**3GPP TSG-RAN WG2 Meeting #116 electronic R2-21xxxx**

**Online, 1 - 12 November 2021, 2021**

**Agenda Item: 8.9.3**

**Source: Xiaomi Communications (email discussion rapporteur)**

**Title: Summary of [Post115-e][089][ePowSav] Paging Subgrouping**

**Document for: Discussion and Decision**

# Introduction

This contribution provides a summary of the following email discussion:

* [Post115-e][089][ePowSav] Paging Subgrouping (Xiaomi)

Scope: Objective to continue work based on existing agreements. Further progress the roles of AMF gNB UE and potential impact to stage-2. Take RAN1 agreements into account. Progress how CN subgrouping and UE ID subgrouping relates to L1 and the control of this.

Intended outcome: Report to pave the way for progress

Deadline: Long

Deadline for companies’ inputs:

1st round deadline: initial comments collection, October 14th, 0900 UTC

2nd round deadline: one week for proposal checking and companies can further comment by October 21th, 0900 UTC

# Contact information

|  |  |
| --- | --- |
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# Discussion

## 3.1 General

The motivation of UE paging subgrouping is to reduce power consumption in the UE due to false paging alarms (i.e. when the UE receives a paging message on PDSCH on its paging occasion, which is not intended for that UE). This is done by further dividing the UEs within a paging occasion into multiple subgroups. A UE will decode the Paging message in its Paging occasion only if it is received an indication that its subgroup is being paged.

In the previous RAN2 #115e meeting, the following agreements were made [1] and a LS [2] was sent to other TWG.

|  |
| --- |
| * When AMF has assigned a UE with a Paging subgroup, some NAS signaling should be supported between AMF and UE to convey the related information to the UE. Exact information is FFS. The design and procedure are up to SA2/CT1. * When AMF has assigned a UE with a Paging subgroup, some signaling should be supported between AMF and gNB(s) to inform gNB(s) about the related subgroup information for paging a UE in RRC\_IDLE/RRC\_INACTIVE. Exact information is FFS. The message(s) and associated design are up to RAN3. * It is FFS when a UE in RRC\_INACTIVE has been assigned by CN a Paging subgroup, whether some signaling should be introduced between gNBs to inform each other about the UE’s subgroup for RAN paging. * If RAN2 agrees to support UE assistance information to CN in support of Paging subgroup assignment, RAN2 will focus on the paging probability and power profile attributes. * UEID-based subgroup method requires, in addition to the already available information for legacy UEID-based grouping in PO, the total number of supported UEID-based subgroups by the network. * At least for UEID-based subgroup method the total number, Nsg, of supported subgroups by the network is decided by RAN and broadcasted in System Information. * At least for UEID-based subgroup method the total number, Nsg, of supported subgroups is controlled on a cell basis and can be different in different cells. * We go with Option 1 (CN assigns subgroup ID) * R2 assumes that All the cells within the registration area supports the same number of CN assigned subgroups, i.e. no remapping of CN assigned group ID to RAN subgroup ID (will revisit only if serious issues are found). * For the purpose of continued discussions, R2 assumes that UE has separate UE caps for CN assigned and UEID based subgrouping, the actual decision to be taken later. * RAN capability is known based on broadcast information. FFS with explicit indication or implicitly based configuration. |

RAN1 is discussing the design of Lay1 subgrouping indication and the following agreements were made in the previous RAN1 #105e-106e meetings [3]:

|  |
| --- |
| RAN1 #105e meeting  Agreement :  For UE subgroups indication in physical layer, maximum of 8 subgroups per PO is supported.  **Conclusion:**  To down-select one solution for PEI physical-layer channel/signal in RAN1 #106-e, using below as a starting point:   * PDCCH-based PEI * SSS-based PEI * TRS/CSI-RS-based PEI   Note: Additional details for each of the above 3 solutions are encouraged for more informed down-selection  Note: further refinement of the above list is possible, e.g., by merging/further splitting, depending on significance of the commonality and/or differences  RAN1 #106e meeting  Conclusion:  To down-select one solution for PEI physical-layer channel/signal in RAN1 #106-e,   * PDCCH-based PEI * SSS-based PEI   Proposed Working Assumption   * PDCCH-based PEI   Supported by 20 companies, but can not be accepted by 3 companies, i.e., Intel, CATT, Sony. |

RAN plenary discussed the design of Lay1 subgrouping indication and RAN3 is now included in the WID [23]:

|  |
| --- |
| conclusion:  Issue 1 (How to proceed PEI in Rel-17):  Support PDCCH-based PEI as the only option  - Only essential function for PEI is support  • New DCI format  • Higher layer configuration, including SS  • Details of the procedures of PEI monitoring, and identification of MOs before PO  • Only Behv-A (per RAN1#104e agreement) is supported  • If TRS availability indication is agreed to be supported in both paging DCI and the DCI format for PEI, same mechanism/principle for TRS availability indication is adopted for the two DCI formats  • Supporting TRS availability indication in DCI format for PEI shall not delay the completion of essential functionality of PEI    Issue 2 (Whether or how to involve RAN3 for supporting paging sub-grouping):  revised WID RP-212619 was at first approved and later revised in RP-212630    Issue 3 (Whether or what to modify the Status report RP-212307):  SR is updated to RP-212612 to reflect  - RAN decision on PEI (see Issue 1 above)  - Core part completion level of 65%  - To capture RAN2 request to RAN3 from R2-2108917 as open issues for RAN3 |

## 3.2 On the roles of AMF/gNB/UE

For CN-assigned subgrouping, we have agreed the option1 last meeting as illustrated in the following figure [5] which has the following characteristics:

* CN assigns subgroup ID to UE and indicates to gNB when the UE is paged
* gNB and the UE apply the assigned subgroup ID
* gNB broadcast subgroup configuration (e.g. number of total subgroups)
* If specific subgrouping information is not provided from CN, UE ID based subgrouping may be used
* possible with or without remapping to RAN subgroup ID depends on the sub-options



Figure 1: message sequence chart for option 1

To help people have a clear view and to help the discussion step by step, the rapporteur divides it into 3 parts.

3.2.1 is mainly focusing on RAN capability for CN-assigned subgrouping. It is possible that RAN can only support CN-assigned subgrouping.

3.2.2 is mainly focus on RAN capability for UE-ID based subgrouping. It is possible that RAN can only support UE-ID based subgrouping.

3.2.3 is discussing about co-existing of both.

### 3.2.1 CN-assigned subgrouping

The first question is how gNB informs the UE that it supports CN-assigned subgrouping. According to [5], all the companies agree RAN capability could be known based on broadcast information. And we need to further discuss whether explicit indication or implicitly based configuration will be used. In LTE, presence of additional information related to group based WUS configuration is used as the indication for NW capability. I.e., whether NW supports paging probability based grouping is based on the presence of relevant resource mapping for this paging probability information and WUS group on Uu interface. If we take the same principle as in LTE, a candidate solution would be network capability to support CN assigned subgrouping can be implicitly indicated by presence of CN assigned subgrouping configuration with the details discussed later.

Hence, we have 2 options:

* Option 1: network capability to support CN assigned subgrouping can be implicitly indicated by presence of CN assigned subgrouping configuration (e.g., X number of CN based subgroups by the network);
* Option 2: via an indication in SIB [9][12][15] (e.g., if the X number of CN based subgroups by the network by fixed and specified in Q10, then an indication in SIB is used for RAN supporting )

Q1: Which option do companies prefer out of option 1-2 on RAN capability indication about supporting CN assigned subgrouping?

|  |  |  |
| --- | --- | --- |
| Company | Option1/2 | Comments |
| Ericsson | Option 3: via PEI configuration. | The gNB has to provide the PEI configuration in system information, and the DCI information will indicate if CN grouping is supported or not. The details depend on progress/agreements in RAN1 about the DCI format and the number of bits available to indicate the CN group, and potentially other information carried in the PEI.  PS: we do not see the need to indicate the number of CN subgroups to the UE, but the UE only needs to know which DCI bits of the PEI to monitor to acquire the CN subgroup ID. |
| Samsung | Option 2 | We do not see any need to indicate total number of CN assigned subgroups to UE. In our understanding, PEI will include a bitmap where each bit maps to a paging subgroup identity. UE checks for the bit corresponding to its paging subgroup identity. |
| OPPO | Option 2 | Since we have agreed that RAN2 assumes all the cells within the registration area supports the same number of CN assigned subgroups, the maximum CN assigned subgroup number can be fixed in the spec. So we see no need to indicate the total CN assigned subgroup number. |

As described above, in LTE eNB configures via broadcast the relation between this paging probability information and WUS group on Uu interface. The UE will first choose a “WUS group set” based on paging probability and corresponding thresholds, and then selects its WUS group from the WUS group set based on UE ID as captured in TS 36.304.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| The UE determines the WUS group set corresponding to its probability PNAS, if configured, as defined in Table 7.5.2-1 If PNAS is not configured, UE selects the WUS group set with highest index.  Table 7.5.2-1: WUS group set definition when *probThreshList* is configured   |  |  |  |  | | --- | --- | --- | --- | | WUS group set | probThreshList | WUS group index in WUS groups list | | | Lower bound | Upper bound | | 1 | PNAS ≤ Thresh1 | 0 | Nth1 -1 | | 2 | Thresh1 < PNAS ≤ Thresh2 (Note) | Nth1 | Nth1 + Nth2 -1 | | 3 | Thresh2 < PNAS ≤ Thresh3 (Note) | Nth1 + Nth2 | Nth1 +Nth2 + Nth3 -1 | | 4 | PNAS > Thresh3 | Nth1 +Nth2 + Nth3 | maxWG-1 | | where  Threshi is the value signalled in the ith entry of *probThreshList*  Nthi is the value signalled in the ith entry of *groupsForServiceList*  Note: When the total number of WUS group sets is less than 4, the upper bound for the WUS group set with highest index is maxWG-1. | | | | |

In the following, we needs to consider how to relate the CN assigned subgrouping information to Lay1 subgrouping indication(s) [9][13]. The concept is similar to LTE. Note that the design of Lay1 subgrouping indication itself is not in the scope of the email as RAN1 is still discussing it. A Lay1 subgrouping indication can be a bit or a code point from DCI bit in PEI resource(s) which depends on RAN1 input. And PEI configurations giving Lay1 subgrouping indications will be discussed on more RAN1 inputs.

Option1 is gNB mapping a subgrouping to a Lay1 subgrouping indication while option2 is gNB mapping a subgrouping to multiple Lay1 subgrouping indications while for the later the UEs will still uniformly been distributed into different Lay1 radio resources based on UE\_ID as in LTE. The benefits of it is that if the number of UE in the same paging group is very large, the second level group as UE-ID based is applied. The drawback is that UE has to perform extra step of hashing to determine its subgroup assignment.

Table 1: Mapping subgroup(s) to a Lay1 subgrouping indication (Option1)

|  |  |
| --- | --- |
| CN-assigned subgroup | Lay1 subgrouping indication |
| Subgroup0 | PEI subgrouping indication 0 |
| Subgroup1 | PEI subgrouping indication 1 |
| Subgroup2 | PEI subgrouping indication 2 |
| … | … |

Table 2: Mapping subgroup(s) to multiple Lay1 subgrouping indications (Option2)

|  |  |
| --- | --- |
| CN-assigned subgroup | Lay1 subgrouping indications |
| Subgroup0 | PEI subgrouping indication 0  PEI subgrouping indication 1 |
| Subgroup1 | PEI subgrouping indication 2  PEI subgrouping indication 3  PEI subgrouping indication 4 |
| … | … |

People did not like UE to perform extra step of hashing so the 2-step way in LTE is excluded in last meeting. Rapporteur think it is good to confirm that we will not pursue this when considering how gNB configures the mapping between subgrouping information to Lay1 subgrouping indication(s) on Uu interface.

Q2: Companies are invited to confirm that a subgroup can only be mapped to a Lay1 subgrouping indication rather than multiple Lay1 subgrouping indications on Uu interface?

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Ericsson | Not option 2, and wait for RAN1 progress | What is a "Lay1 subgrouping indication"? Bit or codepoint, or…? If there is no hashing, it is not clear how the UE determines which "PEI subgrouping indication" to use? We think this is unclear and therefore it is also difficult to really answer this question.  We cannot discuss and agree how the CN subgroup ID (integer 0..7) should be encoded into the PEI DCI bits for the CN grouping, because we do not know how many bits are available, and whether bits/codepoints are used, and whether 1-to-N mapping of PEI to Pos is included/excluded, and whether the encoding depends on configuration in system information. We think RAN2 should wait for RAN1 progress.  Option 2: in case many UEs are assigned to a certain CN subgroup, the CN can allocate those type/category of UEs to another CN subgroup, i.e. distribute the UEs over two CN subgroups. We do not think the RAN is needed for this and this can be left to CN implementation. |
| Samsung | Yes | However, we do not see any need to explicit signal mapping between subgroup and PEI subgrouping indication by gNB.  Paging subgroup IDs can be sequentially mapped to PEI subgrouping indications in DCI. |
| OPPO | Yes | From RAN2 point of view, 2-step grouping method has been excluded, so we don’t need to discuss option 2.  Option 1 is a straightforward way for mapping, we can take it as baseline. The details should be up to RAN1 design, e.g., the number of available bits for subgrouping indication in PEI, whether to use bitmap or codepoint, etc. |

It was agreed that the number of CN assigned subgroups should be the same across the registration area, with a possible interpretation that there will not be any remapping of CN assigned subgroup ID to RAN subgroup ID or Lay1 subgrouping indication, interpretation which can be revisited “if serious issues are found”. On the other hand, it was also agreed that “**at least** for UEID-based subgroup method the total number, Nsg, of supported subgroups is controlled on a cell basis and can be different in different cells”. Considering some gNB can only support limited subgroups for a PO (e.g., the DCI bit in PEI will be used for other futures or the DCI bits in a PEI would be potentially shared by multiple POs. More RAN1 input is needed), it is seems reasonable gNB can map several CN assigned subgroups to the same Lay1 subgrouping indication where the network can allow subgroupings of similar paging probability range to share WUS resources for efficiency. In other words, the above “at least” could be extended to both UEID-based and CN-assigned subgroups. The rapporteur wants to ask companies whether it is feasible for RAN to support the same number of CN assigned subgroups across gNBs with different Lay1 resources in each cell, without remapping. An example of N to 1 mapping based on option1 in Q2 is illustrated in the following table.

Table 3: Mapping subgroups to a Lay1 subgrouping indication (N to 1 mapping)

|  |  |
| --- | --- |
| CN-assigned subgroup | Lay1 subgrouping indication |
| Subgroup0  Subgroup1 | PEI subgrouping indication 0 |
| … | … |

Hence we have 2 options

* Option1: Yes
* Option2: Not needed.
* Option3: whether N to 1 mapping is needed depends on RAN1 outcome?

Q3: Which option do companies prefer out of option 1-3 regarding to whether different subgroups can be mapped to the same Lay1 subgrouping indication(s) on Uu interface?

|  |  |  |
| --- | --- | --- |
| Company | Option1/2/3 | Comments |
| Ericsson | Option 3 | Wait for RAN1 progress.  In our view we should not re-discuss the remapping of the CN assigned subgroup ID to RAN subgroup IE (option 3). This was discussed several times in different proposals, and there was a SoH in last meeting where it was agreed that RAN2 assumes that the RAN nodes in the registration area support the number of CN groups. This assumptions will only be revisited if serious issues are found.  RAN plenary agreed that only DCI based PEI will be used, which compared to sequency based PEI can support more groups. RAN1 agreed to need 8 subgroups and we do not expect any serious issues that would require remapping in RAN.  Anyways, we think that RAN2 should wait for RAN1 progress on the number of bits for CN groups in PEI. After that RAN2 can discuss if there is a problem to support 8 groups. But we think it is currently a waste of time to discuss if companies prefer remapping one more time. |
| Samsung | Option 2 | Support, one to one mapping between paging subgrouping and paging early indication. Why to create more paging groups than the number of paging early indications? |
| OPPO |  | This question is similar as Question 2, we don’t need to re-discuss it. |

### 3.2.2 UE-ID based subgrouping

Same as for CN-assigned subgrouping, we first check how gNB informs the UE that it supports UEID-based subgrouping. As we have agreed “UEID-based subgroup method requires, in addition to the already available information for legacy UEID-based grouping in PO, the total number of supported UEID-based subgroups by the network”, the candidate solution could be the implicit way.

Hence, we have 2 options:

* Option 1: network capability to support UEID-based subgrouping can be implicitly indicated by presence of the total number of supported UEID-based subgroups by the network;
* Option 2: via an indication in SIB [15]

Q4: Which option do companies prefer out of option 1-2 on network capability indication about supporting UE-ID based subgrouping?

|  |  |  |
| --- | --- | --- |
| Company | Option1/2 | Comments |
| Ericsson | Option 1 |  |
| Samsung | Option 1 |  |
| OPPO | Option 1 |  |

In LTE, if the relation between the paging probability information and Lay1 WUS group(s) on UU interface is not broadcasted but the Lay1 WUS groups, UE will assumes that all the Lay1 WUS groups are available and select its Lay1 WUS group from all the Lay1 WUS groups based on UE ID as captured in TS 36.304:

|  |
| --- |
| If *probThreshList* is not present in *gwus-Config*, there is only one WUS group set containing all the WUS groups configured in *numGroupsList*. The total number of WUS groups is maxWG.  After selection of the WUS group set as specified in clause 7.5.2, the UE selects the WUS group to monitor as below.  For BL UE or UE in enhanced coverage, the UE determines wg with following equation:  For NB-IoT, the UE determines wg with following equation:  where:  UE\_ID, N, Ns, Nn and Ware definedin clause7.1.  Nw is the number of WUS groups in the selected WUS group set.  wg is the index of the WUS group in the selected WUS group set, determined as defined in clause 7.5.2, 0 .. Nw-1. |

Hence rapporteur think it is also possible for RAN to implement UE-ID only by configuring all the subgroup for UE-ID based subgrouping, i.e., no subgroup used for CN assigned subgrouping means all the RAN configured subgroups will be used by UE-ID assigned subgrouping.

Q5: Do companies agree that RAN may configure all subgroups for UE-ID based subgrouping?

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Ericsson | Yes, RAN may configure the UE to use UE-ID based subgrouping, also when the UE has a CN group ID assigned. | We are not sure if we fully understood the question, i.e. not sure why there is a reference to the LTE solution? Furthermore, what are "Lay1 WUS groups"? RAN2 agreed to exclude option 2 "CN assigns a set of subgroup IDs".  But if we read Q5 literally we understand that only UE-ID based subgroups are used, i.e. the gNB can configure the UE to use UE-ID based grouping (even when a CN group ID is assigned).  Rapp:  Yes, the purpose is to confirm whether RAN can configure only to support UE-ID based subgrouping. LTE’s case is to illustrate that all the L1 resource can be for UE’s modular operation if no configuration for CN. |
| Samsung | - | In our understanding if total number of paging subgroups for UE ID based subgrouping is P, paging subgroup identities of paging subgroups are 0 to P-1. |
| OPPO | Yes | It is up to RAN implementation. |

### 3.2.3 Co-exist of CN-assigned subgrouping and UE-ID subgrouping

#### 3.2.3.1 UE’s behavior

To make things simple, Q6 is based on UE has capability for subgrouping and UE’s capability in detail will be discussed in Q7.

The network can broadcast it support CN assigned subgrouping and/or UE-ID based subgrouping. UE needs to determine which scheme it will use based on UE identity or paging subgroup assigned by CN. [6][9][11]gives views on UE’s behaviour under various configurations and [6] gives nice tables to clarify this and rapporteur would like to quote here by categoried in 2 cases.

Case1: If UE has a CN-assigned subgroup ID

If UE has a CN-assigned subgroup ID and the camped cell supports CN-assigned subgroup, UE will performs paging indication monitoring based on CN-assigned subgrouping. However, if the camped cell only supports UE ID based subgrouping, UE will use UE ID based subgrouping. If the camped cell does not, UE needs to fallback to legacy paging.

Table 4: UE has a CN-assigned subgroup ID (case1)

|  |  |  |  |
| --- | --- | --- | --- |
| Paging subgroup assigned to UE by CN | RAN supports CN assigned paging subgroups | RAN supports UE ID based subgrouping | Paging indication monitoring based on paging subgroup assigned by CN or based on UE ID |
| Yes | Yes | Yes | CN assigned |
| Yes | No | Yes | UE ID based |
| Yes | Yes | No\* | CN assigned |
| Yes | No | No | No sub grouping |

\*: The validity of the configuration will be further discussed in 3.2.3.

Case2: If UE has not a CN-assigned subgroup ID

UE definitely cannot use CN-assigned subgrouping no matter the network supports it or not. If the camped cell supports UE-ID based subgrouping, UE will performs paging indication monitoring based on UE-Id based subgrouping. If the camped cell does not, UE needs to fallback to legacy paging.

Table 5: UE has not a CN-assigned subgroup ID (case2)

|  |  |  |  |
| --- | --- | --- | --- |
| Paging subgroup assigned to UE by CN | RAN supports CN assigned paging subgroups | RAN supports UE ID based subgrouping | Paging indication monitoring based on paging subgroup assigned by CN or based on UE ID |
| No | Yes | Yes | UE ID based |
| No | No | Yes | UE ID based |
| No | Yes | No\* | No sub grouping |
| No | No | No | No sub grouping |

\*: The validity of the configuration will be further discussed in 3.2.3.

Hence, we propose:

**Proposal: If UE has paging subgroup ID assigned by CN and camped cell supports CN-assigned subgroup:**

* + - **UE will performs paging indication monitoring based on CN-assigned subgrouping**

**Else if camped cell supports UE-ID based subgrouping:**

* + - **UE performs paging indication monitoring based on UE-ID based subgrouping.**

Q6: Do companies agree UE’s behaviour in the above proposal? If not, a modification is most welcomed.

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Ericsson | Modification | We think the use case that the CN supports subgrouping, but does not assign an ID to the UE does not exist. Why would the CN do like that? The CN can always assign the UE to a "default" group when it does not have UE specific information for grouping.  Furthermore the simultaneous use of both CN and UE-ID based grouping creates problems to "share" or "divide" PEI bits, which has its disadvantages.  We think it is beneficial to have these two possible deployment scenarios:   1. Enhanced but more complex/costly: CN assigns a subgroup based on UE characteristics (and UE-ID based grouping is not used). 2. Simple but it might do the trick: Random RAN assignment based on UE-ID (no impact on CN/NAS).   We would like to ask for the support of option 2, i.e. UE-ID based grouping over-writes the CN group, if assigned. |
| Samsung | Yes |  |
| OPPO | Yes |  |

In [5], people have different views on whether we should pursue common capability for subgroup or separate capability for CN assigned and UE-ID based subgrouping among CN, UE and gNB. Opponents of separate capabilities think this will lead more complicated cases for subgrouping while proponents think separate capabilities facilities implementation in different layers (NAS vs AS) and RAN2 should not mandate UE to signal only one capability for features in two different functional units.

So rapporteur suggest companies to re-consider this question. If UE gets the CN assigned subgroup ID, it implies that UE can support the CN-assigned subgrouping. gNB only needs to know UE’s capability for UE-ID based subgrouping if it only supports it. For the case UE has not got the CN assigned subgroup ID, gNB only needs to know whether UE support for UE-ID subgrouping or not. If not, the UE would be paged in the legacy way. As analysed above, the rapporteur thinks that a candidate solution is that RAN only needs to care about UE’s capability of supporting the UE ID based subgrouping. RAN can get this capability for UE-ID by paging message from CN while CN can get this capability by NAS reporting from UE or via UE capability transfer procedure from gNB. In the meanwhile, UE’s capability of supporting the CN-assigned subgrouping is reported to CN by NAS signalling.

However if both are combined together as a single UE capability (I.e., only one UE capability reported to CN), which means that if the UE gets CN paging subgrouping ID, gNB will know UE supports both and the benefits of paging subgrouping can be maximum since paging subgrouping can always be used no matter which method is supported in a cell [22]. It seems leads less capability judgment in gNB. However, if the UE has not got a CN paging subgrouping ID, the gNB anyway needs to know UE’s capability for subgrouping.

The rapporteur thinks both way can work. Hence, we have 2 options:

* Option 1: introduce common UE capability for UE ID based subgrouping and network-assigned subgrouping in CN and RAN (i.e., only one UE capability reported to RAN or CN by NAS);
* Option 2: introduce separate UE capabilities for UE ID based subgrouping and network-assigned subgrouping;
* Option 2a: RAN only needs to care about UE’s capability of supporting the UE ID based subgrouping (UE’s capability of supporting the UE ID based subgrouping is reported to RAN by AS UE capability signalling) while UE’s capability of supporting the CN-assigned subgrouping is handled in NAS (UE’s capability of supporting the CN-assigned subgrouping is reported to CN by NAS signalling).
* Option2b: both capabilities are reported to CN by NAS signalling and CN forwards both to RAN in paging message( indicates UE’s subgroup or whether UE supports UE-ID based subgrouping);
* Option2c: one of the 2 capabilities is supported by default. E.g., UE supports only UE ID based subgrouping, or supports both, or supports neither [22];

Q7: Which option do companies prefer out of option 1-2 described above for UE capability?

|  |  |  |
| --- | --- | --- |
| Company | Option1/2 | Comments |
| Ericsson | Option 2 when RAN UE-ID can over-write CN group ID, otherwise option 1. | Q7 is a mixture of optionality discussion and the need for capability signalling for an optional feature. In our understanding:   * Subgrouping grouping should be optional for the UE * Explicit NAS capability signalling is required for CN grouping:   + CN grouping capability is implicitly indicated in PAGING message from CN to RAN when CN group ID is included. * In case it is agreed that the RAN UE-ID can over-write the CN group ID, i.e. the NW can deploy grouping using either CN assigned group ID or RAN assigned UE-ID, it makes sense to have two separate UE capabilities for this as well. But if the UE-ID method is used as a fallback when the CN does not assign a group ID, then there should be a common/single capability.   In case of option 2, it is beneficial for the RAN to know if the UE that is paged supports UE-ID based subgrouping. If the UE does not support UE based subgrouping the subgroup can be omitted from the PEI. The same of course applies to the CN group ID. |
| Samsung | Option 1 | Option 1 seems simpler. |
| OPPO | Option 2a | We think UE ID based subgrouping should be an AS capability while network-assigned subgrouping should be a NAS capability, we prefer to introduce separate UE capabilities, which would be more flexible for UE implementation. |

#### 3.2.3.2 gNB’s behavior

The network can broadcast its support for CN assigned subgrouping and/or UE-ID based subgrouping. The rapporteur would like to invite people to anlysis whether the following cases are all valid and how to achieve them.

* Case1: RAN support UE-ID based subgrouping only;
* Case2: RAN support CN assigned subgrouping only;
* Case3: Both CN assigned subgrouping and UE-ID based subgrouping are supported in RAN (Both subgrouping methods can co-exist in a cell)
* Case4: Neither CN assigned subgrouping nor UE-ID based subgrouping is supported in RAN;

As we have agreed UE-ID based subgrouping is the baseline for UE not having a CN-assigned subgroup, to begin with, the rapporteur would like to quote TR23.501 below for people to understand better why CN will not assign a subgroup,:

|  |
| --- |
| To support the Wake Up Signal (WUS), the WUS Assistance Information is used by the ng-eNB to help determine the WUS group used when paging the UE (see TS 36.300 [30]).  The content of the WUS Assistance Information consists of the paging probability information. The paging probability information provides a metric on the probability of a UE receiving a paging message based on, e.g. statistical information.  The UE may in the Registration Request message provide its capability to support receiving WUS Assistance Information. If WUS Assistance Information is supported by the UE, then the UE in the Registration Request message may provide the additional UE paging probability information. The AMF may use the UE provided paging probability, local configuration and/or previous statistical information for the UE, when determining the WUS Assistance Information. If the UE supports WUS Assistance Information, the AMF may assign WUS Assistance Information to the UE, even when the UE has not provided the additional UE paging probability information.  If the AMF has determined WUS Assistance Information for the UE, the AMF provides it to the UE in every Registration Accept message. The AMF stores the WUS Assistance Information parameter in the MM context and provides it to the ng-eNB when paging the UE.  UE and AMF shall not signal WUS Assistance Information in Registration Request, Registration Accept messages when the UE has an active emergency PDU session. |

As captured in TR23.501, if the UE does not supports WUS Assistance Information, the AMF may not assign WUS assistance Information to the UE and UE and AMF shall not signal WUS assistance Information in Registration Request, Registration Accept messages when the UE has an active emergency PDU session. For such cases, UE will be assigned to the WUS group set corresponding to the highest probability in LTE which is very reasonable, i.e., CN assignment and UE-ID based can share the same subgroups. In this way, CN assigned subgrouping configuration can be used by both types. In [5], the proponent think in NR we can reuse this as a simplest approach and hard split would lead to inefficient use of the bits with less subgroups while the opponents think hard split is required to mitigate false alarm among the two grouping schemes.

Hence, we have some options for subgroups splitting in RAN for UEs in the cell with CN assignment and UE-ID based:

* Option 1: The subgrouping configuration used by CN assigned subgrouping is also used for UE ID based subgrouping; (overlap case)

e.g., if multiple Lay1 subgrouping indications mapped to a subgroup, UE-ID based grouping is anyway needed for deriving the exact Lay1 subgrouping indications (as described in 3.2.1);

e.g., the last RAN configured subgroup for CN assigned subgrouping is used by UE for UE-ID based subgrouping as in LTE show below (For such case, RAN broadcasting only one total number of subgroup for CN assigned subgrouping means RAN supports both);



Figure 2: an example of overlapped case (the last subgroup is overlapped)

e.g., some subgroups for CN assigned subgrouping can be used by UE for UE-ID based subgrouping [19];



Figure 3: an example of overlapped case (some subgroups are overlapped)

* Option 2: The subgrouping configuration used by CN assigned subgrouping cannot be used for UE ID based subgrouping; (non-overlap case)

e.g., there should be two separate sets of subgroups at the same time, e.g., X (>=0) number of CN based subgroups and Y (>=0) number of UE-ID based subgroups (with only one Lay1 subgrouping indication would be allocated to a subgroup where there will be no need for UE-ID based grouping.) [7]



Figure 4: an example of non-overlapped case

e.g., there should be only one set of subgroup at the same time, e.g., all bits/subgroups are either used for CN assigned subgrouping or for UE-ID based subgrouping;

* Option 3: Left to gNB implementation whether to allow overlapping or not [8][19];

Q8: Which option do companies prefer out of option 1-3 described above for subgroups splitting in RAN?

|  |  |  |
| --- | --- | --- |
| Company | Option1/2/3 | Comments |
| Ericsson | None | We think that CN and UE-ID grouping should not be used simultaneous in the cell, because this leads to the question whether the precious DCI grouping bits should be shared or divided. Both sharing and dividing the bits have disadvantages and these disadvantages are avoided when either CN or UE-ID grouping is used in the cell.  When bits are shared this implies that multiple groups are triggered at the same time, when perhaps only one of the groups is paged. When bits are divided, this leads to an in-efficient use of the bits, and the PEI size is increased and the power saving gains of the PEI are decreased.  Rapp:  I think your concern has been captured in the second example of option2. |
| Samsung | None | Agree with Ericsson |
| OPPO | Option 2 | The subgroups for CN assigned subgrouping and UE id based subgrouping should not be overlapped to avoid false alarm among the two grouping schemes. |

For option1, since the subgroups configured can be used for both CN assigned subgrouping and UE ID based subgrouping, it also implies both types are supported in RAN (UE-ID based is anyway supported thus case3 below is invalid). For option2, since separate subgroups configured can be used for CN assigned subgrouping and UE ID based subgrouping individually, it also implies either type is supported by the presence the associated subgrouping configuration. The rapporteur summarize in a table and gives some examples on how to achieve.

Table 5: gNB broadcast its support for CN assigned subgrouping and/or UE-ID based subgrouping

|  |  |  |  |
| --- | --- | --- | --- |
| cases | supports CN assigned subgrouping | supports UE-ID based subgrouping | How to achieve that?  (Based on the previous discussion) |
| case1 | Yes | Yes | Both CN-assigned subgrouping and UE-ID based subgrouping configuration is present (whether the configuration is the number of group or a flag is discussed in 3.2.1 and 3.2.2)  e.g., overlap case as option1 in Q8 described;  e.g., Network broadcast each type of configurations as option2 in Q8 described; |
| case2 | No | Yes | Only UE-ID based subgrouping configuration is present  e.g., no subgroup used for CN assigned subgrouping as described in Q5 |
| case3 | Yes | No | Only CN-assigned subgrouping configuration is present.  However, if option1 is agreed, case3 is invalid. |
| case4 | No | No | Neither CN-assigned subgrouping nor UE-ID based subgrouping configuration is present  e.g., No PEI configurations are broadcasted. |

Q9: Companies are asked to give comments on which cases the RAN should support (companies can select multiple and companies are welcomed to gives comments on how it is achieved)?

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Company | 1 | 2 | 3 | 4 | Comments |
| Ericsson | No | Yes | Yes | Yes | We think that simultaneous use of CN and UE-ID based grouping has disadvantageous, and we think that the following two deployment options should be supported:   1. Enhanced but more complex/costly: CN assigns a subgroup based on UE characteristics. 2. Simple but it might do the trick: Random RAN assignment based on UE-ID (no impact on CN/NAS).   Perhaps the whether the UE-ID configuration in RAN over-writes or is only used as fallback can be made configurable, if both options need to be supported. |
| Samsung | No | Yes | Yes | Yes |  |
| OPPO | Yes | Yes | Yes | Yes |  |

## 3.3 issues related to other WG

This session relates to issues related to other WG. The rapporteur believes it is worthy to discuss this as the chairman has made the guideline that we can outline what information we expect need to be exchanged while the details are up to other WG. LS can be considered if necessary.

### 3.3.1 Assistant information to between CN/gNB/UE

We have agreed that all the cells within the registration area should support the same number of CN-assigned subgroups in order not to have mapping rules from CN subgroup ID to RAN subgroup ID if the ID from CN is larger than RAN. We discuss whether this “no-remapping” interpretation should be revisited in Section 3.2.1, Q3. Assuming no remapping, the rapporteur think we need to discuss how to ensure that all the cells within the registration area do configure the same number of CN-assigned subgroups:

* Option 1: The total number of CN-assigned subgroups is fixed and specified [13]
* Option 2: The total number of CN-assigned subgroups is decided by CN and informed to RAN [13]
* Option 3: gNB(s) to provide assistance to CN for CN paging subgroup configuration within the RA [10];
* Option 4: No need to specify, e.g., by OAM
* Option 5: leave it to SA2/CT1

Q10: Which option do companies prefer out of option 1-5 described above to ensure all the cells within the registration area to support the same number of subgroups for CN assigned subgrouping?

|  |  |  |
| --- | --- | --- |
| Company | Option1-5 | Comments |
| Ericsson | Option 1: for the maximum number of 8 subgroups that can be signalled.  Option 2: for the number of groups that is used for CN grouping, which enables the gNB to configure the appropriate number of bits in PEI.  Option 3 or 4: RAN can provide assistance info to CN for the UE's paging probability in Inactive mode. | RAN1 agreed that the number of subgroups is 8, i.e. the maximum number of subgroups that can be used is 8 in our understanding. This is also sufficient from a power saving gain perspective, i.e. 16 does not add much.  Option 5: RAN2 should discuss and agree on the overall solution, including UE assistance/capability via NAS or RAN assistance info to CN via NGAP, and only leave the implementation of the signalling details to CT1/RAN3. This was also clarified in the updated SR ([RP-212612](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_93e/Docs/RP-212612.zip)). Otherwise there will be parallel discussions on the overall solution in different WGs, leading to possible conflicts. |
| Samsung | - See comments | Maximum number of paging subgroups is fixed in specification.  The number of CN assigned paging subgroups can be decided by CN and informed to RAN, so RAN can configure appropriate number of PEI bits.  Rapp:  Is this option2? |
| OPPO | Option 1 | Option 1 is simple, and we don’t need to introduce signaling for the total number of CN-assigned subgroup. |

For assistant information, apart from total number of subgroups from CN to gNB (if option2 of Q10 is accepted), the rapporteur would like to invite people to discuss whether there should be some assistant information from CN to gNB in support of paging subgroup configuration. [21] points out that in LTE, RAN might want to have more WUS group for the higher paging probability range to reduce paging false alarm. Or the network can configure several adjacent CN assigned subgroups to the same Lay1 subgrouping indication as described in Q3. However unlike in LTE, the gNB does not know the exact meaning of a certain subgroup. A question is whether the CN need to provide some assistance information for gNB to know the subgroup index it assigns will be ranked by a matrix, e.g., paging probability?

Companies are welcomed to bring other some assistance information to gNB(s) in support of paging subgroup configuration to discuss.

Q11: Do you support CN providing some assistance information to gNB(s) in support of paging subgroup configuration besides of Q10? If “Yes”, please indicated which information would be needed from RAN2 perspective?

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Ericsson | No | RAN2 agreed that CN assigns a subgroup ID to the UE (and not RAN), i.e. there is no need for CN assistance information to RAN to enable RAN to assign more WUS groups. Let's stop re-discussing RAN2 agreements. |
| Samsung | No |  |
| OPPO | No | We share the same view as Ericsson. |

In [4], the need for gNB(s) assistance information to CN in support of paging subgroup assignment was discussed. At that time, the framework of subgrouping is not decided, so the issue was not discussed. However, we saw people’s interest in pursuing this in contributions [11][17][18][20]. The motivation of this is that UE may have different paging probabilities in RRC Idle and RRC Inactive, hence gNB may want to update the UE’s subgroup when releasing it into RRC\_INACTIVE while the opponents says subgroup determination should be up to CN implementation.

Note this does not break our previous agreement of using the same subgrouping for CN paging and RAN paging as the CN may assign a new subgroup ID when UE goes to Inactive. Hence it is proposed to re-assess this.

Q12: Do you support gNB(s) providing some assistance information to CN in support of paging subgroup assignment when IDLE UE moves to RRC\_INACTIVE? If “Yes”, please indicated which information would be needed from RAN2 perspective?

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Ericsson | Yes, for inactive paging probability only. | See also our reply to Q10. Perhaps this can also be solved via OAM.  Q12 seems to indicate that the assistance info is provided when IDLE UE moves to RRC\_INACTIVE. In our understanding this assistance information could be provided when the UE leaves CM-CONNECTED mode (e.g. the time UE spend in CM-CONNECTED and the number of times RAN PAGING is used for that UE). |
| Samsung | No | We have agreed to have same paging subgroup in idle and inactive. |
| OPPO | No | Same understanding as Samsung. |

As we have made the working assumption that RAN will focus on the paging probability and power profile attributes if RAN2 agrees to support UE assistance information to CN in support of Paging subgroup. Therefore, it is helpful for UEs to report these attributes to assist network in subgroup assignment. Here comes the question whether the assistance information sent to CN by NAS or UE reports them to gNB by RRC signaling?

* Option 1: The assistance information sent to CN by NAS; LS sent to CT1;
* Option 2: The assistance information sent to RAN by UAI?
* Option 3: leave it to SA2/CT1

Q13: Which option do companies prefer out of option 1-3 described above on UE assistance information to the network?

|  |  |  |
| --- | --- | --- |
| Company | Option1-3 | Comments |
| Ericsson | Not option 2 | Any UE assistance information should be sent to CN, because CN assigns the subgroup ID, i.e. option 2 is excluded. |
| OPPO | None | How to allocate UEs into subgroup is totally up to CN implementation, we see no need for such UE assistance information. |
|  |  |  |

### 3.3.2 RAN paging

In [4] most companies suggest that for a UE in RRC\_INACTIVE, anchor gNB should provide UE’s subgroup ID to serving gNB when it sends paging notification. If this is the common view, this requires, at least from RAN2 perspective, the need for some signaling between gNBs to inform about the UE’s subgroup while [24] has a different view. The reason is that the UE only monitors the PEI in the last used cell, and a gNB that receives a PAGING message over the Xn-interface during paging escalation does not use PEI. The rapporteur wants to ask whether the last used cell can be a non-anchor cell.

Also, one company also brings an issue of gNB interoperability [16], i.e., when the anchor gNB is a non-supporting gNB whether the UE’s paging subgrouping related information is forwarded or not. The rapporteur thinks we can discuss this later after we are clearer.

So the first question is:

Q14: Do companies agree that restricting the PEI monitoring by UE to the last used cell?

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Ericsson | Yes | In LTE WUS is only used in last used cell, see 36.300:  When (G)WUS is used in RRC\_IDLE, the following are applicable:  - The UE monitors (G)WUS only in the last used cell as defined in TS 36.304 [11];  The reason why WUS is only used in the last used cell in LTE, and why PEI should also only be used in last used cell in NR, is that when the CN cannot find the UE in the first paging attempt (e.g. because the UE has moved), the CN may page the UE in the complete registration area [24, [R2-2105736](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2/TSGR2_114-e/Docs/R2-2105736.zip)]. This paging escalation phase may thus cause a lot of paging, because the registration area may consist of many cells. Thus using PEI during paging escalation causes a lot of PEI transmissions, which increases the NW power consumption. Furthermore these PEI transmissions are rather useless, because the "missing" UE will only be found in a single cell of the registration area.  Typically the UE is reached in the first paging attempt, i.e. there is little impact on the UE power saving gains, when PEI is only used in the last use cell. |
| Samsung | No | UE may not be always in the last use cell due to mobility. From UE's power saving perspective, we prefer not have this restriction. |
| OPPO | No | We see no need to introduce such restriction as UEs will not always camp on the last used cell. |

Based on this, we can discuss whether UE’s paging subgrouping related information should be in a forwarded RAN paging message. Hence, we have some options:

* Option 1: When a UE in RRC\_INACTIVE, UE’s paging subgrouping related information should be in a forwarded RAN paging message; the message and associated design are up to RAN3;
* Option 2: When a UE in RRC\_INACTIVE, UE’s paging subgrouping related information should not be in a forwarded RAN paging message; No impact on RAN3.
* Option 3: Left to RAN3

Q15: Which option do companies prefer out of option 1-3 described above on whether UE’s paging subgrouping related information should be in a forwarded RAN paging message?

|  |  |  |
| --- | --- | --- |
| Company | Option1-3 | Comments |
| Ericsson | Option 2 | PEI should not be used during RAN paging escalation. The RNA area can be large, and the unnecessary PEI overhead should be avoided, i.e. similar motivation as for CM-IDLE mode paging. |
| Samsung | Option 1/3 |  |
| OPPO | Option 1 | We think PEI and paging subgrouping can be used in any cell, so when network releases a UE into RRC INACTIVE, UE’s paging subgrouping related information should be forwarded from anchor gNB to non-anchor gNB. |

## 3.4 Other

Q16: Any other relevant issue to discuss (Only limits to paging subgrouping)?

|  |  |
| --- | --- |
| Company | Issue description |
| Ericsson | **Subgrouping without PEI**  Paging subgrouping should also be supported with normal Paging PDCCH and cross-slot scheduling (without PEI). The PEI power saving gains may depend on UE implementation and only apply to UEs is in bad coverage while the UE typically is in good coverage. The power saving gains with subgrouping is perhaps lower compared to PEI, but they are beneficial for all UEs and do not require additional NW transmissions. Furthermore subgrouping might be more simple to implement (e.g. UE-ID random grouping in RAN only).  Rapp:  Should it be discussed in RAN1?  **SIB provides DCI subgroup configuration**  In SIB it can be indicated how many bits in the DCI are used for subgrouping and how the bits are used (e.g. each bit indicates one CN subgroup (and subgroups can be signalled independently), or a CN subgroup is indicated by a codepoint (and there is an "all" subgroup when more then one subgroup needs to be paged in the same PO)). This strategy offers a semi-static flexibility in the DCI configuration, and can adapt to the number of subgroups used by the CN, and given the expected paging load whether bit or codepoints should be used. |
|  |  |
|  |  |

# Conclusions

Based on companies’ inputs to this email discussion, the following proposals are listed for agreement:

# References

1. RAN2 #115-e Meeting minutes
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3. RAN1 #105e-106e meeting minutes
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5. [R2-2109094](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_115-e\Docs\R2-2109094.zip), [AT115-e][043][ePowSav] Paging Subgrouping (Nokia), Nokia
6. [R2-2106998](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_115-e\Docs\R2-2106998.zip) Further details of UE Subgrouping Samsung Electronics Co., Ltd
7. [R2-2107067](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_115-e\Docs\R2-2107067.zip) Discussion on grouping-based paging OPPO discussion
8. [R2-2107068](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_115-e\Docs\R2-2107068.zip) Discussion on UE paging capabilities OPPO
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10. [R2-2107549](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_115-e\Docs\R2-2107549.zip) Further considerations on Network assigned subgrouping Intel Corporation
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14. [R2-2108027](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_115-e\Docs\R2-2108027.zip) Further discussion on paging subgrouping Huawei, HiSilicon
15. [R2-2108237](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_115-e\Docs\R2-2108237.zip) Grouping methods for Paging Ericsson
16. [R2-2108461](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_115-e\Docs\R2-2108461.zip) Handling network nodes not supporting UE paging subgrouping Futurewei Technologies
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22. [R2-2108028](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_115-e\Docs\R2-2108028.zip) Discussion on paging subgrouping supporting on UE and network Huawei, HiSilicon
23. RAN#93e Meeting minutes, RP-212611, RP-212630
24. [R2-2105736](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2//TSGR2_114-e/Docs/R2-2105736.zip) PEI monitoring in NR: CN and System level impacts, Vodafone, Ericsson