idle/inactive UEs for the same PO.  Observation 5: In the 20MHz bandwidth, to indicate which UE sub-group(s) of 8 UE sub-groups is paged   * For SSS based PEI, 3 unique sequences are needed * For CSI-RS based PEI, 12 unique sequences are needed.   Observation 6: The number of REs reserved by the PEI at a configured PEI occasion is determined by whether the resource is semi-statically or dynamic not available to legacy channels and signals   * If resource for the configured PEI occasion is semi-statically not available to the other channels and signals, PDCCH based PEI has lower resource overhead than CSI-RS and SSS based PEI. * If resource for the configured PEI occasion is dynamically not available to the other channels and signals, PDCCH based PEI has higher resource overhead than CSI-RS and SSS based PEI.   Observation 7: Depending on network implementation and UE capability   * For higher layer configured or SPS CSI-RS, resources of configured PEI occasions are semi-statically not available * For legacy PDCCH or aperiodic CSI-RS, resources of configured PEI occasions can be dynamically not available if the PDCCH or CSI-RS is not transmitted when it collides with a transmitted PEI. Table 6 is the lower bound of amount of unavailable resources   Observation 8: Regarding Behv-A and Behv-B for PEI   * When group paging rate for each PO is below 50% (e.g., 10%), Behv-A allows network to less often transmit PEI (10% of the time), and Behv-B requires network to more often transmit the PEI (90% of the time) * NB-IoT has assumed Behv-A type of wake-up signal design * Support of Behv-B unnecessarily increases the UE implementation complexity   **Proposal 1: Support UE sub-group indication carried by narrowband sequence-based (e.g., SSS) PEI for Rel-17 idle/inactive mode power saving.**  **Proposal 2: Base station transmits the PEI around the nearest SSB to the PO before the PO. There is no need to have multiple SSBs between the PEI and PO.**  **Proposal 3: Discuss the handling of collision between PEI and the other channels (UL symbol, DL broadcast channel including SIB, SIB PDCCH, SSB, idle/inactive TRS). No requirement for UE blind detection of the collision.**  **Proposal 4: Regarding the following Behv-A and Behv-B in RAN1 #104-e agreements, it should be clarified that the UE is allowed to choose a subset of PEI occasions to detect the PEI based on the wording in red color**   * **Behv-A:**    + **PEI indicates UE should monitor a PO if UE’s group/subgroup is paged**   + **UE is not required to monitor a PO if UE does not detect PEI at all PEI occasion(s) chosen by the UE for PEI detection for the PO** * **Behv-B:**   + **PEI indicates whether or not UE should monitor a PO**   + **UE is required to monitor a PO if UE does not detect PEI at all PEI occasion(s) chosen by the UE for PEI detection for the PO** * **Note: It is up to UE implementation which PEI occasion(s) is chosen by the UE for PEI detection.**   **Proposal 5: Only support Behv-A for Rel-17 PEI design from the two UE behaviors identified in RAN1# 104-e.**  **Proposal 6: Transmit power of the PEI is configured as a power offset to the SSS in the PEI configuration.**  **Proposal 7: Rel-17 PEI design is based on sequence**   * **Narrowband sequence such as SSS is preferred. Different SSS sequences can be multiplexed in the frequency domain in the same OFDM symbol** * **Availability of TRS at configured occasion(s) is indicated by paging PDCCH** * **How paging PDCCH and paging PDSCH are transmitted follows legacy rules but is not impacted by PEI**   **Proposal 8: One of three sequences is transmitted to indicate whether a UE sub-group is paged within the associated set of time and frequency resources according to the following rules**   * **Sequence 1: UE sub-group A is paged** * **Sequence 2: UE sub-group B is paged** * **Sequence 3: Both sub-groups A and B are paged**   **Proposal 9: Basic PEI design is common to one PEI per PO and one PEI per N>1 POs design. Potential discussion on one PEI for multiple POs can be postponed after the basic PEI design is complete.** |
| CMCC | **Proposal 1. Support PDCCH-based PEI.**  **Proposal 2. Support one-to-one and one-to-many mapping between PEI and PO(s).**  **Proposal 3. If UE subgrouping is not configured,**   * **If one PEI associates with Ns POs in one PF, the i\_sth bit in PEI is used to indicate wake up information of i\_sth PO.** * **If one PEI associates with K\*Ns POs in K PFs, the [(SFN\*N/T mod K) \*Ns+ i\_s]th bit in PEI is used to indicate wake up information of i\_sth PO, which SFN is the SFN for the PF, N is the number of PFs in one DRX cycle and K is the ratio between the periodicity of PEI and PF.**   **Proposal 4. If UE subgrouping is configured, define M is the number of subgroups in one PO and the UE subgroup index m is 0, 1, … M-1,**   * **If one PEI associates with one PO, the mth bit in PEI is used to indicate wake up information of UE with subgroup index m.** * **If one PEI associates with Ns POs in one PF, the [i\_s\*M+m]th bit in PEI is used to indicate wake up information of UE with subgroup index m in i\_sth PO.** * **If one PEI associates with K\*Ns POs in K PFs, the [(SFN\*N/T mod K) \*Ns+ i\_s]\*M+m th bit in PEI is used to indicate wake up information of UE with subgroup index m in i\_sth PO, which SFN is the SFN for the PF, N is the number of PFs in one DRX cycle and K is the ratio between the periodicity of PEI and PF.**   **Proposal 5. For UE-ID based subgrouping, the subgroup index for one UE can be calculated as floor[UE\_ID/(N\*Ns)] mod M, where M is the number of subgroups in one PO.** |
| LG | Observation 1: The UE sub-group indication using PEI outperforms UE sub-group indication within a PO.  Observation 2: Compared to the case where only UE\_ID based sub-grouping is supported, higher UE sub-grouping efficiency can be achieved when network controlled sub-grouping is configured.  Observation 3: Once the SI change indication is transmitted, repetitions of SI change indication may occur within preceding modification period.  Observation 4: Informing short messages over the PEI avoids unnecessary UE wake ups at PO.  Observation 5: A PEI occasion may need to consist of multiple monitoring occasions to support multi-beam operation.  Observation 6: PDCCH based PEI can support coexistence with the legacy PDCCH.  **Proposal 1: PEI should at least convey the information on UE sub-group indication and short message, and TRS/CSI-RS availability indication.**  **– FFS: UE group indication via PEI**  **Proposal 2: Support PDCCH based PEI.**  **Proposal 3: Introduce a new DCI format that conveys PEI information with smaller DCI bits than paging DCI.**  **- FFS: Reuse existing DCI format (e.g. DCI format 1\_0 with CRC scrambled by P-RNTI)**  **Proposal 4: PDCCH monitoring occasions for PEI are determined by PEI frame and PEI occasion**  **- PEI frame is determined by offset from the PF**  **- PEI occasion is configured within a PEI frame**  **- PDCCH monitoring occasions of PEI is either same as one for RMSI or configured by higher layer signal dedicated for the PEI** |
| MTK | Observation 1: Minimum UE operations with Rel-17 paging enhancement for idle/inactive mode include:   * One SS burst processing for serving-cell measurement and coarse synchronization (to comply with RRM accuracy requirements) * Paging early indication monitoring   Observation 2: [-0.5 0.5] ppm residue CFO before PEI detection is a reasonable assumption given that one SS burst can be utilized for CFO compensation, as supported by companies’ contributions in Table 1.  Table 1: Residue CFO given that one SS burst can be utilized for CFO compensation   |  |  |  |  | | --- | --- | --- | --- | | T-doc number | R1-2007869 (CATT) | R1-2008175 (Samsung) | R1-2008964 (MediaTek) | | Reference | Table 1 | Figure 4 | Figure 2 | | Results | CFO can be reduced from  1 ppm to 0.6 ppm | Reduced CFO has  Mean < 0.15 ppm  STD < ~0.1 ppm | Reduced CFO has STD < 600 Hz, corresponding to [-0.26 0.26] ppm uniform random CFO |   Observation 3: All companies checked that the performance requirement for PEI can be achieved with any of the PEI candidate designs under [-0.5 0.5] ppm residue CFO before PEI detection, confirming the achievability of the minimum UE operations for idle/inactive mode.  Observation 4: The range of achievable UE power saving gains are comparable, reflecting the achievability of the minimum UE operations by any of the PEI candidate designs.  Table 2: UE power saving gain comparison based on RAN1 #105-e observation   |  |  |  |  | | --- | --- | --- | --- | | Without UE subgrouping | | | | | #SS bursts before PO | PDCCH PEI | TRS PEI | SSS PEI | | 1 (High SNR) | 6.2% - 16.3% | 6.2% - 17.7% | | | 2 (Med. SNR) | 5.0% - 26.1% | 5.0% - 27.3% | | | 3 (Low SNR) | 12.5% - 37.0% | 15.7% - 35.0% | | | With UE subgrouping (8 subgroups) | | | | | #SS bursts before PO | PDCCH PEI | TRS PEI | SSS PEI | | 1 (High SNR) | 11.3% - 20.0% | 12.5% - 18.1% | 12.5% - 15.8% | | 2 (Med. SNR) | 6.3% - 32.0% | 6.3% - 30.7% | 6.3% - 28.9% | | 3 (Low SNR) | 17.9% - 42.2% | 17.9% - 39.7% | 17.9% - 38.1% |   Observation 5: For resource sharing with the channels of legacy/R15 UEs, the following have been investigated:   * Sharing PDSCH resource with legacy/R15 UEs: There requires additional gNB DCI indication for legacy/R15 UE to perform rate matching for PDSCH * Sharing PDCCH resource with legacy/R15 UEs: There requires NO additional gNB DCI for legacy/R15 UE by virtue of UE blind decoding   Observation 6: PDCCH PEI can reuses R15 PDCCH multiplexing design and requires the least network effort to ensure coexistence with legacy/R15 UEs    Observation 7: Because of special network handling required to realize dynamic resource sharing for TRS PEI and SSS PEI, there may only be static resource applied, which causes wider ranges of average resource overhead per PO.  Table 3: Comparison of average resource overhead per PO   |  |  |  |  | | --- | --- | --- | --- | |  | PDCCH PEI | TRS PEI | SSS PEI | | Average resource overhead per PO (REs) | 17.2 – 57.6 | 14.4 – 300 | 25.4 – 288 |   Proposal 1: PDCCH-based PEI is selected as PEI physical-layer channel/signal.   * **LS to RAN2 for informing RAN1 decision and providing related design decisions**   Observation 8: It is beneficial to merge the following useful characteristics from sequence PEI to PDCCH PEI:   * Allowing simplified implementation of a dedicated simple receiver (a.k.a WUR), which has the potential for further reduction in deep sleep power and PEI reception power. * Accommodating worse synchronization condition, e.g., the residue CFO can have wider range than [-0.5 0.5] ppm, which has the potential to accommodate relaxed serving-cell measurement.   Observation 9: When the number of PDCCH PEI realizations UE needs to detect is limited, UE can directly apply non-coherent sequence detection over PDCCH PEI. There can achieve similar PEI detection performance as TRS/SSS PEI as well as tolerating much worse CFO of [-1 1] ppm.    Figure 4: Performance comparison of applying non-coherent sequence detection to the PEI candidate designs    Figure 5: Performance of non-coherent sequence detection over PDCCH PEI under different CFO  Proposal 2: To enable UE to directly apply non-coherent sequence detection over the limited PDCCH PEI realizations, 4-bit code-point based mapping for indicating up to 8 subgroups is supported.  Table 4: Comparison for bit-map based and code-point based mapping design for subgroup indication   |  |  |  | | --- | --- | --- | | **Subgroup indication mapping type** | **DCI to UE subgroups mapping for 8 UE subgroups** | **#PDCCH realizations  for UE to detect** | | Bit-map | 1 bit per UE (sub)group; total 8 bits |  | | Code-point | 1000: Wake up all (sub)groups | 2  (e.g. UE belongs to  2nd subgroup) | | 0000: Wake up only 1st (sub)group  0001: Wake up only 2nd (sub)group  0010: Wake up only 3rd (sub)group  …  0111: Wake up only 8th (sub)group |   Proposal 3: To enable UE to detect DMRS of PDCCH PEI for whether to monitor PO, allow one different DMRS scrambling ID for PDCCH PEI (new RRC parameter)   * **UE can differentiate DMRS of PDCCH PEI from that of a legacy PDCCH** * **Note: This method is restricted to Behv-A**   Proposal 4: To merge the benefits of sequence PEI to PDCCH PEI, namely allowing simple sequence detection and tolerating larger CFO, the following alternatives can be considered:   * **Alt 1: Enable UE to detect PDCCH PEI via non-coherent sequence detection by including code-point based indication mapping to UE (sub)groups** * **Alt 2: Enable UE to detect DMRS of PDCCH PEI for whether to monitor PO by allowing one different DMRS scrambling ID from legacy PDCCH in the same CORESET**   Proposal 5: For PDCCH PEI, DCI format 2\_6 is extended with new content subject to P-RNTI. The following is the suggested content, depending on whether compact DCI format is configured (new RRC parameter)   |  |  |  | | --- | --- | --- | |  | **Normal DCI format** | **Compact DCI format** | | **PO/Subgroup indication** | **8 bits (one bit per PO/UE subgroup)** | **4 bits (code-point based mapping)** | | **TRS availability indication** | **2 bits** | **[1] bit** | | **Reserved bits** | **2 bits** | **[1] bit** | | **#DCI payload bits** | **12 bits** | **6 bits** |   Proposal 6: For PEI Monitoring Occasion (MO) determination, the following two steps are utilized   * **Broadcast potential MOs via a dedicated search space setting**   + **One PEI MO can contain multiple slots, accommodating beam sweeping**   + **Period of PEI MOs should be multiple of SS burst period**   + **Period of PEI MO should be no smaller than PO period** * **UE monitors the nearest MO subject to a configured minimum time gap (new RRC parameter) from UEs’ PO start to the end of PEI MO**   Proposal 7: To limit the PEI detection complexity, one single aggregation level is configured for monitoring PDCCH PEI (new RRC parameter)  Proposal 8: Both Behv-A and Behv-B are supported. gNodeB configure one to apply (new RRC parameter)   * **Note: Behv-B is useful for PDCCH PEI coexistence with legacy PDCCH that is infrequent but of high priority (e.g. SI update or ETWS indication)** |
| Intel | Observation 1: For the agreed evaluation assumptions (i.e., for a given # SS burst(s) before PO in Rel-16 baseline, PO paging rate, assumed # SS burst(s) before PEI etc.), TRS/CSI-RS or SSS- based PEI results in potentially higher power saving gain than PDCCH based PEI, according to the table on average power saving gain agreed in RAN1-105e at least when number of sub-groups in a PO is 1.  Observation 2: Both TRS and PDCCH-based PEI could meet the MDR requirements however TRS-based PEI provides significant resource overhead advantage over PDCCH-based PEI.   * For example, to meet SNR -7.79dB at 1% BLER for PDSCH with TB scaling 1 and CFO 0ppm, 24 RBs (144 REs) suffices for TRS whereas AL8 (576 REs) are needed for PDCCH-based PEI.   Observation 3: TRS-based PEI may include UE subgrouping information for at least 8 sub-groups where TRS BW can be as low as 24 RBs  Observation 4: AL 8+ is necessary for PDCCH-based PEI in most cases.  Observation 5: Joint MDR is mostly dominated by paging PDCCH performance, i.e., at the target SNR, MDR of TRS with FAR 1% is much lower than that of paging PDCCH.  Observation 6: Assuming dynamic rate matching and 1 PEI to 1 PO as baseline, it is quite clear from Observation 3a agreed in RAN1-104bis-e, that both SSS- and TRS/CSI-RS-based PEI with 2OS/slot can potentially achieve lower average resource overhead per PO for the meeting the MDR requirement.  Observation 7: According to the observations on coexistence of different PEI candidates with legacy signal/channels, none of the considered PEI candidates seems to pose any significant issue regarding coexistence and impact to legacy signal/channel transmissions.  Observation 8: TRS-based PEI achieves most efficient rate matching when coexisting with PDSCH.  Observation 9:   * TRS-based PEI can reuse Rel-15 TRS design as is, e.g., 2OS per slot * SSS-based PEI can be based on Rel-15 SSS signal design occupying multiple symbols in a slot * PDCCH-based PEI may require introduction of a new DCI format   Observation 10: Using DMRS of PDCCH as PEI and DCI content for delivering other information suffers from same performance drawback as PDCCH based PEI compared to sequence-based PEI. Moreover, DMRS may potentially need to be processed twice: once for detection of PEI and later for channel estimation of PDCCH.  Observation 11: For 1 PEI to 1 PO association, Behv-B could cause more signalling overhead for PEI transmission and/or increased UE power consumption compared to Behv-A. This makes benefits of Behv-B over Behv-A questionable.  Observation 12: Need for PEI at high paging load is questionable.  Observation 13: If N sub-groups are indicated via sequence transmission, UE needs to check 2^(N-1) sequences, i.e., only the sequences that would wake up UE’s subgroup.  Observation 14: Although PDCCH-based PEI may potentially include information of a larger number of UE sub-groups, this does not seem to offer critical PS advantage compared to the case, when both PEI and Paging PDCCH jointly indicate the UE sub-groups.  **Proposal 1: Support sequence-based PEI for Rel-17.**   * **FFS: TRS/CSI-RS based PEI or SSS-based PEI**   **Proposal 2: Support Behv-A only as PEI functionality.**   * **Behv-A:**    + **PEI indicates UE should monitor a PO if UE’s group/subgroup is paged**   + **UE is not required to monitor a PO if UE does not detect PEI at all PEI occasion(s) for the PO**   **Proposal 3: 1 PEI to 1 PO is supported only for Rel-17 PEI design.**  **Proposal 4: Both PEI and paging DCI may jointly indicate UE sub-grouping information, especially when number of sub-groups is large and PEI is sequence based.**  **Proposal 5: Sub-grouping indication by TRS-based PEI can be achieved as follows:**   * + **Subgroups in a PO can be indicated by a set of TRS sequences indicating the subgroups with one selected sequence transmitting in one TRS resource**   **Proposal 6: Signalling design for UE sub-grouping can be postponed until after PEI signal/channel design is confirmed.** |
| Panasonic | **Proposal 1: To firstly agree on functionalities of PEI and the number of bits supported by PEI, before agreeing on PDCCH, SSS or TRS/CSI-RS based design. If 5 or more bits are supported by PEI, where PEI is located close to SSB instead of each PO, PDCCH-based design should be taken. Otherwise, sequence based design should be taken.**  **Proposal 2: Behv-A should be supported. If PEI is sent other than PDCCH region like sequence based design, Behv-B also should be selectively supported for the protection of URLLC.**  **Proposal 3: When UE is certain about the SIB configuration of PEI, if UE does not detect PEI, UE is not required to continue monitoring paging PDCCH in the PO after PEI.**  **Proposal 4: When UE is not certain about the SIB configuration of PEI, e.g. during SI modification period or before obtaining SIB configuration related to PEI and/or TRS/CSI-RS for time/frequency tracking availability status, UE should continue monitoring paging PDCCH in the PO after PEI.**  **Proposal 5: Sub-grouping information can also be carried in the paging DCI. When PEI is configured, more refined sub-grouping indication is achieved. When PEI is not configured, just sub-grouping indication within paging DCI can also serve the function.** |
| Apple | **Proposal 1: Use PDCCH to carry paging early indication.**  **Proposal 2: Adopt Behv-A, i.e.,**   1. **PEI indicates UE should monitor a PO if UE’s group/subgroup is paged.** 2. **UE is not required to monitor a PO if UE does not detect PEI at all PEI occasion(s) for the PO.**   **Proposal 3: Support of separate PO configurations for legacy UEs and new UEs.** |
| IDC | Observation 1: The MDR of TRS and 2-symbol SSS are close to each other and about 1 dB better than PDCCH with AL8.  Observation 2: PDCCH with AL4 cannot meet the agreed joint MDR requirement.  Observation 3: Sequence-based PEI offers similar or lower resource overhead than PDCCH-based PEI.  **Proposal 1: Sequence-based paging early indication is adopted for UE power saving in Rel-17.** |
| DoCoMo | *Observation 1: If UE needs to monitor PO for SI change and/or ETWS in the case of configuring PEI, it causes additional UE power consumption.*  *Observation 2: Availability indication of TRS/CSI-RS for idle/inactive mode UE to acquire ACG and synchronization can be informed by DCI-based PEI.*  *Observation 3: DCI-based PEI that can notify a lot of information is desirable for subgroups.*  *Observation 4: The power saving gain can be obtained at any grouping rate by combining PEI with subgroup indication and/or TRS/CSI-RS indication.*  *Observation 5: There are some restrictions in SSS-based PEI to avoid to impact legacy UE.*  ***Proposal 1:*** ***It should be considered that ETWS and SI update is indicated via PEI.***  ***Proposal 2: Not only Behv-A but also Behv-B should be supported, which should be configured by the NW.***  ***Proposal 3: DCI-based PEI should be supported.***  ***Proposal 4: The following candidates can be considered as the information notified by PEI:***   * ***Whether or not UE wakes up at PO*** * ***Subgroup Information*** * ***Availability of TRS/CSI-RS for idle/inactive mode*** * ***legacy indication (ETWS, SI update)*** |
| Xiaomi | *Observation 1:* *DCI-based PEI and sequence-based PEI has similar power saving gain when the two forms of PEI have similar relative locations to the target PO.*  *Observation 2:* *Compared to sequence-based PEI, DCI-based PEI can carry more information such as subgrouping indication/ TRS/CSI-RS for idle UE indication/ paging type.*  *Observation 3:* *DCI-based PEI can reuse legacy DCI format and PDCCH search space/CORESET configuration while sequence-based PEI needs extra specification design.*  *Observation 4: DCI-based PEI can adjust its coverage flexibly by shifting AL while sequence-based PEI can hardly do.*  *Observation 5: Sequence-based PEI, especially TRS/CSI-RS, can easily encounter resource conflicting issue with legacy channels/signals.*  *Observation 6: SSS-based PEI may be mistaken as SSS for cell identification/synchronization by legacy UEs.*  ***Proposal 1: DCI-based PEI is preferred and can be carried in paging search space. For target UE group A’s PO for paging, its PEI can be located in another UE group B’s PO which is earlier in time domain.***  ***Proposal 2: Sub-grouping methods by 1) reserved bits in legacy paging DCI and 2) DCI-based PEI should be further studied.*** |
| Ericsson | Observation 1 A DCI-based PEI, compared to the sequence-based, can conveniently carry more information, is future extendable, brings configurable contents, has lower standardization effort.  Observation 2 A DCI-based PEI, compared to the sequence-based, has less impact on UE and the NW both in terms of power, complexity, and consumed resources when multiple groups are addressed simultaneously and/or including various information elements.  Observation 3 In multi-beam deployments for which PEI needs to be swept in multiple occasions, a single symbol PDCCH based PEI is more efficient both in terms of UE/NW power consumption and system resource utilization than multi-symbol TRS/SSS based PEI.  Observation 4 Dynamic resource reservation through “Rate matching indicator” in DCI is an optional UE capability and can therefore not be assumed for legacy UEs.  Observation 5 Reserved (semi-)static resources used for sequenced-based PEI for the sake of potential PEI transmission locks up resources even though no paging occurs. Furthermore, these reserved resources cannot be communicated to UEs in idle/inactive mode and would therefore limit the occasions used for broadcast transmission.  Observation 6 Use of reserved bits in paging DCI (as a PDCCH-PEI) in one PO as paging early indication for UEs in one or more groups in other POs can further reduce PEI signaling overhead.  Observation 7 As PEI is only monitored in RRC Idle/inactive states where only fallback DCI is used, a DCI based PEI does not impact DCI size budget of up to 4 for a cell.  Observation 8 PEI transmissions should not be restricted to be in conjunction/adjacent to other transmission.  Observation 9 Irrespective of an average assumed group paging rate, during periods of extensive paging load, the PEI transmissions lead to unacceptable blockage of control channel especially in multi-beam deployments where PEI needs to be swept.  Observation 10 A one-to-many mapping scheme between a PEI and multiple POs can provide multiplexing gain and reduce system overhead compared to a one-to-one mapping scheme.  Observation 11 Irrespective of PEI format, from the UE power consumption perspective, at average 10% paging rate, the UE can at 90% of the time in idle mode immediately go back to deep sleep after PEI decoding regardless of PEI location with respect to PO.  **Proposal 1 In deployments of high paging rate, in order to avoid excessive false paging during simultaneous paging of more than one sub-group, PEI supports addressing individual sub-group invocation (i.e. 8 bits, one per each of 8 subgroups in a PO).**  **Proposal 2 In deployments of high paging rate, where one-to-many PEI configuration is a necessary tool for the NW for avoiding excessive resource waste, PEI supports addressing sub-groups of at least up to 4 POs (i.e. in addition to the 8 bits used for sub-groups).**  **Proposal 3 In order to not waste bits unnecessarily in deployments where low paging rate is expected (few sub-groups/one-to-one configured), the sub-group/PO addressing bits shall be configurable (both number of bits and their meaning).**  **Proposal 4 Physical layer design for PEI is based on PDCCH DCI.**  **Proposal 5 In order to facilitate flexible content in PEI, the number of information bits conveyed by PEI is configurable between 1 and a maximum value PEImax (FFS on PEImax).**  **Proposal 6 For the PEI DCI, the RNTI used for CRC masking is configured via higher layers.**  **Proposal 7 PEI design supports associating one PEI DCI with multiple POs and/or paging groups.**  **Proposal 8 PEI design supports higher-layer configuration of UE behavior wrt PEI detection/absence of PEI, i.e. whether UE follows Behv-A or Behv-B.**  **Proposal 9 RAN1 to discuss UE behavior w.r.t. PO PDCCH monitoring (e.g. to acquire ETWS/SI updates) even when UE determines that PEI indicates no paging in corresponding PO.**  **Proposal 10 Search space for PEI PDCCH monitoring can be configured separately from or can be same as one of the existing search spaces configured for PDCCH monitoring in Idle/inactive.**  **Proposal 11 PO-specific configuration of the PEI includes an offset from PO ranging at least up to 3 SSBs prior to PO and includes a window of PEI monitoring occasions during which the UE searches for PEI.**  **Proposal 12 PEI design should allow the use of reserved bits in paging DCI in one PO as paging early indication for UEs in one or more groups in other POs.** |
| Nokia | **Observation:** *DCI-based EPI consistently provides the highest energy saving potential for low/medium/high SINR UEs as compared to SSS- and TRS-based EPI.*  **Proposal:** **It is suggested to capture these results to the power saving result summary.**  **Observation:** *It is not possible to apply dynamic resource sharing with TRS based PEI and CORESET#0 in symbols occupied by any SS set associated to CORESET#0.*  **Observation:** *PDCCH-based EPI multiplexing with Connected Mode UEs is most straight forward, while with different mechanisms multiplexing of TRS-EPI and SSS-EPI with Connected mode UEs can be achieved, it is not as straight forward.*  **Observation:** *In TRS- and SSS-based EPI design sufficient sequence space would need to be reserved to avoid collisions between neighbouring cells. In asynchronous deployments, frequency domain and sequence domain would need to be used ensure the orthogonality.*  **Observation:** *PDCCH based EPI offers the best flexibility in terms of information payload support, enabling option to support multiple POs with one PEI, L1 availability indication, with easy forward compatibility for future extensions.*  **Observation:** *In terms of specification RAN1 effort different EPI designs are somewhat comparable, while PDCCH based design would be most straight forward.*  **Observation:** *For TRS-EPI and SSS-EPI some receiver changes may be needed, depending on the final EPI design. Use of TRS-EPI for time/frequency synchronisation for paging reception or in general would not be feasible in all cases and in all behaviours*.  **Observation:** *For TRS-EPI there would be a need for new performance requirements for missed detection. For SSS-EPI new requirements maybe needed as current cell detection requirements cover joint detection of PSS and SSS. For PDCCH-EPI existing requirements can be re-used, similarly as for paging.*  **Proposal:** **Base the EPI design on PDCCH/DCI.**  **Observation:** *Behv-A should be assumed as a baseline operation for EPI.*  **Proposal: Enable support of both Behv-A and Behv-B based on network configuration. Details would be for RAN2.**  **Proposal:** **Network flexibility to choose in which cells/beams paging is sent, should be maintained and applied also to EPI.**  **Proposal:** **Network should be able to configure the EPI to only sub-set of SSB/‘broadcast’ beams.**  **Proposal: A single EPI should be able to address multiple POs to reduce EPI (PDCCH) indication overhead.**  **Proposal: The monitoring occasions defined for PDCCH-EPI are defined by search space configuration. The paging search space (‘*pagingSearchSpace*’) configuration could be re-used for EPI.**  **Proposal: Define the reference location for EPI monitoring, EPI frame (EPI-F), based on offset to PF. Offset could be defined in radio frames.**  **Proposal: Define a PO specific offset (EPI-O) in relation to EPI monitoring reference location (EPI-F). Offset could be defined in symbols.**  **Proposal: Determine the valid PDCCH-EPI monitoring occasions from the search space configuration (e.g. ‘*pagingSearchSpace*’) based on monitoring occasion timing indicated by EPI-F and EPI-O and number of actually transmitted SSBs.**  **Proposal: To enable/disable broadcast beam specific PEI, bit map could be used to indicate the SSBs to which the EPI is active.**  **Proposal: The PDCCH-PEI configuration needs to provide for each PO the location of the sub-grouping field. The size of the sub-grouping field could be common for all EPIs in the cell.**  **Proposal: The TRS occasion availability indication in PDCCH-EPI can be configured in cell specific manner, providing the location and size of the information field.**  **Observation:** *Consider further whether EPI would carry systemInfoModification or etwsAndCmasIndication bit.* |
|  |  |

1. Agreements Related to PEI Comparison

* Identified physical-layer configurations with minimum impact to paging PDSCH performance:

Agreement:

**Observation 2a:**

For the evaluation and comparison of PEI candidate designs, the following summarize the identified configurations of PEI candidate designs, including pairs of the minimum required resource and maximum UE (sub)group indication capacity per PEI, that can comply with the mandatory performance metrics agreed in RAN1 #104-e:

* If Behv-A is assumed,

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Paging Setting | PEI candidate design | Physical-layer configuration and resource | UE (sub)group indication capcity | Number of companies providing performance results |
| PDSCH: MCS0, TB scaling 1.0 PDCCH: AL8, 41-bit payload | PDCCH-based PEI | AL4 PDCCH with 12-bit payload, occupying 288 REs | 12 bits | 5  (HW/HiSi, OPPO, ZTE, CATT, MTK) |
| AL8 PDCCH with 12-bit payload, occupying 576 REs | 12 bits | 7  (Xiaomi, Intel, QC, Samsung, IDCC, Ericsson, vivo) |
| AL8 PDCCH with 41-bit payload, occupies 576 REs | 41 bits | 1 (CATT) |
| SSS-based PEI | 1-symbol SSS, occupying 132 REs  (11 RB x 1 symbol) | 3 bits | 1 (IDCC) |
| 2-symbol SSS, occupying 264 REs  (11 RB x 2 symbols) | 1 bit | 6  (HW/HiSi, vivo, ZTE, CATT, QC, Samsung) |
| 3 bits | 1 (IDCC) |
| 3-symbol SSS, occupying 396 REs  (11 RB x 3 symbols) | 4 bits | 1 (MTK) |
| TRS/CSI-RS-based PEI | 1-slot 24-RB TRS, occupying 144 REs (24 RB x 3 REs per RB x 2 symbols) | ≥ 8 bits | 1 (Intel) |
| 1-slot 28-RB TRS, occupying 168 REs (28 RB x 3 REs per RB x 2 symbols) | 1 bit | 1 (HW/HiSi) |
| 1-slot 36-RB TRS, occupying 216 REs (36 RB x 3 REs per RB x 2 symbols) | 1 bit | 1 (Samsung) |
| 1-slot 48-RB TRS, occupying 288 REs (48 RB x 3 REs per RB x 2 symbols) | 1 bit | 3  (vivo,  ZTE, Ericsson) |
| 6 bits | 1 (CATT) |
| 1-slot 50-RB TRS, occupying 300 REs (50 RB x 3 REs per RB x 2 symbols) | 1 bit | 2  (OPPO, QC) |
| 4 bits | 1 (MTK) |
|  | | | | |
| PDSCH: MCS0, TB scaling 0.5; PDCCH: AL16, 41-bit payload | PDCCH-based PEI | AL8 PDCCH with 12-bit payload, occupying 576 REs | 12 bits | 4  (OPPO, ZTE, MTK, Intel) |
| SSS-based PEI | 3-symbol SSS, occupying 396 REs  (11 RB x 3 symbols) | 4 bits | 1 (MTK) |
| TRS/CSI-RS-based PEI | 1-slot 24-RB TRS, occupying 144 REs (24 RB x 3 REs per RB x 2 symbols) | 3 bits | 1 (Intel) |
| 1-slot 36-RB TRS, occupying 216 REs (36 RB x 3 REs per RB x 2 symbols) | 8 bits | 1 (Intel) |
| 1-slot 50-RB TRS, occupying 300 REs (50 RB x 3 REs per RB x 2 symbols) | 1 bit | 1 (OPPO) |
| 4 bits | 1 (MTK) |

* If Behv-B is assumed,

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Paging Setting | PEI candidate design | Physical-layer configuration | UE (sub)group indication capcity | Number of companies providing performance results |
| PDSCH: MCS0, TB scaling 1.0 PDCCH: AL8, 41-bit payload | PDCCH-based PEI | AL4 PDCCH with 12-bit payload, occupying 288 REs | 12 bits | 4  (HW/HiSi, OPPO, ZTE, MTK) |
| AL8 PDCCH with 12-bit payload, occupying 576 REs | 12 bits | 2  (vivo, Samsung) |
| SSS-based PEI | 2-symbol SSS, occupying 264 REs  (11 RB x 2 symbols) | 1 bit | 3  (HW/HiSi, vivo, ZTE) |
| 3-symbol SSS, occupying 396 REs  (11 RB x 3 symbols) | 1 bit | 1 (MTK) |
| TRS/CSI-RS-based PEI | 1-slot 28-RB TRS, occupying 168 REs (28 RB x 3 REs per RB x 2 symbols) | 1 bit | 1 (HW/HiSi) |
| 1-slot 48-RB TRS, occupying 288 REs (48 RB x 3 REs per RB x 2 symbols) | 1 bit | 2 (vivo, ZTE) |
| 6 bits | 1 (CATT) |
| 1-slot 50-RB TRS, occupying 300 REs (50 RB x 3 REs per RB x 2 symbols) | 1 bit | 1 (OPPO) |
| 2 bits | 1 (MTK) |
|  | | | | |
| PDSCH: MCS0, TB scaling 0.5 PDCCH: AL16, 41-bit payload | PDCCH-based PEI | AL8 PDCCH with 12-bit payload, occupying 576 REs | 12 bits | 3  (OPPO, ZTE, MTK) |
| SSS-based PEI | 3-symbol SSS, occupying 396 REs  (11 RB x 3 symbols) | 1 bit | 1 (MTK) |
| TRS/CSI-RS-based PEI | 1-slot 50-RB TRS, occupying 300 REs (50 RB x 3 REs per RB x 2 symbols) | 1 bit | 1 (OPPO) |
| 2 bits | 1 (MTK) |

* Coexistence and resource sharing with Rel-15 UEs:

Agreement:

**Observation 1a:**

For the evaluation and comparison of PEI candidate designs, the following observations for coexistence with legacy PDSCH are identified:

1. For coexistence with legacy PDSCH, semi-static resouce sharing by configuring RB-symbol-level or RE-level rate-matching patterns covering PEI REs is supported for all PEI candidate designs.
2. For coexistence with legacy PDSCH, dynamic resource sharing can be realized for all PEI candidates if PDSCH is scheduled by DCI format 1\_1
   * For PDCCH based PEI, CORESET-level rate matching can be realized for the PDSCH as per mandatory capability
   * For SSS-based PEI, CORESET-level rate matching may be realized for the PDSCH as per mandatory capability, depending on the design of SSS-based PEI and UE capability regarding number of supported CORESETs
   * For TRS/CSI-RS based PEI, RE-level rate matching can be realized for the PDSCH as per mandatory capability
   * When PDSCH is not scheduled by DCI format 1\_1, it is up to gNB implementation whether and how PEI is transmitted in PDSCH resource

Agreement:

**Observation:**

Dynamically sharing PDCCH resource***s*** of Rel-15 UEs (whether or not this is an important aspect to consider for PEI is FFS)

* + For PDCCH-based PEI,
    - PEI can dynamically share resources with PDCCH for Rel-15 UEs within a PDCCH CORESET at granularity of one or more candidates
      * Exact number of multiplexed/impacted Rel-15 PDCCH candidates depends on AL used for PDCCH-based PEI and relative size of PDCCH CORESET, etc.
  + For SSS-based PEI and for the case of partial overlap of CORESET and PEI
    - For interleaved CORESET (such as CORESET#0), SSS-based PEI can dynamically share resources with PDCCH for Rel-15 UEs only at CORESET-level granularity
    - For non-interleaved CORESET, SSS-based PEI can dynamically share resources with PDCCH for Rel-15 UEs within a PDCCH CORESET at granularity of one or more candidates
      * Exact number of impacted Rel-15 PDCCH candidates depends on relative size and location of PDCCH CORESET, etc.
  + For TRS/CSI-RS-based PEI and for the case of partial overlap of CORESET and PEI
    - For interleaved CORESET (such as CORESET#0), TRS/CSI-RS-based PEI can dynamically share resources with PDCCH for Rel-15 UEs only at CORESET-level granularity
    - For non-interleaved CORESET, TRS/CSI-RS-based can dynamically share resources with PDCCH for Rel-15 UEs within a PDCCH CORESETat candidate level granularity
    - Exact number of impacted Rel-15 PDCCH candidates depends on CSI-RS mapping pattern, relative size and location of PDCCH CORESET, etc.)
* Average resource overhead per PO and the corresponding conditions:

Agreement:

**Observation 3a**:

For the evaluation and comparison of PEI candidate designs, the following summarize average resource overheads per PO for PEI candidate designs, considering the configurations identified from performance observation.

* ~~The average overhead results are based on PO settings without impact from UE sub-grouping indication within the PO.~~
* Note: For comparison purpose, single-beam transmission for PEI is assumed, and results with multi-beam transmission for PEI is scaled. This doesn’t preclude any beam-forming related design for PEI.
* If Behv-A is assumed:

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Paging Setting | PEI candidate design | | Physical-layer configuration and resource | UE (sub)group indication capacity | Number of companies providing performance results | | Average resource overhead per PO (REs) | | | | PO and PEI related assumptions | Resource sharing assumption |
| PDSCH: MCS0, TB scaling 1.0 PDCCH: AL8, 41-bit payload | PDCCH-based PEI | | AL4 PDCCH with 12-bit payload, occupying 288 REs | 12 bits | 5  (HW/HiSi, OPPO, ZTE, CATT, MTK) | | 17.2 | | OPPO | | 1 PEI for up to 12 PO's | PEI is transmitted as a Rel-15 PDCCH in a CORESET when a UE group is paged |
| 17.2 | | ZTE | | 1 PEI for up to 12 PO's |
| 17.6 | | HW/HiSi | | 1 PEI for up to 12 PO's |
| 21.8 | | MTK | | 1 PEI for up to 12 PO's; averaged all PO settings for 1.28-sec cycle |
| 28.8 | | CATT | | 1 PEI for 1 PO | Dynamic rate-matching in PDSCH |
| 288.0 | | CATT | | 1 PEI for 1 PO | Semi-static rate-matching in PDSCH |
| AL8 PDCCH with 12-bit payload, occupying 576 REs | 12 bits | 7  (Xiaomi, Intel, QC, Samsung, IDCC, Ericsson, vivo) | | 49.5 | | vivo | | 1 PEI for 4 PO | PEI is transmitted as a Rel-15 PDCCH in a CORESET when a UE group is paged |
| 57.6 | | vivo | | 1 PEI for 1 PO |
| 57.6 | | QC | | 1 PEI for 1 PO |
| 57.6 | | Samsung | | 1 PEI for 1 PO;  PEI RE# scaled w.r.t. 1-beam |
| AL8 PDCCH with 41-bit payload, occupies 576 REs | 41 bits | 1 (CATT) | | 57.6 | | CATT | | 1 PEI for 1 PO | Dynamic rate-matching in PDSCH |
| 576.0 | | CATT | | 1 PEI for 1 PO | Semi-static rate-matching in PDSCH |
| SSS-based PEI | | 1-symbol SSS, occupying 132 REs  (11 RB x 2 symbols) | 3 bits | 1 (IDCC) | |  | |  | |  |  |
| 2-symbol SSS, occupying 264 REs  (11 RB x 2 symbols) | 1 bit | 6  (HW/HiSi, vivo, ZTE, CATT, QC, Samsung) | | 25.4 | | Samsung | | 1 PEI for 1 PO;  PEI RE# scaled w.r.t. 1-beam | Dynamic rate-matching in PDSCH |
| 25.4 | | vivo | | 1 PEI for 1 PO |
| 26.4 | | ZTE | | 1 PEI for 1 PO |
| 28.8 | | CATT | | 1 PEI for 1 PO |
| 28.8 | | QC | | 1 PEI for 1 PO |
| 254.0 | | HW/HiSi | | 1 PEI for 1 PO | Semi-static rate-matching in PDSCH |
| 264.0 | | ZTE | | 1 PEI for 1 PO |
| 288.0 | | QC | | 1 PEI for 1 PO |
| 3 bits | 1 (IDCC) | |  | |  | |  |  |
| 3-symbol SSS, occupying 396 REs  (11 RB x 3 symbols) | 4 bits | 1 (MTK) | | 34.0 | | MTK | | 1 PEI for up to 4 PO's; averaged all PO settings for 1.28-sec cycle | Dynamic rate-matching in PDSCH |
| 437.0 | | MTK | | 1 PEI for up to 4 PO's; averaged all PO settings for 1.28-sec cycle; RB-symbol rate-matching pattern period up to 40 ms | Semi-static rate-matching in PDSCH |
| TRS/CSI-RS-based PEI | | 1-slot 24-RB TRS, occupying 144 REs (24 RB x 3 REs per RB x 2 symbols) | ≥ 8 bits | 1 (Intel) | | 14.4 | | Intel | | 1 PEI for 1 PO | Dynamic rate-matching in PDSCH |
| 1-slot 28-RB TRS, occupying 168 REs (28 RB x 3 REs per RB x 2 symbols) | 1 bit | 1 (HW/HiSi) | | 123.4 | | HW/HiSi | | 1 PEI for 1 PO | Dynamic rate-matching in PDSCH |
| 168.0 | | HW/HiSi | | 1 PEI for 1 PO | Semi-static rate-matching in PDSCH |
| 1-slot 36-RB TRS, occupying 216 REs (36 RB x 3 REs per RB x 2 symbols) | 1 bit | 1 (Samsung) | | 21.6 | | Samsung | | 1 PEI for 1 PO;  PEI RE# scaled w.r.t. 1-beam | Dynamic rate-matching in PDSCH |
| 1-slot 48-RB TRS, occupying 288 REs (48 RB x 3 REs per RB x 2 symbols) | 1 bit | 3  (vivo,  ZTE, Ericsson) | | 28.8 | | vivo | | 1 PEI for 1 PO | Dynamic rate-matching in PDSCH |
| 28.8 | | ZTE | | 1 PEI for 1 PO |
| 1-slot 48-RB TRS, occupying 288 REs (48 RB x 3 REs per RB x 2 symbols) | 6 bits | 1 (CATT) | | 28.8 | | CATT | | 1 PEI for 1 PO | Dynamic rate-matching in PDSCH |
| 288.0 | | CATT | | 1 PEI for 1 PO | Semi-static rate-matching in PDSCH |
| 1-slot 50-RB TRS, occupying 300 REs (50 RB x 3 REs per RB x 2 symbols) | 1 bit | 2  (OPPO, QC) | | 30.0 | | OPPO | | 1 PEI for 1 PO | Dynamic rate-matching in PDSCH |
| 30.0 | | QC | | 1 PEI for 1 PO |
| 300.0 | | QC | | 1 PEI for 1 PO | Semi-static rate-matching in PDSCH |
| 4 bits | 1 (MTK) | | 26.0 | | MTK | | 1 PEI for up to 4 PO's | Dynamic rate-matching in PDSCH |
|  | | | | | | | | | | | | |
| PDSCH: MCS0, TB scaling 0.5; PDCCH: AL16, 41-bit payload | PDCCH-based PEI | AL8 PDCCH with 12-bit payload, occupying 576 REs | | 12 bits | | 4  (OPPO, ZTE, MTK, Intel) | 34.4 | OPPO | | 1 PEI for up to 12 PO's | | PEI is transmitted as a Rel-15 PDCCH in a CORESET when a UE group is paged |
| 43.6 | MTK | | 1 PEI for up to 12 PO's; averaged all PO settings for 1.28-sec cycle | |
| 57.6 | Intel | | 1 PEI for 1 PO | | PEI is transmitted as a Rel-15 PDCCH in a CORESET when a UE group is paged |
| SSS-based PEI | 3-symbol SSS, occupying 396 REs  (11 RB x 3 symbols) | | 4 bits | | 1 (MTK) | 34.0 | MTK | | 1 PEI for up to 4 PO's; averaged all PO settings for 1.28-sec cycle | | Dynamic rate-matching in PDSCH |
| 437.0 | MTK | | 1 PEI for up to 4 PO's; averaged all PO settings for 1.28-sec cycle; RB-symbol rate-matching pattern period up to 40 ms | | Semi-static rate-matching in PDSCH |
| TRS/CSI-RS-based PEI | 1-slot 24-RB TRS, occupying 144 REs (24 RB x 3 REs per RB x 2 symbols) | | 3 bits | | 1 (Intel) | 14.4 | Intel | | 1 PEI for 1 PO | | Dynamic rate-matching in PDSCH |
| 1-slot 36-RB TRS, occupying 216 REs (36 RB x 3 REs per RB x 2 symbols) | | 8 bits | | 1 (Intel) | 21.6 | Intel | | 1 PEI for 1 PO | | Dynamic rate-matching in PDSCH |
| 1-slot 50-RB TRS, occupying 300 REs (50 RB x 3 REs per RB x 2 symbols) | | 1 bit | | 1 (OPPO) | 30.0 | OPPO | | 1 PEI for 1 PO | | Dynamic rate-matching in PDSCH |
| 4 bits | | 1 (MTK) | 26.0 | MTK | | 1 PEI for up to 4 PO's; averaged all PO settings for 1.28-sec cycle | | Dynamic rate-matching in PDSCH |

* If Behv-B is assumed:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Paging Setting | PEI candidate design | Physical-layer configuration | UE (sub)group indication capacity | Number of companies providing performance results | Average resource overhead per PO (REs) | | PO and PEI related assumptions | Coexistence assumption |
| PDSCH: MCS0, TB scaling 1.0 PDCCH: AL8, 41-bit payload | PDCCH-based PEI | AL4 PDCCH with 12-bit payload, occupying 288 REs | 12 bits | 4  (HW/HiSi, OPPO, ZTE, MTK) | 24.0 | HW/HiSi | 1 PEI for up to 12 PO's | PEI is ALWAYS transmitted as a Rel-15 PDCCH in a CORESET |
| 24.0 | OPPO | 1 PEI for up to 12 PO's |
| 24.0 | ZTE | 1 PEI for up to 12 PO's |
| 51.0 | MTK | 1 PEI for up to 12 PO's; averaged all PO settings for 1.28-sec cycle |
| AL8 PDCCH with 12-bit payload, occupying 576 REs | 12 bits | 2  (vivo, Samsung) | 518.4 | vivo | 1 PEI for 1 PO | PEI is ALWAYS transmitted as a Rel-15 PDCCH in a CORESET |
| 518.4 | Samsung | 1 PEI for 1 PO; PEI RE# scaled w.r.t. 1-beam |
| SSS-based PEI | 2-symbol SSS, occupying 264 REs  (11 RB x 2 symbols) | 1 bit | 3  (HW/HiSi, vivo, ZTE) | 228.6 | vivo | 1 PEI for 1 PO | Dynamic rate-matching in PDSCH |
| 228.6 | ZTE | 1 PEI for 1 PO |
| 254.0 | HW/HiSi | 1 PEI for 1 PO | Semi-static rate-matching in PDSCH |
| 264.0 | ZTE | 1 PEI for 1 PO |
| 3-symbol SSS, occupying 396 REs  (11 RB x 3 symbols) | 1 bit | 1 (MTK) | 561.0 | MTK | 1 PEI for 1 PO; average over all PO settings for 1.28-sec cycle; RB-symbol rate-matching pattern period up to 40 ms | Semi-static rate-matching in PDSCH |
| TRS/CSI-RS-based PEI | 1-slot 28-RB TRS, occupying 168 REs (28 RB x 3 REs per RB x 2 symbols) | 1 bit | 1 (HW/HiSi) | 168.0 | HW/HiSi | 1 PEI for 1 PO | Semi-static rate-matching in PDSCH |
| 1-slot 48-RB TRS, occupying 288 REs (48 RB x 3 REs per RB x 2 symbols) | 1 bit | 2  (vivo, ZTE) | 259.2 | ZTE | 1 PEI for 1 PO | Dynamic rate-matching in PDSCH |
| 259.2 | vivo | 1 PEI for 1 PO |
| 6 bits | 1 (CATT) | 288.0 | CATT | 1 PEI for 1 PO | Semi-static rate-matching in PDSCH |
| 1-slot 50-RB TRS, occupying 300 REs (50 RB x 3 REs per RB x 2 symbols) | 1 bit | 1 (OPPO) | 279.0 | OPPO | 1 PEI for 1 PO | Semi-static rate-matching in PDSCH |
| 2 bits | 1 (MTK) | 150.0 | MTK | 1 PEI for 2 PO's | Semi-static rate-matching in PDSCH |
|  | | | | | | | | |
| PDSCH: MCS0, TB scaling 0.5 PDCCH: AL16, 41-bit payload | PDCCH-based PEI | AL8 PDCCH with 12-bit payload, occupying 576 REs | 12 bits | 3  (OPPO, ZTE, MTK) | 48.0 | OPPO | 1 PEI for up to 12 POs | PEI is ALWAYS transmitted as a Rel-15 PDCCH in a CORESET |
| 102.0 | MTK | 1 PEI for up to 12 POs |
| SSS-based PEI | 3-symbol SSS, occupying 396 REs  (11 RB x 3 symbols) | 1 bit | 1 (MTK) | 561.0 | MTK | 1 PEI for 1 PO;  RB-symbol rate-matching pattern period up to 40 ms | Semi-static rate-matching in PDSCH |
| TRS/CSI-RS-based PEI | 1-slot 50-RB TRS, occupying 300 REs (50 RB x 3 REs per RB x 2 symbols) | 1 bit | 1 (OPPO) | 270.0 | OPPO | 1 PEI for 1 PO | Semi-static rate-matching in PDSCH |
| 2 bits | 1 (MTK) | 150.0 | MTK | 1 PEI for 2 PO's | Semi-static rate-matching in PDSCH |

* Subgroups indication requirement and design:

Agreement:

For UE subgroups indication in physical layer, maximum of 8 subgroups per PO is supported.

Agreement:

For paging indication to the subgroups in a PO,

* For PDCCH-based PEI, subgroups in a PO are indicated by one PEI
  + One bit in the DCI payload indicating one UE subgroup is supported
    - FFS: Whether code-point based mapping is utilized, and, if so, how to map to the subgroups in a PO
* For SSS-based PEI, subgroups in a PO are indicated by a set of sequence realizations
  + FFS: Sequence mapping design for supporting up to 8 subgroups per PO
  + Physical-layer configuration(s) and sequence generation design are subject to no impact to initial access and RRM measurements of legacy UEs
* For TRS/CSI-RS-based PEI, subgroups in a PO can be indicated by the following alternatives
  + Alt 1: One TRS sequence with orthogonal cover as PEI transmitted in the PEI monitoring occasion where one orthogonal cover of the PEI indicates one subgroup or combination of subgroups
    - FFS: Design details for the orthogonal cover
  + Alt 2: A set of TRS sequences indicating the subgroups with one selected sequence transmitting in one TRS resource
    - FFS: Sequence mapping design for supporting up to 8 subgroups per PO and combination of subgroups
  + Alt 3: Multiple TRS/CSI-RS resources FDMed/TDMed /CDMed in the same monitoring occasion where one TRS/CSI-RS resource indicates one subgroup
    - Reuse Rel-15/16 CSI-RS FDM/TDM/CDM patterns for supporting up to 8 subgroups per PO
* Note : It is RAN1 understanding that Physical-layer configuration(s) for paging early indication to the subgroups is subject to the same idle-mode reception bandwidth as CORESET-0 frequency span
* UE power saving gains:

Agreement

Observation:

For the comparison of PEI candidate designs, the following table summarizes average power saving gains based on companies contributions:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| UE subgroups in a PO | PEI candidate type (PDCCH, SSS, TRS/CSI-RS) | #SS burst(s) before PO in Rel-16 baseline | PO paging rate | **Power Saving Gain** | Company | Assumed #SS burst(s) before PEI | Assumed #SS burst(s) between PEI and PO when UE is paged |
| 1 | PDCCH | 1 | 10% | **8.95%** | Samsung | 1 | 0 |
| 10% | **11.09%** | QC | 1 | 0 |
| 10% | **14.8%** | MTK | 1 | 0 |
| 10% | **15.7%** | ZTE | 1 | 0 |
| 10% | **~~[~~16.32%~~]~~** | Intel | 1 | ~~[~~1~~]~~ |
| 40%-60% | **6.2% - 9.8%** | ZTE | 1 | 0 |
| 2 | 10% | **2.16%** | Samsung | **2** | 0 |
| 10% | **5.0%** | QC | 1 | 1 |
| 10% | **15.60%** | Intel | **2** | 0 |
| 10% | **15.64%** | Samsung | 1 | 1 |
| 10% | **19.5%** | MTK | 1 | 1 |
| 10% | **22.5%** | ZTE | 1 | 1 |
| 10% | **~~[24.938%]~~26.14%** | Intel | 1 | 1 |
| 40%-60% | **9.3% - 14.4%** | ZTE | 1 | 1 |
| 3 | 10% | **1.88%** | Samsung | **3** | 0 |
| 10% | **5.83%** | CATT | **3** | 0 |
| 10% | **13.92%** | Intel | **3** | 0 |
| 10% | **15.7%** | QC | 1 | 2 |
| 10% | **25.5%** | MTK | 1 | 2 |
| 10% | **25.33%** | Samsung | 1 | 2 |
| 10% | **26.3%** | Apple | 1 | 2 |
| 10% | **29.6%** | DoCoMo | 1 | 2 |
| 10% | **31.4%** | ZTE | 1 | 2 |
| 10% | **33% - 37%** | Ericsson | 1 | 2 |
| 10% | **~~[31.75%]~~32.82%** | Intel | 1 | 2 |
| 40%-60% | **12.5%** | DoCoMo | 1 | 2 |
| 40%-60% | **13.2% - 20.3%** | ZTE | 1 | 2 |
| SSS or TRS/CSI-RS (same results) | 1 | 10% | **11.09%** | QC | 1 | 0 |
| 10% | **14.8%** | MTK | 1 | 0 |
| 10% | **15.4%** | Samsung | 1 | 0 |
| 10% | **15.7%** | ZTE | 1 | 0 |
| 10% | **17.67%** | Intel | 1 | 0 |
| 40%-60% | **6.2% - 9.8%** | ZTE | 1 | 0 |
| 2 | 10% | **5.0%** | QC | 1 | 0 |
| 10% | **6.3%** | QC | **0** | 1 |
| 10% | **20.49%** | Samsung | 1 | 0 |
| 10% | **20.7%** | MTK | 1 | 0 |
| 10% | **22.5%** | ZTE | 1 | 0 |
| 10% | **27.33%** | Intel | 1 | 0 |
| 40%-60% | **9.3% - 14.4%** | ZTE | 1 | 0 |
| 3 | 10% | **15.7%** | QC | 1 | 0 |
| 10% | **17.8%** | QC | **0** | 1 |
| 10% | **26.6%** | MTK | 1 | 1 |
| 10% | **27.9%** | Apple | 1 | 0 |
| 10% | **30.19%** | CATT | 1 | 0 |
| 10% | **30.84%** | Samsung | 1 | 0 |
| 10% | **31.4%** | ZTE | 1 | 2 |
| 10% | **34.96%** | Intel | 1 | 0 |
| 40%-60% | **13.2% - 20.3%** | ZTE | 1 | 2 |
| 8 | PDCCH | 1 | 10% | **11.31%** | Samsung | 1 | 0 |
| 10% | **11.9%** | CMCC | 1 | 0 |
| 10% | **12.5%** | QC | 1 | 0 |
| 10% | **18.0%** | MTK | 1 | 0 |
| 20%-35% | **11.89%** | Samsung | 1 | 0 |
| 20%-35% | **12.04%** | CMCC | 1 | 0 |
| 20%-35% | **18.40%** | MTK | 1 | 0 |
| 40%-60% | **19.20% - 20.00%** | MTK | 1 | 0 |
| 2 | 10% | **6.3%** | QC | 1 | 1 |
| 10% | **20.36% - 31.70%** | HW | 1 | 1 |
| 10% | **22.40%** | MTK | 1 | 1 |
| 10% | **25.40%** | ZTE | 1 | 1 |
| 20%-35% | **22.50%** | MTK | 1 | 1 |
| 20%-35% | **20.71% - 31.95%** | HW | 1 | 1 |
| 40%-60% | **20.73% - 31.64%** | HW | 1 | 1 |
| 40%-60% | **22.80% - 23.20%** | MTK | 1 | 1 |
| 40%-60% | **25.40% - 25.70%** | ZTE | 1 | 1 |
| 3 | 10% | **17.9%** | QC | 1 | 2 |
| 10% | **22.65%** | CMCC | 1 | 2 |
| 10% | **28.70%** | MTK | 1 | 2 |
| 10% | **30.65% - 42.19%** | HW | 1 | 2 |
| 10% | **35.1%** | ZTE | 1 | 2 |
| 20%-35% | **23.08%** | CMCC | 1 | 2 |
| 20%-35% | **28.80%** | MTK | 1 | 2 |
| 20%-35% | **30.72% - 42.12%** | HW | 1 | 2 |
| 40%-60% | **29.00% - 29.10%** | MTK | 1 | 2 |
| 40%-60% | **29.42% - 42.11%** | HW | 1 | 2 |
| 40%-60% | **33.6% - 34.5%** | ZTE | 1 | 2 |
| SSS | 1 | 10% | **12.5%** | QC | 1 | 0 |
| 10% | **15.80%** | MTK | 1 | 0 |
| 20%-35% | **14.10%** | MTK | 1 | 0 |
| 40%-60% | **7.60% - 10.80%** | MTK | 1 | 0 |
| 2 | 10% | **6.3%** | QC | 1 | 0 |
| 10% | **7.7%** | QC | **0** | 1 |
| 10% | **18.53%- 28.90%** | HW | 1 | 1 |
| 10% | **21.40%** | MTK | 1 | 0 |
| 10% | **23.50% - 25.40%** | ZTE | 1 | 0 |
| 20%-35% | **16.98% - 26.18%** | HW | 1 | 1 |
| 20%-35% | **20.60%** | MTK | 1 | 0 |
| 40%-60% | **10.70% - 20.77%** | HW | 1 | 1 |
| 40%-60% | **15.00% - 25.70%** | ZTE | 1 | 0 |
| 40%-60% | **17.50% - 19.00%** | MTK | 1 | 0 |
| 3 | 10% | **17.9%** | QC | 1 | 0 |
| 10% | **20.2%** | QC | **0** | 1 |
| 10% | **27.20%** | MTK | 1 | 1 |
| 10% | **27.69% - 38.11%** | HW | 1 | 2 |
| 10% | **35.1%** | ZTE | 1 | 2 |
| 20%-35% | **25.15% - 34.49%** | HW | 1 | 2 |
| 20%-35% | **25.80%** | MTK | 1 | 1 |
| 40%-60% | **14.30% - 26.7%** | HW | 1 | 2 |
| 40%-60% | **20.30% - 23.00%** | MTK | 1 | 1 |
| 40%-60% | **33.6% - 34.5%** | ZTE | 1 | 2 |
| TRS/CSI-RS | 1 | 10% | **12.5%** | QC | 1 | 0 |
| 10% | **15.80%** | MTK | 1 | 0 |
| 10% | **18.08%** | Samsung | 1 | 0 |
| 20%-35% | **14.10%** | MTK | 1 | 0 |
| 20%-35% | **18.54%** | Samsung | 1 | 0 |
| 40%-60% | **7.60% - 10.80%** | MTK | 1 | 0 |
| 2 | 10% | **6.3%** | QC | 1 | 0 |
| 10% | **7.7%** | QC | **0** | 1 |
| 10% | **19.99% - 30.66%** | HW | 1 | 0 |
| 10% | **21.40%** | MTK | 1 | 0 |
| 10% | **23.50% - 25.40%** | ZTE | 1 | 0 |
| 20%-35% | **19.93% - 29.79%** | HW | 1 | 0 |
| 20%-35% | **20.60%** | MTK | 1 | 0 |
| 40%-60% | **15.00% - 25.70%** | ZTE | 1 | 0 |
| 40%-60% | **17.50% - 19.00%** | MTK | 1 | 0 |
| 40%-60% | **19.34% - 26.11%** | HW | 1 | 0 |
| 3 | 10% | **17.9%** | QC | 1 | 0 |
| 10% | **20.2%** | QC | **0** | 1 |
| 10% | **27.20%** | MTK | 1 | 1 |
| 10% | **29.05% - 39.74%** | HW | 1 | 1 |
| 10% | **31.55%** | CATT | 1 | 0 |
| 10% | **35.1%** | ZTE | 1 | 2 |
| 20%-35% | **25.80%** | MTK | 1 | 1 |
| 20%-35% | **27.72% - 37.54%** | HW | 1 | 1 |
| 40%-60% | **20.30% - 23.00%** | MTK | 1 | 1 |
| 40%-60% | **21.90% - 32.78%** | HW | 1 | 1 |
| 40%-60% | **33.6% - 34.5%** | ZTE | 1 | 2 |

* Conclusion to have final decision:

|  |
| --- |
| **Conclusion:**  To down-select one solution for PEI physical-layer channel/signal in RAN1 #106-e, using below as a starting point:   * PDCCH-based PEI * SSS-based PEI * TRS/CSI-RS-based PEI   Note: Additional details for each of the above 3 solutions are encouraged for more informed down-selection  Note: further refinement of the above list is possible, e.g., by merging/further splitting, depending on significance of the commonality and/or differences |