3GPP TSG-RAN WG2 Meeting #112-e R2-20xxxxx

Online, 2nd – 13th November 2020

Agenda Item: x.x.x

Source: MediaTek Inc.

**Title: [DRAFT] Report of email discussion [Post111-e][907][ePowSav] UE grouping**

Document for: Discussion and decision

# Introduction

During the RAN2#111-e meeting, RAN2 had online discussions about paging enhancements for UE power saving. Since the UE grouping method is mentioned in the contributions from many companies, RAN2 set up the following email discussion:

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| * [Post111-e][907][ePowSav] UE grouping (Mediatek)

 Scope: UE grouping, put solutions on the table, describe intentions / how they work (high level), and their potential to save power. Possibly take into account R1 evaluation methodology (if they have agreements on the evaluation parameters). Intended outcome: Report Deadline: Long |

In this email discussion, we invite companies to share their views on further details about UE grouping as a paging enhancement method for UE power saving. Moreover, since we received RAN1 LS [1] about the evaluation methodology, the models from RAN1 may be taken into account.

# Discussions

## Paging enhancement with UE grouping

The idea of paging enhancement by UE grouping is to reduce the probability that a UE decodes paging message and realizes that itself is not paged (i.e. the “false alarm” rate), using some kind of sub-group paging indication. Among to the contributions submitted to RAN2#111-e, 14 companies mentioned UE grouping as paging enhancement: Qualcomm [2], vivo [4], Xiaomi [6], Samsung [7], OPPO [8], ZTE [9], CATT [10], SONY [13], MediaTek [14], ITRI [15], CMCC [18], Huawei [19], Lenovo [20], and LG [23]. Therefore, we first discuss whether UE grouping should be considered as a kind of paging enhancement for UE power saving.

**Q1: Should UE grouping be considered as a kind of paging enhancement for UE power saving?**

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| **Company name** | **Yes/No** | **Comments** |
| Ericsson | Depends | It depends how much power saving gains a false paging solution using grouping is going to give, i.e. depends on the outcome of the RAN1 evaluation, whether this enhancement is justified. |
| Qualcomm | Yes | We see UE grouping as one of the key pieces in power saving enhancements for paging procedure. |
| Samsung | Yes | If large number of UEs monitor the same PO, UEs may unnecessarily receive and decode PDSCH which increases UE’s power consumption. PDCCH+PDSCH processing power consumption in L1 is 2.4 times the power consumption of processing only PDCCH.  |
| MediaTek | Yes | The power saving gain of UE grouping largely depends on how network indicates paging for UE subgroups, as to be discussed in subsequent questions. But in general we think that UE grouping should be considered as a kind of paging enhancement for UE power saving.**Note:** By saying “considered as a kind of paging enhancement”, we mean that RAN1 or RAN2 will evaluate the gain of UE grouping. Whether UE grouping is adopted as a part of final R-17 conclusion depends on the evaluation results.  |
| OPPO | Yes | UE group-based paging can reduce unnecessary paging reception. The power saving gain could be evaluated further. |
| Futurewei | Yes | We see UE grouping as a way to reduce false paging alarms in UEs. |
| Intel | Yes | We can include UE sub-grouping as potential paging enhancement in the evaluation. Anyway, RAN1 is also considering it in their evaluation Agreements:Group paging rate of 10% is assumed for the evaluation of Rel-17 paging enhancement* FFS: Another group paging rate > 10%
* Note: If UE sub-grouping is applied, the sub-group paging rate can be reduced w.r.t. the total sub-group number for a PO

For potential paging enhancements, RAN1 to study the following candidate schemes:* Paging early indication before a target PO to indicate UE whether to monitor PDCCH scrambled with P-RNTI at the PO. Potential candidate indication methods include
	+ DCI-based indication, e.g., based on
		- Extending existing DCI format 1\_0 or 2\_6
		- New DCI format
	+ RS-based or sequence-based indication, e.g., based on TRS/CSI-RS or SSS
* Sub-grouping for paging, based on
	+ Legacy paging DCI
	+ Paging early indication
	+ Additional reception occasions in time/frequency domain
	+ Multiple P-RNTIs
* Cross-slot scheduling for paging PDSCH
* Other proposal is not precluded
 |
| vivo | Yes | It is obvious that UE grouping can reduce the paging false alarm rate. But how much the power saving from UE grouping can be obtained depends on how to group and how to indicate the UE grouping, which should be further discussed and evaluated. Thus, we think it could be considered as an approach for paging enhancement by now. After we have further detailed design and evaluation on power saving gain, we could make the final decision.  |
| ETRI | Yes | UE grouping can reduce unnecessary paging reception. |
| Huawei, HiSilicon | Yes | Most of the time the UE stays in IDLE state, so the probability of IDLE mode power consumption may be equal or comparable to the CONNECTED mode power consumption, e.g. especially for wearable devices. Based on statistical data from field testing, the average false alarm probability for the observed UE can be above 95%. Thus, UE grouping can be considered as a direction for paging enhancement. |
| Nokia | FFS | Agree with Ericsson: should wait for RAN1 tevaluation. |
| LG | Yes | It is essential to reduce the false alarm. |
| ITRI | Yes | We think that the UE group-based paging could reduce the need to unnecessarily receive and decode PDSCH.  |
| Xiaomi | Yes | We think false alarm is a main issue in paging, and when a large number of UEs monitor a same PO, the power consumption comes from false alarm is very serious. By the way, RAN1 has already discussed this issue and reached a agreement for next meeting. Therefore UE grouping should be studied in paging enhancement. |
| Sony | Yes | We support MediaTek’s view. RAN1 should evaluate the gain of UE grouping. Whether UE grouping is considered as a part of paging enhancement depends on the outcome of the evaluation.  |
| Sequans | Yes | We believe it to be potentially very important. Of course, a thorough evaluation is needed. |
| CMCC | Yes | Based on the agreement in RAN1, we assume grouping for paging is already considered as the potential solution for paging enhancement. The performance gain of four sub-grouping schemes listed in RAN1 can be further evaluated. |

## Paging for UE subgroups

If UE grouping is considered as a kind of paging enhancement for UE power saving, UEs monitoring the same paging occasion (PO) are divided into subgroups, and the network needs to indicate whether a subgroup of UEs need to monitor paging message. Some contributions in RAN2#111-e provided more details about how to indicate paging for UE subgroups, for example

* Paging for UE subgroups using multiple P-RNTI:
	+ Additional P-RNTI(s) are introduced.
	+ Different UE subgroups monitor paging PDCCHs with CRCs scrambled different P-RNTIs.
	+ Supporting company: Qualcomm [2] **(1)**
* Paging for UE subgroups using different time/frequency resources:
	+ The paging message of different UE subgroups are transmitted on different time/frequency resources.
	+ Supporting company: OPPO [8] **(1)**
* Paging indication for UE subgroups using paging DCI:
	+ In paging DCI, network indicates whether each subgroup of UEs needs to monitor the corresponding paging PDSCH.
	+ Spare bits in paging DCI may be used, or we can define new DCI format.
	+ Supporting companies: vivo [4], Xiaomi [6], Samsung [7], OPPO [8], ZTE [9] **(5)**
* Paging early indication or wake-up signal (WUS) for UE subgroups:
	+ Transmit early indication or wake-up signal before paging occasion. The indication or WUS may apply to a subgroup of UEs.
	+ UE needs not to monitor PO in case of negative indication.
	+ Supporting companies: vivo [4], Xiaomi [6], MediaTek [14], ITRI [15], Huawei [19], LG [23] **(5)**

Note: This email discussion focus on UE grouping, and thus other proposals not related to UE grouping are not shown in the above list.

Although many details of this topic require RAN1 involvement, we think that RAN2 may list candidate solutions, and then inform RAN1 to continue the detailed designs. In the following discussions, we invite companies to share their views about the candidate solutions, and analyse what part of the power consumption can be saved with each solution. Initial justifications, e.g., power saving gain, may also be provided, if available. For both qualitative and quantitative analyses, please take in to account the evaluation methodology from RAN1 [1]. Please also specify your own assumptions beyond what RAN1 suggests.

**Q2: Should we consider “paging for UE subgroups using multiple P-RNTI” as a candidate solution? What part of power can be saved with this method? Please provide initial justifications, if available.**

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| **Company name** | **Yes/No** | **Comments** |
| Ericsson | No | We want to be able to use the full Paging bandwidth and maximum aggregation level for Paging to reach all UEs in the cell reliably. In case different P-RNTIs are used for grouping, this would imply that legacy Paging is impacted, when the NW needs to page legacy UE and one or more REL-17 groups. The WID ([RP-200938](https://www.3gpp.org/ftp/tsg_ran/TSG_RAN//TSGR_88e/Docs/RP-200938.zip)) says that the paging enhancement should not impact legacy Paging. Furthermore paging one or more groups with full BW/aggregation level at the same time may also be prevented.**About the “evaluation methodology from RAN1”:** we think that RAN2 can discuss paging enhancements, but RAN2 should not try to re-do the RAN1 evaluation, i.e. this activity belongs in RAN1. RAN2 can inform RAN1 about the results of RAN2 discussions, but RAN2 cannot perform nor judge the evaluations and assumptions performed by RAN1, i.e. this is outside RAN2 expertise. [Comment by Qualcomm] Generally PDSCH is the bottleneck for coverage. If network needs to use full aggregation level to send paging DCI to a UE, that UE will not be able to receive PDSCH anyway. We do not think this solution has impact on legacy UEs, because legacy can still use legacy P-RNTI and new UEs use new P-RNTIs.  |
| Qualcomm | Yes | In our view, we have to consider a candid solution for UE grouping together with other enhancements, in order to properly evaluate its potential power savings. For example, UE grouping alone may not save much power if paging indication and paging messages (PDSCH) are sent in the same slot, because in that case UE has to wake up the entire transceiver for a paging occasion, in order to be fully ready to decode and process both paging indication and a potential paging message in the same slot. Even if UE grouping can help UE avoid unnecessary reception of paging message (PDSCH), skipping the PDSCH processing yields only marginal power savings. On the other hand, if cross-slot scheduling or early paging indication is used, UE can first turn on only part of its transceiver which can be power optimized to decode just paging DCI or an early-indication signal. After UE determines that there is a paging message for it, it then turns on the rest of the transceiver. Only with this separation of paging indication and paging reception, full potential of power savings can be achieved, in the same way how two-stage wakeup enabled by DCP in RRC Connected saves UE power.If companies agree to study a new signal for early indication which can include information for UE grouping, then multiple P-RNTI is not necessary. However, we think introducing a new signal for early indication would require a significant amount of work in RAN1, which is impractical given the amount of objectives they need to study and specify within only 1 TU. On the other hand, cross-slot scheduling is much more feasible, because it can achieve compatible power savings but requires much less work, as cross-slot scheduling has already been supported since Rel-16. If companies can agree to adopt cross-slot scheduling, then in our view multiple P-RNTI is a good candidate solution to pair with it, because* It can save power by avoid unnecessary reception of paging message, i.e. if it does not receive a paging DCI scrambled by its assigned P-RNTI, it does not turn on the circuit for PDSCH processing.
* It is flexibility and scalable, as network can decide how many P-RNTIs to configure based on paging load or how to use it to separate different types of UEs (e.g. R17 UEs vs legacy UEs)

It is simple to implement and does not require time out of RAN1’s TU. |
| Samsung |  | PDSCH decoding and processing of paging message due to false alarm can be minimised with this approach. However, this approach may increase paging overhead when there is paging for multiple subgroups as gNB needs to send separate PDCCH and PDSCH for each subgroup. Similarly, when there is paging for legacy UEs and UEs supporting subgrouping, separate PDCCH and PDSCH needs to be sent.RAN1 input is also needed to determine the number of P-RNTIs and number of PDCCHs addressed to P-RNTI that can be concurrently sent in paging search space.Regarding Qualcomm’s comment on cross slot scheduling, we agree that cross slot scheduling is beneficial as UE can avoid receiving/buffering PDSCH until PDCCH processing is complete. With sufficient gap between PDCCH addressed to P-RNTI and PDSCH, PDCCH basically acts like a wakeup signal. |
| MediaTek | No | Our major concerns about Multiple P-RNTI:* Impact to legacy paging
* The number of UE subgroups are limited and not adjustable, since the P-RNTIs must be fixed values defined in the specifications.
 |
| OPPO | No | We also have similar concerns for multiple P-RNTI as the previous companies regarding the impacts on legacy UEs. However, we share sympathy on the cross-slot scheduling, we think it’s beneficial for power saving.Another concern is that for UE group-based paging with multiple P-RNTI, since the P-RNTIs would be specified in the spec, the UE group number is fixed and could not be adjusted based on the paging load, which is not feasible.  |
| Futurewei | No | We share similar concerns about the impact on legacy paging. We are also concerned with the scalability issue when in practice we can only spare a small and fixed number of RNTIs to be defined as P-RNTIs.  |
| Intel | No | Even though unnecessary PDSCH reception can be minimized with this scheme, this approach may increase the chance of false alarm rate with respect to no grouping if the UE has to decode more than its P-RNTI. |
| vivo | No | Technically, we would like to check what other comments that “the impact on legacy paging” means. In our understanding, legacy UE use the legacy P-RNTI, and UEs supporting grouping use the new added P-RNTI(s). There is no impact to legacy UEs. The only impact is that network needs to send separate PDCCH and PDSCH for each subgroup with Multiple P-RNTIs, but in legacy, network may only send only one PDCCH and PDSCH. This will introduce the legacy system overhead. Our concern on this multiple P-RNTI mechanism by now is:1. We donot see much power saving gain based on current RAN1 power model.
2. The UE group number is fixed if the P-RNTIs should be defined.

If supporting companies could provide the power saving gain for multiple P-RNTI based UE grouping, we would like to discuss it. |
| ETRI | Neutral | This option can improve the power saving gain although the paging process with the new P-RNTI can affect legacy UE. |
| Huawei, HiSilicon | No | To be compatible with legacy Paging, if the NW needs to page UE, the NW needs to always send the paging DCI scrambled by legacy P-RNTI, and send the paging DCI scrambled by new RNTI(s) based on the UE groups. It leads to larger signalling overhead.BTW. In response to Qualcomm’s comment on early paging indication, we don’t think early paging indication necessarily introduce new physical signal. If DCI based early paging indication is used, there is no new physical layer signal or channel introduced. We expect the RAN1 impact is quite limited for DCI based early paging indication. |
| Nokia | No | Agree with MediaTek. It should be possible to page legacy UEs and UEs supporting Rel-17 power saving as well as different groups in the same paging msg with the same DCI to avoid impact on NW scheduler. |
| LG | No | Agree with MediaTek. |
| ITRI | No | We share the same view as MediaTek. |
| Xiaomi | No | We agree with vivo that multiple P-RNTIs will require network to send separate PDCCH for each subgroup which results in system overhead and increaseing DCI blocking probability. In addition, since UE is still required to attempt to perform PDCCH blind detection, the gain brought is mainly to reduce the power consumption of PDSCH decoding. And we think that for those schemes that needs to process paging PDCCH, paging DCI-based UE grouping scheme may be a better way. |
| Sony | - |  PDSCH decoding and processing of paging message due to false alarm can be minimised with this approach. However, if gNB needs to page two UEs belonging to different sub-groups at the same time, gNB needs to transmit either separate PDCCH and PDSCH for each subgroup or use a common RNTI. The former approach leads to extra paging overhead and with the latter ~~extra~~ there is no reduction in overhearing cost and therefore no power saving. Of course we need to study and evaluate how often and when a scenario as such happens.If cross-slot scheduling is adopted instead of early paging indicator, using the 5-extra bit in paging DCI for subgrouping can be more beneficial as we will not face any of the above drawbacks. |
| Sequans | Yes | Agree with QC’s comments. It’s true that several PDCCHs will need to be sent (at least 2: legacy and “all UEs” Rel-17 P-RNTI), but presumably in many cases some of the PDSCHs can be scheduled to the same one. It is also worth noting that a physical WUS is also quite limited in its number of groups.Of course, this solution should be compared to other solutions. |
| CMCC | No | Since the lack of flexibility and the potential impact on legacy paging, we prefer not supporting this solution. However, we can restart the discussion if enormous power saving gain can be achieved by this solution based on the evaluation result of RAN1. |

**Q3: Should we consider “paging for UE subgroups using different time/frequency resources” as a candidate solution? What part of power can be saved with this method? Please provide initial justifications, if available.**

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| **Company name** | **Yes/No** | **Comments** |
| Ericsson | No | In our understanding spending a few bits in paging DCI, compared to doubling the paging capacity in time or frequency, is a much simpler, less costly, and more effective solution with less impact for the false paging alarms.  |
| Qualcomm | Neutral | We think this approach may be considered as a candidate solution, because of its simplicity (it requires only limited study in RAN1). One of the downsides is that it may limit gNB scheduler’s flexibility in scheduling paging messages.  |
| Samsung | No | Agree with Ericsson |
| MediaTek | No | The impact is high and it’s not very clear how this can be achieved, e.g., by multiple P-RNTI, or multiple CORESETs… |
| OPPO | Yes | In this approach, separate paging search spaces/ CORESETs or even PDCCH monitoring occasions can be configured for different UE groups, so that unnecessary reception of paging message could be reduced. With this method, network could adjust the UE group number according to the paging load. Furthermore, in the massive UE scenario (e.g. after introducing massive RedCap UEs), this approach could increase the paging capacity without increasing the false alarm probability. |
| Futurewei | Neutral | We agree that this approach is relatively simple but are concerned with the constrain on gNB’s scheduling and potential impact on paging latency. |
| Intel | No | Again, unnecessary PDSCH reception can be minimized with this scheme and thus some power saving can be achieved. On the other hand, this scheme may potentially increase the power consumption due to increase in PDCCH decoding efforts if the UE has to monitor/decode not just the PDCCH on time/frequency resource for paging but also decode PDCCH on other time/frequency resource  |
| vivo | No | According to the proponent explaination, we think this approach has much impact on RAN1 design. RAN1 needs to discuss the split search spaces/ CORESETs or even PDCCH monitoring occasions for different UE groups, which may impact on scheduling restriction.For power saving gain, we don’t see much difference between this approach and UE grouping by paging DCI. Thus, we don’t think it is an efficient approach by now.  |
| ETRI | No | This option can be considered a candidate solution because it can reduce PDCCH monitoring. However, as the number of UE subgroups increases, the benefits of power saving may be less than the requiring resource cost. |
| Huawei, HiSilicon | No | Just like using separate new RNTI(s), using different T/F resources will increase the signalling overhead. |
| Nokia | No | Same reason as above. |
| LG | No | Agree with Ericsson. |
| ITRI | No | Agree with Ericsson |
| Xiaomi | No | For current paging mechanism, PFs per DRX cycle is select from {oneT, halfT, quarterT, oneEighthT, oneSixteenthT} according to higher layer parameter nAndPagingFrameOffset, and DRX cycle has been extended to 10.24s, which means network has already supported high flexibility for UE grouping in time domain. For frequency domain UE grouping, subgrouping frequency resources seems to require a lot of work by RAN1 and increasing network overhead. As mentioned in Q2, for those schemes that need to process paging PDCCH anyway, paging DCI-based UE grouping scheme may be a better way. |
| Sony | Neutral | The approach can be considered as a candidate solution, but it can lead to paging latency (when different time resources are used) and extra system overhead. Again, if cross-slot scheduling is adopted instead of early paging indicator, using the 5-extra bit in paging DCI for subgrouping can be more beneficial as we will not face any of the above drawbacks.  |
| Sequans | Probably No | This does look to have a large impact on NW flexibility and RAN1. However, it does not require cross-slot scheduling to be truly efficient so may be useful to consider at lower priority. |
| CMCC | No | Since UEs still need to monitor/decode PDCCH, this solution is not that effective. |

**Q4: Should we consider “paging indication for UE subgroups using paging DCI” as a candidate solution? What part of power can be saved with this method? Please provide initial justifications, if available.**

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| **Company name** | **Yes/No** | **Comments** |
| Ericsson | Yes, if… | Yes, provided that this paging enhancement is going to give significant power saving gains. |
| Qualcomm | Neutral | Technical speaking, bits in paging DCI may be used for UE grouping. However, we think this approach has a few drawbacks:* If we introduce a new paging DCI format, it would have impact on legacy UE and hence is not feasible.

If we repurpose the reserved bits in paging DCI, there are limited number of them available for UE grouping. That thus limits the maximum number of UE groups that a PO can have. Since there are other good alternative solutions available for UE grouping, it is sensible to keep those reserved bits for more critical use in the future. |
| Samsung | Yes | PDSCH decoding and processing of paging message due to false alarm can be minimised with this approach.  |
| MediaTek | No | The DCI-based method is simple if we use spare bits, and it’s acceptable if new DCI format is needed. Our concern is about the power saving gain: If paging indication for UE subgroups is sent in paging DCI, UEs not paged can only skip the following PDSCH decoding. Our analysis shows that the power saving gain is less than 2%, even when (original) UE group paging rate is as high as 40% and UEs monitoring the same PO are divided into 2 subgroups. |
| OPPO | Neutral | Including UE group information in the paging DCI is simple. But as also commented by Qualcomm, the UE group number would be limited, and the network could not adjust the UE group number according to the paging load which is not feasible. |
| Futurewei | No (for now) | Share the concern with MediaTek about the power saving gain being low, but are willing to reconsider if study shows otherwise.  |
| Intel | Yes | Unnecessary PDSCH reception can be minimized with this scheme and thus some power saving can be achieved and will not increase false alarm rate like in the multiple P-RNTI scheme as well as not increasing the PDCCH decoding effort as in the separate time/frequency resource scheme. This will also have less specification impact. |
| vivo | Depends | Technically, this approach could reduce the PDSCH reception for false alarm case. It is a simple solution for UE grouping via reserved bits in paging PDCCH DCI, with almost no specification impact. However, according to our evaluation based on RAN1 power model, this approach could only achieve less than 2% power saving. More detailed simulation results can be found in our contribution in [R2-2006689]. We think whether this approach could be considered as a candidate is up to the evaluation results. By now, we donot think it is a good approach.  |
| ETRI | Yes | This option can achieve the enhancement for power saving performance in a relatively simple manner. |
| Huawei, HiSilicon | Yes | As our comments for Q5, the information for UE subgroups can be included in DCI. The sub-grouping information can be carried in paging DCI and/or PEI DCI. The design on introducing sub-grouping indication in legacy paging DCI and PEI DCI can be jointly considered to maximize the power saving gain. |
| Nokia | FFS | Sub-grouping DCI would likely not provide as much gain as EPI/WUS with grouping since the UEs would still always need to decode DCI. Anyway, it is to be further evaluated in RAN1 which way provide better power saving gain. |
| LG | No | The DCI based solution cannot solve the inter-slot problem raised by QC when the SCS is 15khz. |
| Xiaomi | Neutral | The paging DCI-based method is simple and straightforward way to grouping but the power saving gain it brought is limited as it requires decoding paging PDCCH anyway. So we are open for it. |
| Sony | Yes | RAN1 should evaluate the gain of UE grouping using this approach. Whether this UE grouping scheme is considered as a part of final paging enhancement depends on the outcome of the evaluation. |
| Sequans | Yes | Introducing a new DCI format is not feasible due to legacy impact, but using spare bits is an extremely simple solution that should be considered. It also should be coupled with cross-slot scheduling to bring significant benefit. |
| CMCC | No | As we stated in the above question, the power saving gain is relatively low since this solution only avoid unnecessary PDSCH reception. Besides, the bits in paging DCI is limited and reserved for critical use.  |

**Q5: Should we consider “paging early indication or wake-up signal (WUS) for UE subgroups” as a candidate solution? What part of power can be saved with this method? Please provide initial justifications, if available.**

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| **Company name** | **Yes/No** | **Comments** |
| Ericsson | No | We think WUS/PEI is a complex solution, with a lot of RAN1 impact, that is not justified for the expected power saving gains.  |
| Qualcomm | No | Introducing a new signal for paging early indication requires considerable amount of work and meeting time in RAN1. In our view, it is not realistic in Rel-17, because RAN1 already have a very tight schedule given all the objectives they have to study with only one TU. On the other hand, as we explained in our reply to Q2, cross-slot scheduling can achieve compatible power savings but requires much less study (i.e. it is already available since Rel-16). Therefore, it is not sensible to go for a complex solution while a simpler one with compatible benefits is already available. |
| Samsung | - | This has significant RAN1 impact. So the decision to support/not support is up to RAN1.If cross slot scheduling is supported, with sufficient gap between PDCCH addressed to P-RNTI and PDSCH, this PDCCH basically can act like a wakeup signal instead of defining a new WUS/PEI. |
| MediaTek | Yes | * With WUS/PEI, when a UE knows that it is not to be paged in advance, it can save not only the paging PDCCH/PDSCH reception, but also the pre-synchronization steps before PO, which also consumes significant amount of power especially in low SINR cases.
* Regarding “new signal for paging early indication”, WUS/PEI is nothing new. WUS has been introduced for NB-IoT in R-15, and UE-group WUS (GWUS) was then introduced in Rel-16. If sequence-based WUS is not preferred, we also introduced WUS conveyed by DCI signalling with a new DCI format 2\_6, in Rel-16 NR.
* Most important of all, UE grouping with PEI/WUS shows significant power saving gain. Assume UEs monitoring the same PO are divided into 2 subgroups, and PEI is configured. Our calculation based on the evaluation methodology in RAN1 LS [1] shows 25% power saving gain for low-SINR case and 17% gain for high-SINR case.
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| OPPO | No | Since it has significant impacts on RAN1, we prefer to leave it up to RAN1 whether we go for this approach or not.  |
| Futurewei | Yes | This approach has the potential of large power saving gain. |
| Intel | Yes | Unnecessary PDCCH/PDSCH reception can be minimized with this scheme and thus power saving can be achieved. However, it provides higher power saving gain e.g. UE could skip both PDCCH/DPSCH reception in the paging occasion if a WUS/PEI is used.The decision to support this should be based on the RAN1 evaluation and performance metrics. Our understanding is that RAN 1 is already taking this scheme into consideration. Therefore, RAN2 should wait until RAN1 completes RAN1 evaluation instead of discussing RAN1 impacts in RAN2. |
| vivo | Yes | This approach can reduce the unnecessary reception for both PDCCH and PDSCH of paging. Regarding the work load/TU in RAN1 commented by other companies, we observed that the discussion on this approach has been ongoing in RAN1. At the same time, we already have idle mode WUS in NB-IoT and DCP in connected mode in NR rel-16. Thus, we don’t think it is a Mission Impossible in RAN1. We could wait for more detailed sign for this approach from RAN1. According to our evaluation based on RAN1 power model, this approach could only achieve significant power saving gain in idle mode (in both low SINR and high SINR cases), i.e. 8%-25%. More detailed simulation results can be found in our contribution in [R2-2006689].  |
| ETRI | Yes | We agree with MediaTek. |
| Huawei, HiSilicon | Yes | According to our RAN1 study, power consumption is increased due to a lot of unnecessary ‘state transition’ and ‘light sleep’ in the unpaged DRX cycles, this can be reduced for power saving by introducing PEI before PO to inform the UE whether to monitor the following PO(s), and therefore, the light sleep transition can be avoided for unpaged paging cycles. As we commented, the PEI does not introduce new physical signal/channel, it reuses the legacy PDCCH structure and just extend/re-interpret paging DCI format, which is a reasonable/acceptable RAN1 impact in Rel-17 in our view.Regarding the comment from Qualcomm on cross-slot scheduling, we think the power saving gain would be very limited if only cross-slot scheduling is used to avoid the buffering of potential PDSCH. Our RAN1 results showed that a significant part of power consumption is the ‘state transition’ and ‘light sleep’ due to the SSB reception for potential PDSCH decoding performance, not the buffering of PDSCH. Without other RAN1 enhancement, the SSB reception before the potential PDSCH reception is still needed and therefore power saving gain would be limited if only cross-slot scheduling is used. Therefore, cross-slot scheduling solution needs further RAN1 effort to introduce new mechanism to obtain power saving gain. |
| Nokia | FFS | To be further evaluated in RAN1 which way provide better power saving gain. |
| LG | Yes | WUS is transmitted before the PO. If WUS like signal is used, the problem caused by scheduling DCI/paging PDSCH in the same slot can be solved. |
| ITRI | Yes | We share the same view as MediaTek. |
| Xiaomi | Yes | We agree with Media Tek that it can save not only the paging PDCCH/PDSCH reception, but also the pre-synchronization steps and transition energy before PO especially for low SINR. So, PEI/WUS grouping scheme can be studied. Furthermore, if we can prove this scheme can bring power saving gain, we think RAN1 can handle the issue of WUS design since the WUS has been introduced into MTC/NB-IoT. |
| BT | Depends but tend to yes | The answer should be based on the benefit this solution can bring rather than the complexity. Then, if PEI/WUS provides the main benefit to UE power saving in idle, RAN1/RAN2 should work on it.Based on current RAN2 studies, this solution bring the major gains. |
| Sony | Yes | Using a pre-paging indicator can lead to reduction of idle channel listening and overhearing. However, the amount of gain is highly depends on the design of pre-paging indicator. RAN1 should evaluate the gain and system impact. Whether this approach is considered as a part of final paging enhancement depends on the outcome of the evaluation. |
| Sequans | Probably yes to PEI | The possible gains are significant, but the RAN1 impact is an issue, better left to them to decide on. We do not see the benefit of a physical WUS when paging does not use repetition, but that is of course a Ran1 decision as well |
| CMCC | Yes | With this method, UE monitors the following PO(s) if only detecting its UE-group WUS or PEI. The unnecessary reception for both PDCCH and PDSCH can be both reduced. Therefore, paging sub-grouping with WUS or PEI can be supported in NR to further reduce UE power consumption. |

**Q6: Should we consider any other candidate solution(s) for paging for UE subgroups? What part of power can be saved with the method(s)? Please provide initial justifications, if available.**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Yes/No** | **Comments** |
| Ericsson | Yes | In our understanding a PRNTI/DCI based solution requires a K0>0 configuration for Paging to be effective, i.e. typically UE implementation can otherwise not avoid receiving the Paging PDSCH when it is not paged, which is the whole point of this enhancement. In case a PRNTI/DCI based solution is considered the impact of cross-slot scheduling requires further discussion, i.e. how to avoid impact on legacy Paging when both legacy UE and UE supporting cross-slot scheduling are paged. Furthermore capability signalling aspects need to be considered.  |
| Qualcomm | Yes | The candidate solutions mentioned in Q2~Q5 do not have to be exclusive to each other, as long as they do not conflict with each other. For example, candidate solutions in both Q2 and Q4 can be supported. So we can consider such possibilities too. |
| Samsung | Yes | Information indicating presence of only RAN paging (or absence of CN paging) in paging message can be informed using DCI. RRC\_IDLE UE is not required to receive paging message if scheduled paging message only includes RAN paging. |
| MediaTek | See comments | [Comments for “Cross-slot scheduling”] Cross-slot scheduling is a kind of “early indication”: * The major difference from PEI/WUS is that the early transmitted DCI in cross-slot scheduling not only indicates whether a subgroup of UEs is paged, but also indicates the time-frequency resources of paging PDSCH. Since there are legacy UEs monitoring the same PO, there must be a DCI right before the paging PDSCH. This not only wastes the radio resources, but also requires the network to ensure that the scheduling is the same in the “early” and “late” DCIs.
* Moreover, even with largest K0, DCI is still relatively close to PO (32 slots~16ms), and UE is unable to skip pre-synchronization steps. Our analysis shows that cross-slot scheduling brings around 7% power saving gain.
* With existing mechanism, non-zero values for K0 are not possible in Idle-mode. Thus we cannot simply “reuse” cross-slot scheduling for paging. There are specification impacts, and this also impacts paging reception for legacy UE.
 |
| Nokia | FFS | Whether cross-slot scheduling can bring any gain and can be supported might depend on RAN1 DCI design of the early indication if to go that direction, e.g. whether the scheduling can be done in the early indication. More RAN1 scope. |
| Xiaomi | FFS | It worth noting that paging probability is introduced into MTC/NB-IoT, and the current PF/PO calculation formula is to uniformly assign UEs into the PO. Therefore, can we introduce the probability into the calculation formula of PO/PF to achieve a better PO allocation method? |
| Sequans | Yes | Cross-slot scheduling is essential to some of the solutions, and could be beneficial by itself |

## How to group UEs

If UE grouping is applied, we need to find the methods to divide UEs into subgroups. One prior example of UE-group paging is the Group Wake Up Signal (GWUS) introduced in Rel-16, where a UE selects one WUS group based on its UE paging probability information and /or its UE NAS identity (UE ID). For UE grouping in Rel-17, we may start from these methods.

**Q7: Do you support UE grouping based on UE paging probability information?**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Yes/No** | **Comments** |
| Ericsson | No | It is our understanding that grouping based on paging probably, aims to create groups such that UEs in a group “equally disturb each other”. Perhaps there is some fairness principle in that, but we wonder if it effectively reduces the overall false paging alarms? |
| Qualcomm | No | We have reservations on the effectiveness of this method. |
| Samsung | No | Same view as Qualcomm. |
| MediaTek | Neutral | This method is effective for IoT where paging probabilities are quite different for different device types (e.g. sensors, meters, etc.). In NR we are not sure if it helps. Perhaps this is useful if RedCap UEs are considered. |
| OPPO | No | Same view as Qualcomm. |
| Futurewei | Neutral | We are open to it, if study shows such information is helpful and obtainable. |
| Intel | No | See our response to Q9. It can be left to the network |
| vivo | No | Not sure whether there is benefit to support UE grouping based on UE probability information.  |
| ETRI | No | Paging probability information may be useful only on limited types of devices. |
| Huawei, HiSilicon | Yes | It has been supported in NB-IoT and MTC, and can be simply extended. The user habits can be diverse, e.g. the paging probability for smartphones and wearable devices are obviously different. As commented by MediaTek, we understand RedCap UEs can also be considered and the paging enhancement can be reused for RedCap UEs. |
| Nokia | No | Not practical from NW point of view. Should seek for some simple solution if to do grouping. |
| LG | No | We don’t think the paging probability based grouping is more effective than other simple solutions, e.g. grouping based on UE ID. |
| ITRI | Neutral | Same view as MediaTek. |
| Xiaomi | Neutral | We think paging probability combining UE\_ID based grouping is better than that only based on UE\_ID if the paging probability of different UE varies greatly. |
| Sony | Neutral | Scenarios and use cases should be further discussed based on discussion for IoT devices for MTC/NB-IoT. |
| Sequans | Neutral | Agree with MediaTek |
| CMCC | Neutral | Share the same view with MTK. |

**Q8: Do you support UE grouping based on UE ID?**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Yes/No** | **Comments** |
| Ericsson | Yes | We think this solution is simple (which fits with the expected power saving gains) and we think this solution is (most like) to be effective.  |
| Qualcomm | Yes | We think it is a simple and natural extension of the current method of mapping a UE to its PO. |
| Samsung | Yes | Currently UEs are distributed across PFs/POs based in UE ID. Using UE ID is simple extension of current design. |
| MediaTek | Yes | This is a simple and intuitive solution. |
| OPPO | Yes | This solution is simple and is fair to all the UEs.  |
| Futurewei | Yes | UE ID can be the baseline. |
| Intel | No | See our response to Q9. It can be left to the network |
| vivo | Yes | Considering current UE\_ID is used for PF/PO distribution, it is simple to use UE\_ID also for further UE grouping.  |
| ETRI | Yes | The current scheme for PO mapping is easily reused. |
| Huawei, HiSilicon | Yes | It is simple. |
| Nokia | Yes | If with grouping |
| LG | Yes | UE ID can be the baseline. |
| ITRI | Yes | UE grouping based on UE ID can be the baseline. |
| Xiaomi | Yes | There is no doubt that UE\_ID based grouping is a simple and effective way. |
| Sony | Yes | That can be the baseline. |
| Sequans | Yes | As baseline |
| CMCC | Yes | This grouping method can be the baseline. |

**Q9: Do you support UE grouping based on any other methods?**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Yes/No** | **Comments** |
| Ericsson | TBD | Mobility, i.e. paging the UE in the complete TA because the UE could not be reached in the cell where the UE was paged before, could have a big impact on false paging (in addition to the fact that more than one UE is monitoring the same PO). But the NW can also use intelligent strategy to page the UE based on past mobility patterns, which in many cases are very predictable/repetitive. It is not clear to us whether grouping based on mobility is needed, i.e. TBD.  |
| Qualcomm | Yes | UE grouping can include the release(s) that UE supports. For example, it is useful to separate legacy UEs and Rel-17 in different groups, because legacy UEs may not be able to support new paging enhancements and hence should be mapped to different groups from Rel-17 UEs. |
| Samsung |  | UE ID seems sufficient for grouping.Information indicating presence of only RAN paging (or absence of CN paging) in paging message can be additionally informed using DCI. RRC\_IDLE UE is not required to receive paging message if scheduled paging message only includes RAN paging. |
| MediaTek | Yes | For example, if we can distinguish between UEs with different sensitivity to power consumption, such UE power consumption profile can be considered for UE grouping. |
| OPPO | Yes | Agree with Qualcomm. Considering backward compatibility, it is meaningful to divide legacy UEs and R17 UEs in different groups.  |
| Futurewei | Yes | For example, the UE’s current battery status, e.g., provided as UE assistance information, can be considered for UE grouping. |
| Intel | Yes | Instead of specifying the UE grouping determination via formula as in eMTC/NBIoT, another method is RAN derives by implementation method the UE grouping ID that a UE should be in and provide the ID to the UE in RRC message before the UE goes into idle or inactive mode.The advantage of this is that there is no need to specify the method used for the subgrouping in the specification (i.e. it can be left to network to consider many factors for the subgrouping – mobility status of UE, probability threshold etc.) and hence it can be made to be transparent to any UE and it can be left to network implementation to ensure UE subgrouping for UEs is secured. This makes the solution flexible, allowing the network to implement the optimal method rather than be tied to the specified algorithm for a UE type/category or may not be optimal in the future. |
| vivo | TBD | This can be further discussed based on companies’ contributions. We are open to discuss any further grouping method if the motivation is strong enough.  |
| ETRI | - | UE ID based grouping is sufficient, but we are open to other methods. |
| Huawei, HiSilicon | Yes | Using UE ID for grouping is just a pure randomization, other more effective information should not be excluded. |
| Nokia | No | Seems to be enough based on one simple option since anyway all the UE should be able to be indicated. |
| LG | No | We prefer to have a single simple solution, i.e. UE ID based grouping. |
| ITRI | Yes | We should not exclude other grouping method at this stage. |
| Xiaomi | Yes | We think UE\_ID-based grouping is a baseline, but we are also open to other methods. |
| Sony | Yes | Can be further discussed. Mobility is one example. |
| Sequans | TBD | Agree with vivo |
| CMCC | Yes | Concerning the UEs’ condition or characteristic, different grouping should be made. Considering power saving as the main purpose of this WI, we think the power condition of the UE is one of the important factors to be considered in the grouping. |

**Q10: Do you think UE grouping can be based on multiple methods? If yes, what methods should be supported?**

|  |  |  |
| --- | --- | --- |
| **Company name** | **Yes/No** | **Comments** |
| Ericsson | No | In general we do not specify tens different ways to do the same thing, but we should try to compromise on the “best” solution. We think this enhancement is going to give little gain, i.e. from that perspective different options are not justified. Furthermore multiple options are expected to results in multiple option UE capabilities, which makes deployment of the paging enhancement less likely. For the paging enhancement to be effective, the best option is that it is mandatory support for REL-17 UEs, otherwise the little gain will only be experienced in a few UEs.  |
| Qualcomm | Yes | UE grouping should be based on both UE ID and UE’s release. |
| Samsung | No | UE ID seems sufficient for grouping. |
| MediaTek | Yes | If we agree to any UE grouping method(s) in addition to UE\_ID, the additional method(s) may be configured together with UE\_ID-based grouping. |
| OPPO | Yes | UE ID can be the baseline, we’re open to discuss other ones, e.g., UE’s release. |
| Futurewei | Yes | UE ID can be the baseline. We are also open to other methods, such as UE assistance information. |
| Intel | No | Providing UE grouping ID seems sufficient for grouping. |
| vivo | TBD | As we commented above, UE\_ID can be agreed first. We are open to any other method.  |
| Huawei, HiSilicon | Yes | Open to other methods. |
| Nokia | No | See above. |
| LG | No | We prefer to have a single simple solution, i.e. UE ID based grouping. |
| ITRI | Yes | Agree with MediaTek. |
| Xiaomi | Yes | MTC/NB-IoT WUS grouping has shown that UE\_ID can be combined with other methods like probability to achieve more effective grouping. So we are open for this question. |
| Sony | Yes | UE id as the baseline. Then we can discuss paging probability, mobility etc.  |
| Sequans | Yes | But should probably limited to two – one TBD and a subdivision based on UE ID |
| CMCC | Yes | Combination is beneficial. |

## Performance metrics

The purpose of paging enhancements in this WI is to reduce UE power consumption. Therefore, one major performance metric is the power saving gain (PSG), which can be calculated as:

$$PSG=\left(1-\frac{P\_{enh}}{P\_{base}}\right)×100\%$$

where *Pbase* and *Penh* denote the average power consumption of baseline and the enhanced methods, respectively.

In addition to power saving gain, there may be other performance metrics for us to evaluate potential solutions.

**Q11: In addition to power saving gain, what are the performance metrics for us to evaluate potential solutions?**

|  |  |
| --- | --- |
| **Company name** | **Comments** |
| Ericsson | * Impact on legacy Paging
* Impact on paging response latency (due to reduced paging reliability e.g. UE misses first Paging attempt of the NW)
* Impact on NW resource allocation
 |
| Qualcomm | Power saving gain should be the main metric, as the SID clearly specified that the enhancements are for power saving. |
| Samsung | Power saving gain should be the main metric. Impact on network resource allocation should also be considered. |
| MediaTek | Power saving gain should be the main metric for quantitative analysis, and we may also have qualitative analysis for other metrics, e.g., impact on legacy paging, radio resource usage, etc. |
| OPPO | Power saving gain should be the main metric, and the method is not supposed to impact legacy UEs as agreed in the WID |
| Futurewei | * Latency for delivering paging (or the final data).
* Radio resource usage for sending required paging.
 |
| Intel | RAN1 have already identified further metrics to consider other than power saving gain:* Impact to UE paging detection probability
* System impacts such as resources additional overhead and other legacy functionalities including SI change and PWS indication
 |
| vivo | Power saving gain should be the main metric as this enhancement is for power saving. In addition, paging false alarm rate, impact on the legacy UE, network overhead (or system efficiency), paging latency should be also considered when chosing the approaches.  |
| ETRI | In addition to power saving gain, the efficiency on radio resources for paging should also be considered. |
| Huawei, HiSilicon | Power saving gain should be the main metric, other metrics may be considered such as RAN1 agreed metrics, e.g UE paging detection probability etc. |
| Nokia | One main principle from RAN2 point of view is it should be possible to page all of the UEs of the PO at the same time. |
| BT | * Power saving gain
* Impact on legacy paging
* Paging latency for deliver it and to be detected.
 |
| Sony | This has been discussed in RAN1. Other than power saving gain, impact on latency or system overhead needs to be considered. |
| Sequans | Power saving should be the main metric, while considering others (as those identified by RAN1). It is important to note that the SID precludes impact to legacy UEs.  |

## Other issues

Both RAN1 and RAN2 are working on the paging enhancement topic. Based on our discussion above, we may need to send some information to RAN1.

**Q12: Based on RAN2 discussions, what information about UE grouping do we need to send to RAN1?**

|  |  |
| --- | --- |
| **Company name** | **Comments** |
| Ericsson | We indicated earlier in this email discussion that RAN2 should not re-do the RAN1 evaluation, but RAN2 can discuss paging enhancements and inform RAN1 about the RAN2 result. However we think it is too early to discuss a possible LS to RAN1 at this time.  |
| Qualcomm | We think it is too early to discussion this question, as it will largely depend on what agreements we make in RAN2. If needed, we can inform RAN1 those agreements that have impact on their study. |
| Samsung | It’s too early to send LS to RAN1. |
| MediaTek | RAN2 needs to inform RAN1 of our decisions and corresponding evaluations RAN1 needs to do. Regarding potential LS to RAN1, we should wait until RAN2 has agreed to more detailed solutions. |
| OPPO | Maybe it’s beneficial to have some RAN2 agreements unti we decide to send LS to RAN1 |
| Futurewei | RAN2 should inform RAN1 of any RAN2 decisions regarding UE grouping. However, it may be too early to do so at this point.  |
| Intel | Most of the things that we discuss in this email discussion other than Section 2.3 are already being considered in the RAN1 evaluation. Hence, we do not see a need to send a LS to RAN1. |
| vivo | In our understanding, how to group UEs should be decided in RAN2. Regarding paging for UE subgroups, we think we could provide the detailed design for each approach (we decide which one or all of them) to RAN1. In this way, RAN1 could evaluate the power saving gain based on the derived power model. Based on the simulation results, RAN1 or RAN1/RAN2 can make the decision on how to enhance the paging with UE grouping, with further consideration on the above additional metrics.  |
| ETRI | It is better to send LS to RAN1 after RAN2 has some agreements on UE grouping for power saving/paging enhancements. |
| Huawei, HiSilicon | RAN2 needs to inform RAN1 the RAN2 conclusion, e.g. the candidate solutions need to be studied further, it would be helpful for RAN1 evaluations. |
| Nokia | RAN1 is doing the evaluation/discussion, so no LS needed. |
| LG | It’s too early to send LS to RAN1. |
| Xiaomi | Since RAN2 doesn’t make any agreement on UE grouping, we think it’s too early to send LS to RAN1. |
| Sony | Wait and pending maturity of RAN2 discussion. |

Finally, please let us know if there is any other issue to be discussed.

**Q13: Is there any other issue about UE grouping to be discussed?**

|  |  |
| --- | --- |
| **Company name** | **Comments** |
|  |  |
|  |  |

# Conclusion

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