3GPP TSG-RAN WG2 #113 electronic R2-200xxxx

Electronic Meeting, Jan 25 – Feb 5, 2021

Agenda Item: 8.9.2

Source: Intel Corporation

Title: [POST112-e][064][Pow17] Group Determination

Document for: Discussion, Decision

# 1 Introduction

This contribution summarizes the following discussion:

* [Post112-e][064][Pow17] Paging subgroup determination (Intel)

Scope: For how to determine which paging subgroup a UE belongs to, several methods have been proposed, applying hash based on UE-ID similar to today, take into account paging probability, power consumption sensitivity etc. Objective to pave the way for agreements next meeting. Quantitative analysis argumentation is allowed (this is RAN2 scope).

Intended outcome: Report

Deadline: Long

The email discussion is split into 2 phases:

Phase 1: Companies are invited to comment on solution of each of the grouping methods whether they are feasible and on the ‘effectiveness’ of each grouping methods in terms of reducing false alarm and UE power consumption. Deadline is 6th January 2021.

Phase 2: Rapporteur provides summary of the Phase 1 discussion

## 1.1 Contact person

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| **Company** | **Name** | **Email** |
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# 2 Discussion

In RAN2#112e, based on the email discussion in [0], RAN2 confirmed that UE grouping is considered a candidate of paging enhancement for UE power saving. Due to lack of time, the group determination sections were not discussed online.

In the subsequent section, the different UE grouping methods are being described and the available qualitative argument based on the contributions [1-19] for each grouping method is provided. **It would be good that the proponents of different grouping methods can provide some quantitative analysis for the proposed grouping methods.**

## 2.1 Grouping methods

The followings are the different grouping methods that have been gathered from the various contributions:

1. UE ID based grouping [4,5,8]
2. Paging probability based grouping [1,3,6]
3. UE power consumption profile based grouping [9]
4. Network assigned subgrouping [7]
5. UE release [2,5, 7]
6. RRC State grouping [5, 7, 8]
7. Methods considering mobility
   1. UE specific RNTI for Stationary UE paging [3]
   2. Mobility indicator [4]
   3. Dedicated paging group for moving UE [6]
8. Mix of different grouping methods [5,10,12, 16, 15,17]

In the following sections, each of this grouping methods are explained.

### 2.1.2 (1) UE ID based grouping [4,5,8]

On the UE ID based grouping, this approach is to further group the UEs monitoring the same PO into differrent subgroup based on the UE ID. For example as described in [8], UEs mapped to a PO of PF can be further grouped into ‘P’ paging groups where ‘P’ can be signaled by gNB in system information (e.g. as part of paging configuration). A UE belongs to kth paging group, where ‘k’ = (UE\_ID/N\*Ns) mod P, where N is the number of Paging frames and Ns is the number of POs per paging frame.

This method was discussed in [0] and majority of the companies think that UE-ID based grouping can be the baseline. The main qualitative analysis here is that it is simple and is a natural or intuitive extension of the current PO/PF design based on UE-ID. It is also thought that to be most likely effective to reduce false alarm as it can potentially reduce UE unnecessarily receives and decodes paging meassge when many UEs monitor the same paging occasion.

**Q1-1. Do companies have any comment on the high level view of the solution and qualitative analysis of UE ID based grouping to reduce false alarm and improve UE power saving gain for Rel-17 UE? Companies can also add any quantitive analysis (if available).**

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| **Company** | **Comments** | **Proponents‘ response** |
| Ericsson | We agree with this basic description of grouping based on UE\_ID. |  |
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### 2.1.3 (2) Paging probability based grouping [1,3,6]

On the paging probability based grouping, this approach is to further group the UEs monitoring the same PO into differrent subgroups based on the paging probability (i.e. the probability that the UE is paged by the network). For example as described in [3,6], with such grouping, the UEs with low paging probability and UEs with high probability can be split into different subgroups. The solution is similar to the eMTC/NBIoT case where the RAN and the UE are provided with the UE paging probability. Based on the UE paging probability provided by CN, the UE and RAN can determine the subgroup to monitor for a PO of a PF.

The main qualitative analysis here is that UEs with higher paging probability are more likely to cause false paging alarm to UEs with lower paging probability within the same PO, dividing UEs with similar paging probability into one group can reduce the false alarm rate.

**Q2. Do companies have any comment on the high level view of the solution and qualitative analysis of paging probability based grouping to reduce false alarm and improve UE power saving gain for Rel-17 UE? Companies can also add any quantitive analysis (if available).**

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| **Company** | **Comments** | **Proponents‘ response** |
| Ericsson | It is our understanding that this grouping scheme aims towards fairness, i.e. UEs in a group should cause false pages to each other in a fair i.e. equal amount. We do not think that this scheme further reduces the false alarm rate compared to grouping based on UE-ID, i.e. reduction in false alarm rate in first order depends on the number of groups that are used.  This scheme only works (for fairness) when there are different groups with different paging probablities in NR, and when the paging probablities can be determined reliably for individual UEs. |  |
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### 2.1.3 (3) UE power consumption profile based grouping [9]

On the UE power consumption profile, this approach is to further group the UEs monitoring the same PO into differrent subgroups based on the UE power consumption profile. For example as described in [9], with such power consumption sensitivity (PCS) grouping, the UEs with high power consumption sensitivity and UEs with low power consumption sensitivity can be split into different subgroups. Following figure 1 from [9] shows one example of the basic working procedure of the PCS subgrouping method:

AMF

gNB

UE

UE’s Power Consumption Sensitivity (PCS) Reporting

UE’s PCS

Paging Indication

Figure 1. working procedure of PCS subgrouping method

1. UE reports its PCS information (e.g. it is power consumption sensitive, or, its detailed PCS level) to the AMF, during the procedure of Attach request or TAU request. Also, UE could update its PCS information during TAU procedure.
2. AMF informs gNB about the PCS information of the UE.
3. gNB informs UE the subgrouping information of this paging message, e.g. whether power consumption sensitive UEs are paged, or, PCS levels of the paged UEs, by paging early indication or wake-up signal (WUS), or paging DCI.
4. UE decides whether it potentially be paged by checking the indication information in step3. For power consumption UE, only when potentially be paged, it will monitor the following PO(s) or receive PDSCH to check whether itself is paged.

The main qualitative analysis here is that it ican help prevent false paging alarm to UEs with high power consumption sensitivity when network is paging UEs with low power consumption sensitivity within the same PO, and thus help reduced power consumption for these high power consumption sensitivity UEs.

**Q3. Do companies have any comment on the high level view of the solution and qualitative analysis of PCS based grouping to reduce false alarm and improve UE power saving gain for Rel-17 UE? Companies can also add any quantitive analysis (if available).**

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| **Company** | **Comments** | **Proponents‘ response** |
| Ericsson | On a high level the intention of the proposed solution is clear, but details are not clear, for example:   * How to ensure that the information provided by the UE is reliable, i.e. most UEs will prefer a group with a low false paging rate? * How does the UE know to which group it belongs, e.g. PCS level is pre-configured in the UE? * Perhaps one UE is more power sensitive than another UE. But the other UE may receive many more pages, and the false alarm impact also depends on that. Theoretically it might make sense to combine the paging probability with PCS? |  |
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### 2.1.4 (4) Network assigned subgrouping [7]

In this method, the subgrouping is left to the network implementation. The gNB allocates the UE with a subgroup ID before the UE enters idle and inactive mode (e.g. the subgroup ID of a UE can be signalled in the RRC release message to the UE). The network stores the subgroup ID in the CN for an RRC Idle UE; this is done by gNB providing it to the CN for storage. In case of RRC inactive mode, the gNB stores the subgroup ID of a UE as part of the UE context.

During CN paging, the AMF includes this subgroup ID with the CN paging message sent to the gNB and gNB uses the subgroup ID to page UE either in the PEI/WUS or the paging PDCCH.

For RAN paging, the UE context is stored at the source gNB along with the stored subgroup ID in the source gNB node. It is used by the gNB to page UE either in the PEI/WUS or the paging PDCCH for the UE in the RAN paging area.

The main qualitative analysis here is that subgrouping can be left to network implementation to provide further grouping which can be based on network considerations including UE ID, power consumption profile, paging probability etc as discussed in other sections or a combination (the signalling details to be discussed further). There is no need to specify the method(s) used for the subgrouping in the RAN2 specifications and it can be made to be transparent to any UE. This makes the solution flexible, future proof and effective, allowing the network to implement the optimal method rather than be tied to the specified algorithm that may not be optimal for a UE or may not be optimal in the future.

**Q4. Do companies have any comment on the high level view of the solution and qualitative analysis of network assigned subgrouping to reduce false alarm and improve UE power saving gain for Rel-17 UE? Companies can also add any quantitive analysis (if available).**

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| **Company** | **Comments** | **Proponents‘ response** |
| Ericsson | Different gNBs may have different policies how to assign the UE to a group, which may result in a inconsistent configuration in the network. We wonder if a mapping configured during registration would results in a more consistent policy in the network. Furthermore the RAN may not be aware of the paging policy in the CN (e.g. paging escalation), and paging statistics available in CN. | [Intel]:  Our assumption is that the subgrouping configuration will generally be consistent over a registration area. Even if it is not, there should not be any inter-operability issues as the paging subgroup is provided to all the nodes involved in the Page and also to the UE.  We do not see why the paging repetition policy in the CN will directly affect this subgrouping as each CN Paging repetition is treated independently by the RAN. If there is further optimisation to the network algorithm that is possible taking into consideration also CN paging policy, that can be discussed further. |
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### 2.1.5 (5) UE release [2,5,7]

In this method, the subgrouping is based on the UE release. Basically, the Rel-15 and 16 UEs are in no subgrouping while the Rel-17 UEs and beyond are subgrouped. If UE subgrouping is supported by a Rel-17 UE, it needs to be indicated in the UE paging radio capability container stored in AMF for idle mode UE and later shared with gNB during CN paging mechanism so that gNB can perform UE subgrouping for the UEs that support subgroup. This capability information is also needed by the anchor gNB for paging the inactive mode UE via forwarding this capability to the target gNB to perform the paging based on whether the UE support Rel-17 paging enhancement (e.g. subgrouping). For Rel-15 and Rel-16 UEs, such subgrouping will not be performed and the gNB will follow the legacy paging procedure for paging these UEs.

The main qualitative analysis is that if only Rel-15 and Rel-16 UE are paged in a PO of a PF, the gNB will not indicate any subgrouping during this PO when paging the Rel-17 and beyond UE supporting UE subgrouping. This reduces false alarm and improve power saving gain for the Rel-17 UE and beyond Rel-17 UE when only Rel-15/16 UE is paged.

**Q5. Do companies have any comment on the high level view of the solution and qualitative analysis of considering UE release to reduce false alarm and improve UE power saving gain for Rel-17 UE? Companies can also add any quantitive analysis (if available).**

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| **Company** | **Comments** | **Proponents‘ response** |
| Ericsson | It is our understanding that the all the grouping solutions discussed in this email discussion apply to REL-17 (and onwards) UEs only. It seems that this solution is more an observation, than a specific grouping solution? |  |
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### 2.1.6 (6) RRC State or CN vs RAN paging differentiation [5,7,8]

In this method, the RRC\_IDLE UEs are subgrouped separately from the RRC\_INACTIVE UE. As explained in [8], the unnecessary RAN paging reception by the RRC\_IDLE UEs can be avoided if UEs can know in advance that the paging message includes only RAN paging (i.e. it does not include any CN paging). The information indicating presence of only RAN paging or absence of CN paging in paging message can be indicated in DCI/short message. Note that this has no impact to legacy UEs as reserved bit in DCI or short message is used of RAN paging indication. In case WUS/PEI (which is being discussed in RAN1) is agreed, RAN paging or absence of CN paging in paging message can also be indicated in WUS/PEI. This approach also has no impact to legacy UEs as WUS/PEI is not processed by legacy UEs.

The main qualitative analysis is that it can prevent false paging alarm to RRC\_IDLE UEs when perfoming RAN paging to RRC\_INACTIVE UEs, and thus help reduced power consumption for these RRC\_IDLE UE during such scenario.

**Q6. Do companies have any comment on the high level view of the solution and qualitative analysis of considering UE release to reduce false alarm and improve UE power saving gain for Rel-17 UE? Companies can also add any quantitive analysis (if available).**

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| **Company** | **Comments** | **Proponents‘ response** |
| Ericsson | We are not convinced that this is an efficient or effective way of grouping. Furthermore this only divides UEs into two groups (idle, inactive), and to be effective more groups should be used. This method could potentially be used in combination with another grouping solution. |  |
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### 2.1.7 Methods considering mobility [3,4,6]

#### 2.1.7.1 UE specific RNTI for Stationary UE paging [3]

In this method, it takes into consideration that some UEs may be fixed (e.g., industrial wireless sensors) or stay at certain places for a long time (e.g., eMBB UEs in the office during the day or at home during the night). The solution proposed in [3] is to use UE-specific RNTI paging for such UE. These UEs use UE-specific RNTI to monitor paging and the network uses the UE-specific RNTI to page correspondingly.

The qualitative analysis is that this UE can be paged directly without affecting other UEs and thus other UEs can avoid false alarm paging and thus increase power saving gain. [3] also think that such increased paging overhead is acceptable since such stationary UE would not be paged so frequent.

**Q7-1. Do companies have any comment on the high level view of the solution and qualitative analysis of considering stationary UE to reduce false alarm and improve UE power saving gain for Rel-17 UE? Companies can also add any quantitive analysis (if available).**

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| **Company** | **Comments** | **Proponents‘ response** |
| Ericsson | When RNTI based grouping is used this impacts legacy paging when the NW pages the UEs with the full paging bandwidth to reach all the UEs in the cell reliably. Then either the page for the stationary UE is delayed until the next PO (where a similar collision may occur), or the legacy paging is delayed, which is not acceptable. Furthermore, this leads to excessive NW resource wastage as multiple PDCCHs are transmitted to reach both legacy and new UEs. |  |
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#### 2.1.7.2 Mobility Indicator [4]

In this approach, the network indicates whether it is paging a moving UE. [4] provides a quick outline of paging using mobility indicator:

* If the UE is monitoring paging in the cell it was last paged, and the mobility bit is set in Paging PDCCH, then the UE may skip reading following Paging PDSCH
* CN may set the mobility indicator in Paging message when the CN escalates paging, i.e. the CN does not receive paging response from the UE

The qualitative analysis is that paging due to mobility can potentially be a significant factor in the number of Paging messages on PDSCH that the UE receives, i.e. source for false paging. In case the first Paging attempt fails because the UE has moved, and the UE is paged in the complete TA in the next step to limit the overall paging latency, then a lot of pressure is put on the first attempt to get it right. Subscribers move and call in a somewhat predictable way, and intelligent paging strategies are possible, but they would require a substantial effort in the NW implementation, and they cannot be expected to be perfect. By indicating that the paging is due to moving UE via the mobility indicator, it allows UE that is still in the cell that it was last paged to skip those paging and hence reduce false paging alarm and increase power saving gain.

**Q7-2. Do companies have any comment on the high level view of the solution and qualitative analysis of considering paging for moving UE to reduce false alarm and improve UE power saving gain for Rel-17 UE? Companies can also add any quantitive analysis (if available).**

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| **Company** | **Comments** | **Proponents‘ response** |
| Ericsson | On a high level there is some overlap with the solution above, but here stationary means that UE has not moved since last paged, i.e. this solution is more generic, i.e. stationary is defined from a paging perspective. |  |
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#### 2.1.7.3 Dedicated paging group for moving UE [6]

The method is to have one or more dedicated groups for UE not located in the last used cell or not located in a set of cells preconfigured by network.

The qualitative analysis is that by having such dedicated groups for the moving UE (i.e. not located in the last used (paged?) cell or not located in a set of cells preconfigured by network), the UE still in its last paged cell or in a set of cells preconfigured by network to skip those paging and hence reduce false paging alarm and increase power saving gain.

**Q7-3. Do companies have any comment on the high level view of the solution and qualitative analysis of considering paging for moving UE to reduce false alarm and improve UE power saving gain for Rel-17 UE? Companies can also add any quantitive analysis (if available).**

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| **Company** | **Comments** | **Proponents‘ response** |
| Ericsson | This solution overlaps with the solution in 2.1.7.2, except for the „preconfigured“ cells. |  |
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### 2.1.8 (8) Multiple grouping methods [5,10,12, 16, 15,17]

Companies also proposed considering multiple grouping methods. For example, [10] proposes to consider paging probabilities on top of the UE ID based grouping, while [17] suggests considering the CN-RAN paging on top of the UE ID based grouping.

The main qualitative analysis of such combinationof diffferent grouping is that it allows to reduce the false paging alarm further and thus improve UE power saving gain.

**Q8. Do companies have any comment on the qualitative analysis of considering multiple group methods to reduce false alarm and improve UE power saving gain for Rel-17 UE? Companies can also add any quantitive analysis (if available).**

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| **Company** | **Comments** | **Proponents‘ response** |
| Ericsson | The power saving gain of grouping is rather limited, i.e. the first order effect is not due to grouping, but due to generating space between PEI/Paging PDCCH and Paging PDSCH. The grouping solution should be kept simple. It is likely that the solution is not kep simple when solutions are combined.  The grouping based on UE-ID can perhaps be evaluated, but the power saving gains for paging probability, power saving profile and others, will depends on assumptions on the accuracy with which paging probably, power saving profile, etc can be determined, |  |
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### 2.1.9 Any other grouping methods

Please include in the table below any other grouping methods that have been missed:

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| **Company** | **Grouping method** | **Detailed solution** | **Qualitative and/or quantitative analysis** | **Other companies‘ comments** |
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## 2.2 Summary of the email discussion

- To be updated after discussion -

# 3 Proposals

- To be updated after discussion–

# 4 References

[0] [R2-2009784](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2009784.zip) Report of [Post111-e][907][ePowSav] UE grouping (Mediatek) MediaTek Inc. report

[1] [R2-2008952](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2008952.zip) Discussion on paging enhancement Xiaomi Communications discussion

[2] [R2-2009785](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2009785.zip) Paging Enhancements for UE Power Saving in NR MediaTek Inc. discussion

[3] [R2-2010244](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2010244.zip) Paging enhancements for idle/inactive-mode UE Huawei, HiSilicon, British Telecom discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[4] [R2-2009955](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2009955.zip) Paging enhancement to reduce unnecessary UE paging receptions Ericsson discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[5] [R2-2010079](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2010079.zip) Paging Enhancements for UE Power Savings Convida Wireless discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[6] [R2-2009878](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2009878.zip) Consideration on Idle/inactive-mode UE power saving Lenovo, Motorola Mobility discussion Rel-17

[7] [R2-2009274](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2009274.zip) Paging enhancement using UE subgrouping Intel Corporation discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[8] [R2-2009092](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2009092.zip) Paging Enhancements to Reduce False Alarms Samsung Electronics Co., Ltd discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[9] [R2-2010397](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2010397.zip) UE Power profile based UE subgrouping CMCC discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[10] [R2-2010629](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2010629.zip) Further consideration on the UE grouping methods ZTE corporation, Sanechips discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[11] [R2-2008892](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2008892.zip) Power saving enhancements for paging reception Qualcomm Incorporated discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[12] [R2-2009083](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2009083.zip) Paging enhancement in idle inactive mode for power saving vivo discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[13] [R2-2009442](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2009442.zip) Paging enhancement for power saving LG Electronics Inc. discussion

[14] [R2-2009351](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2009351.zip) General requirements for potential paging enhancement Nokia, Nokia Shanghai Bell discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[15] [R2-2009503](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2009503.zip) NR UE Power Save Wakeup and Paging Reception Apple discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[16] [R2-2009893](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2009893.zip) Discussion on reduction of unnecessary UE paging receptions Sony discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[17] [R2-2009642](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2009642.zip) Discussion on the UE grouping method ITRI discussion NR\_UE\_pow\_sav\_enh-Core

[18] [R2-2009464](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2009464.zip) Discussion on UE group based paging OPPO discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[19] [R2-2009502](file:///D:\Documents\3GPP\tsg_ran\WG2\TSGR2_112-e\Docs\R2-2009502.zip) NR UE Power Save False Paging Mitigation Apple discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core