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. |

## 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: 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. |

**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. |

**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. |

**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. |
| 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. |

**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.**

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| **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. |

## 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?**

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| **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. |

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

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| **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. |

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

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| **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. |

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

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| **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. |

## 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:

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?**

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| **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 |

## 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?**

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| **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 |

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?**

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| **Company name** | **Comments** |
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# Conclusion

# Reference

1. R1-2007425 LS on evaluation methodology for UE power saving enhancements, RAN1
2. [R2-2006608](https://www.3gpp.org/ftp/tsg_ran/WG2_RL2//TSGR2_111-e/Docs/R2-2006608.zip) Power saving enhancements for paging reception Qualcomm Inc
3. R2-2006654 UE power saving for paging procedures ETRI
4. R2-2006690 Paging enhancement in idle inactive mode for power saving vivo
5. R2-2006720 Paging enhancements to reduce UE power consumption Intel Corporation
6. R2-2006729 Discussion on UE Power saving for RRC-IDLE and RRC-INACTIVE State Xiaomi Communications
7. R2-2006774 Paging Enhancements to Reduce Unnecessary Paging receptions Samsung Electronics Co., Ltd
8. R2-2006790 Paging enhancement for power saving OPPO
9. R2-2006874 Solutions to reduce unnecessary paging reception ZTE corporation, Sanechips
10. R2-2006990 Considerations on paging enhancements for Power saving CATT
11. R2-2007115 False Paging Mitigation Apple
12. R2-2007116 Wakeup and Paging Reception Apple
13. R2-2007182 Discussion on reduction unnecessary UE paging receptions Sony
14. R2-2008361 Paging Enhancements for UE Power Saving in NR MediaTek Inc.
15. R2-2007249 Discussion on the UE grouping based solution for idle/inactive-mode UE power saving ITRI
16. R2-2007260 Paging enhancement to reduce unnecessary UE paging receptions Ericsson
17. R2-2007261 Exposure of connected mode TRS occasions to Idle and Inactive mode Ericsson
18. R2-2007437 Paging enhancement for idle inactive-mode UE power saving CMCC
19. R2-2007441 Discussion on paging enhancements Huawei, HiSilicon
20. R2-2007468 Consideration on Idle/inactive-mode UE power saving Lenovo, Motorola Mobility
21. R2-2007562 Potential TRS/CSI-RS occasion(s) Nokia, Nokia Shanghai Bell
22. R2-2007563 IDLE / INACTIVE mode UE power saving Nokia, Nokia Shanghai Bell
23. R2-2007990 Paging enhancement for power saving LG Electronics Inc.