**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 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:

|  |
| --- |
| **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-selectionNote: 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

|  |  |
| --- | --- |
| 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 |  |
| 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 | $$2^{8-1}=128$$ |
| Code-point | 1000: Wake up all (sub)groups | 2 (e.g. UE belongs to 2nd subgroup) |
| 0000: Wake up only 1st (sub)group0001: 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 |  |
|  |  |

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

|  |  |
| --- | --- |
|  | 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 2-1We 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 2-3It 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.  |
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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 3: 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 |  |
| 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 : 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.  |
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# Remaining Design Details/Issues

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

Table 5: 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.** |
|  |  |

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 6: Companies' comments/suggestions on Proposal 4-1

|  |  |
| --- | --- |
| 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.  |
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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 7: 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 OKP 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.  |
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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 8: 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.  |
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# Decision of PEI Physical-Layer Channel/Signal

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

Table 9: 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 10: 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.
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| 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.
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| 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.  |
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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-selectionNote: 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 11: Companies' suggestion on the final PEI channel/signal and way forward

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| 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 degradationThe 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 PEIThe 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.  |
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# Summary

(To be updated)

# Reference

1. “Draft Report of 3GPP TSG RAN WG1 #105-e v0.2.0”, MCC Support, RAN1 #105-e, online available @ <https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_105-e/Report>
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
6. R1-2106520, “Potential Paging Enhancements”, TCL Communication Ltd.
7. R1-2106521, “Discussion on power saving enhancements for paging”, ZTE, Sanechips
8. R1-2106606, “Paging enhancements for idle/inactive mode UE power saving”, vivo
9. R1-2106708, “Discussion on potential paging enhancements for UE power saving”, Spreadtrum Communications
10. R1-2106775, “Discussion on paging enhancements”, Transsion Holdings
11. R1-2106815, “Paging enhancements for idle/inactive UE power saving”, Sony
12. R1-2106898, “Discussion on paging enhancements”, Samsung
13. R1-2106983, “Paging enhancement for UE power saving”, CATT
14. R1-2106998, “Discussion on paging enhancements with PEI”, Transsion Holdings
15. R1-2107044, “On paging early indication”, Nordic Semiconductor ASA
16. R1-2107182, “Paging enhancement for UE power saving”, Lenovo, Motorola Mobility
17. R1-2107253, “Further discussion on Paging enhancements for power saving”, OPPO
18. R1-2107356, “Paging enhancements for idle/inactive UE power saving”, Qualcomm Incorporated
19. R1-2107414, “Discussion on paging early indication design”, CMCC
20. R1-2107453, “Discussion on potential paging enhancements”, LG Electronics
21. R1-2107519, “Design of Paging Early Indication for Idle-Mode UE Power Saving”, MediaTek Inc.
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

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|  | 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

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|  | **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) |

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| 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 hasMean < 0.15 ppmSTD < ~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 UEsObservation 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 designsFigure 5: Performance of non-coherent sequence detection over PDCCH PEI under different CFOProposal 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 | $$2^{8-1}=128$$ |
| Code-point | 1000: Wake up all (sub)groups | 2 (e.g. UE belongs to 2nd subgroup) |
| 0000: Wake up only 1st (sub)group0001: 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 RBsObservation 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 1.0PDCCH: 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 1.0PDCCH: 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 0.5PDCCH: 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 1.0PDCCH: 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 1.0PDCCH: 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 0.5PDCCH: 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 |