**3GPP TSG RAN WG2 Meeting #117-e**   **R2-220xxxx**

**E-Meeting, 21st February – 3rd March 2022**

**Agenda Item:** **8.9.3.1**

**Source:**  **Intel Corporation**

**Title:** **Summary report of [Pre117-e][007][ePowSav] UE capabilities**

**Document for:** **Discussion/Decision**

# Introduction

This is to kick-off the following offline discussion:

[Pre117-e][007][ePowSav] UE caps Open Issues Input (Intel)

This document aims to summarize the papers from the previous meeting that have been submitted to agenda item 8.9.3 of RAN2#116bis-e related to the open issues on UE capabilities identified as follow:

Company input into Pre117-e-offline

OI 5.1: How to capture UE AS capabilities for PEI/subgrouping in RAN2 TS?

OI 5.2: For TRS/CSI-RS occasion support in Idle and inactive mode, should gNB need to know UE support it?

OI 5.3: UE AS capabilities for RLM/BFD relaxation

# Companies’ point of contact

|  |  |  |
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# UE AS capabilities for PEI and subgrouping

In last RAN1 meeting, the following is endorsed for paging enhancement:

**Agreement**

* FG 29-1 is kept as “Paging enhancement” as follows

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 29. NR\_UE\_pow\_sav\_enh | 29-1 | Paging enhancement | 1. Support paging early indication  2. Support UE subgroup indication |  |  |  | UE does not support paging enhancement | Per UE | N | N | N | For component 2, it is up to RAN2 whether/how to separate the capability for UE subgroup indication  Leave RAN2 to decide whether ‘optional with capability signalling’ or ‘optional without capability signalling’  Leave RAN2 to decide whether Need for the gNB to know if the feature is supported is Yes or No | Optional |

Note that any contents highlighted in yellow mean FFS and to be discussed further in RAN1.

In the above, it leaves the following questions to RAN2:

1. Whether/how to separate the capability for UE subgroup indication
2. Whether ‘optional with capability signalling’ or ‘optional without capability signalling’
3. Whether Need for the gNB to know if the feature is supported is Yes or No

For 2) and 3), RAN2 have already made the following agreement:

* [058] Paging enhancement capability(-ies) (e.g. PEI capability, UEID based subgrouping capability or the combined capability of PEI and UEID based subgrouping) are ‘optional with capability signalling’ as gNB needs to know the paging enhancement capability(-ies) to page the UE

The only remaining question related to PEI and subgrouping is 1)

## Whether/how to separate the capability for UE subgroup indication

On this point, the following view can be gathered from the contributions.

[1] and [10] proposed introducing separate UE capabilities for PEI and paging subgrouping. UE may support PEI only or support both PEI and paging subgrouping. It assumes that there is 1 bit in the DCI payload used to indicate one UE subgroup of a PO or one PO, for a UE supporting PEI but without a subgroup ID. [6] has the same view that PEI could be used alone as a separate feature without subgrouping. [9] also proposed separate the capability for the PEI and subgrouping indication as the PEI is not just used for subgrouping indication but also for TRS/CSI-RS occasions availability indications. [11] also proposed that PEI and subgrouping are separate capabilities: a UE can support PEI without supporting subgrouping but requires UE to monitors the PEI bit associated with subgroup 0 of the subgroup bitmap.

On the other side, [2] proposed to use one UE capability bit to indicate support for both PEI and subgrouping indication as suggested by the RAN1 feature list (29-1). The reasoning is that it is not possible for the UE to just support PEI only (i.e. K=1) while the cell is configured with PEI and subgrouping (i.e. K>1) as UE will not know which paging indication bit to monitor for the paging indication value of {0,1}. The PEI only UE may have to end up using legacy paging when camping on a cell that support subgrouping. [5] held the same view and suggested to treat paging early indication and UE subgroup indication into same FG. [12] also proposed that a single UE radio access capability is sufficient for indicating support of UE-ID based and CN assigned subgrouping, and the definition should be based on support of PEI rather than subgrouping method. Similarly, [13] thinks that when the UE and gNB make the effort to support PEI, it makes sense to further enhance the power saving with subgrouping and hence proposed that PEI support is coupled with UE-ID based subgrouping.

If support of PEI and subgrouping indication (i.e.R1 29-1) is coupled, the next question is whether the UEID based subgrouping is coupled with R1 29-1.

[2] does not think that it needs to be and proposed to include as pre-requisite in R1 29-1 that UE indicating support of R1 29-1 shall also indicate support of either CN assigned subgrouping over NAS message or UEID based subgrouping in the AS capability or both. In this way, the UE can either support CN assigned subgrouping only or UEID based subgrouping only or both.

[5], [12] and [13] on the other hand thinks that the support of R1 29-1 is coupled with UEID based subgrouping. [5] also think that if the RAN receives the CN assigned subgroup ID from AMF, it also means that the PEI is supported.

Based on the above:

* 5 companies think that PEI capability and subgrouping indication/mechanism should be decoupled
* 4 companies think that PEI capability and subgrouping indication/mechanism should be coupled
  + 3 companies further think that AS capability should couple with the UEID based subgrouping support
  + 1 company think that a prerequisite can be added to couple the R1 29-1 with the subgrouping mechanism

From the reasoning given by companies that want to decouple PEI capability and subgrouping indication capability, they seem to think that there is currently 1 bit in the PEI DCI payload for UE supporting PEI only. On the other hand, one company supporting PEI only suggests having a subgroup to handle PEI without subgrouping capability/PEI only capable UE. As pointed out by a couple of companies (e.g. [2], [5] etc.), there are currently no subgroup to specifically handle such PEI only capable UE in a cell when the cell supports subgrouping in which case such UE will use legacy paging. In summary, if a UE supporting PEI only camps on a cell that supports subgrouping, the UE will have to perform legacy paging.

RAN1 has also sent a LS [R1-2200768] related to this as follow indicating that more work is needed if RAN2 separate the UE capability of subgrouping indication from R1 29-1 as follow:

If a separate FG for component 2 is introduced, then for a UE supporting FG29-1 and not supporting UE subgroup indication (i.e. UE supporting component 1 only), subgroup index to be received by the UE is undefined in current RAN1 specification. Introducing a separate FG for component 2 would require further RAN1 specification work.

On the other hand, RAN2 has made the following assumption:

RAN2 assumes that PEI can be used “without” subgrouping. FFS whether the bits in the PEI for subgrouping then need to have any particular meaning, or whether this would be done by just having one subgroup.

From the observation, there are 2 options for R1-29-1:

* Option 1: supports only PEI (i.e. does not have to support subgrouping indication)
* Option 2: supports both PEI and subgrouping indication as in the existing R1-29-1

**2.1-1. Which Options above for R1-29-1 is preferred?**

|  |  |  |
| --- | --- | --- |
| **Companies** | **Option 1/2** | **Comments** |
| Intel | Option 2 | If a cell supports subgrouping (i.e. either UEID based or CN assigned subgrouping or both), UE that does not support K>1 (i.e. UE supports only PEI) will have to rely on legacy paging. In our understanding of RAN1 LS, RAN1 does not currently support PEI only without subgrouping as there is currently no subgroup index just for PEI “without” subgrouping. Even with RAN2 assumption on PEI “without” subgrouping, UE still needs to support subgrouping.  Furthermore, when the UE and gNB make the effort to support PEI, it makes sense to further enhance the power saving with subgrouping |
| InterDigital | Option 2 | Agree with Intel. There’s no real justification to separate these. |
| Samsung | Option 2 |  |
| Xiaomi | Option2 | Considering that currently the PEI DCI format, defined as DCI format 2\_7 is only used for paging subgrouping (may additionally support availability indication of TRS/CSI-RS) and paging subgroup is indicated by PEI only as was agreed in RAN1#106b-e, it makes sense to treat supporting of PEI and UE subgrouping in the same FG.  And RAN1 has made it very clear, if we introduce a UE supporting FG29-1 and not supporting UE subgroup indication (i.e. UE supporting component 1 only), UE’s behavior is undefined in current RAN1 specification. Consider the limited time, we would rather take the simple way of a common FG. |
| OPPO | Option 1 | Response to Intel’s comments “RAN1 does not currently support PEI only without subgrouping as there is currently no subgroup index just for PEI “without” subgrouping”:  Based on the below RAN2 agreement in RAN2#116bis-e, network can support PEI only without subgrouping.   |  | | --- | | If network supports PEI but not subgrouping, the whole SubgroupConfig-r17 is absent. |   Based on RAN1 agreement, K would be equal to 1 in this case. Then, the 1 bit PEI indication for a PO can be used to indicate whether all the UEs need to monitor paging DCI in this PO. From UE side, supporting PEI without subgrouping can still monitor the PEI bit. |

For companies that agree to option 2 in 2.1-1, which subgrouping method should the R1 29-1 be associated with:

* Option 2.a: A UE supporting Capability R1 29-1 always supports UEID based subgrouping
* Option 2.b: A UE supporting Capability R1 29-1 supports either CN assigned subgrouping or UE ID based subgrouping or both
* Option 2.c: Others

**2.1-2. For companies that selected Option 2 in 2.1-1, which above Option does companies support?**

|  |  |  |
| --- | --- | --- |
| **Companies** | **Option 2.a/2.b/2.c** | **Comments** |
| Intel | Option 2.b | We prefer to allow the UE to choose the subgrouping methods without making 1 of them by default to R1 29-1. However, we are fine to go with the majority |
| InterDigital | Option 2.a | The UE-ID calculation is a very simple calculation that doesn’t warrant having a separate capability. It also simplifies the behaviour overall. It can be easily verified with a RAN5 test even if only CN based grouping has been IoT tested (which anyway seems unlikely – UE-ID based seems like the more straightforward method to use in initial deployments at least, and probably would be the most commonly used since it does not require CN to be upgraded). |
| Samsung | Option 2.b | Same view as intel |
| Xiaomi | Option 2.b |  |

RAN2 agreed to the following:

**[058] UE’s capability of supporting the UE ID based subgrouping is reported to RAN by AS UE capability signalling**

For companies that agree to Option 1 in 2.1-1 or Option 2.b in 2.1-2, the above UE capability may need to have a pre-requisite below:

UE supporting UEID based subgrouping shall indicate support of R1 29-1

**2.1-3. For companies that selected Option 1 in 2.1-1 or Option 2.b or 2.c in 2.1-2, do companies agree to add the above pre-requisite to the UE capability signalling of supporting the UEID based subgrouping?**

|  |  |  |
| --- | --- | --- |
| **Companies** | **Yes/No** | **Comments** |
| Intel | Yes |  |
| Interdigital | Yes | Although we did not select option 1 or option 2b, we think that if those are selected, then this dependency would be needed. |
| Samsung | Yes |  |
| Xiaomi | Yes | Since a UE supporting Capability R1 29-1 supports either CN assigned subgrouping or UE ID based subgrouping or both, then UE supporting UEID based subgrouping implicitly indicates support of R1 29-1. |
| OPPO | Yes | Subgrouping has to work with PEI, but PEI can work alone. |

**2.1-4. For companies that selected Option 1 in 2.1-1 and Option 2.b or 2.c in 2.1-2, companies need to decide on the granularity and the need of FRx and Xdd differentiation for the UE capability signalling of supporting the UEID based subgrouping:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Companies** | **Granularity (per UE, per band, per BC etc.)** | **FRx diff**  **(Yes/No)** | **Xdd diff**  **(Yes/No)** | **Comments** |
| Intel | Per UE | No | No |  |
| InterDigital | Per UE | No | No | Although we did not select option 1 or option 2b, we think that if those are selected, then no need to differentiate further than per UE. |
| Samsung | Per UE | No | No |  |
| Xiaomi | Per UE | No | No |  |
| OPPO | Per UE | No | No |  |

# UE AS capabilities for TRS/CSI-RS in idle and inactive mode

RAN1 also have [29-2] in the feature list for this.

The discussion in [1], [6], [8] and [15] seems to be whether it is an optional capability and whether it should be known to the gNB.

[1], [6] proposed that it is an optional AS capability as UE needs to be able to acquire SIBx, identify the TRS/CSI-RS availability indication bits in DCI, etc. and also that it does not need to be reported to the network.

[8] thinks that it is beneficial if the NW knows if there are certain UEs which support this feature and are currently camped in the cell. Hence [8] proposed to define a UE capability for UEs to indicate support for TRS/CSI-RS configuration for Idle and inactive UEs. Likewise, for [15].

[14] just proposed to have UE capability.

Based on the above,

* 2 companies think that it does not need to be reported to the network and can be optional without UE capability
* 2 companies think that it is beneficial to report to the network
* 1 company think it requires a UE capability

In the R1 feature list, the following UE capabilities for TRS/CSI-RS in idle and inactive mode (R1-29-2):

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 29. NR\_UE\_pow\_sav\_enh | 29-2 | TRS resources for idle/inactive UEs | TRS occassions for idle/inactive UEs  1. Support reading TRS configuration from SIB  2. Support receving L1 indication for TRS availability |  | N |  | Lose of power saving gain on AGC, time/frequency tracking in idle/inactive mode | Per UE | N | N | N |  | Optional without capability signalling |

From the rapporteur point of view, capability signalling is typically needed if the gNB needs to configure the feature in connected mode. If the TRS/CSI-RS configuration or availability indication needs to be configured in dedicated signalling, it would seem needed to have capability signalling to let the gNB know. However, the TRS/CSI-RS configuration is currently agreed to be only sent in the SIB and the TRS/CSI-RS usage of the UE is in idle mode and inactive mode, it seems more an optional capability without signalling. On the other hand, there is at least one network vendor that think it is beneficial to report this capability to the gNB so that the network does not waste resources. Hence rapporteur suggests to check for companies’ view on whether UE capability for TRS/CSI-RS in idle and inactive mode is beneficial for the gNB to know:

**3-1. Do companies see it beneficial for the gNB to know the UE capability for TRS/CSI-RS in idle and inactive mode (i.e. Optional AS capability with signalling)?**

|  |  |  |
| --- | --- | --- |
| **Companies** | **Yes/No** | **Comments** |
| Intel | No | We don’t see a need for this but we are ok to follow the majority. |
| InterDigital | No | Optional without capability signalling is fine, this is idle/inactive. We would need capability signalling only if we have dedicated signalling to enable. |
| Samsung | No |  |
| Xiaomi | NO | [8]’s concern is that the network may waste resources (e.g. large SIBs) when there is on UE supporting the feature camped on it. In fact, the NW can broadcast the SIB-x only on UE’s demand.  [8]’s another concern is that the UE may support the feature, but no use it, so it is worth for the NW to know the capabilities of the UEs to at least make sure if transmitted it can be used by some UEs. We do not understand why the UE not use it since it has the capability. |
| OPPO | No | This is the idle/inactivity mode UE’s feature. |

**3-2. If optional UE AS capability signalling is needed for TRS/CSI-RS in idle and inactive mode, companies are invited to provide your views on Granularities for the capabilities e.g. 1) Per UE or 2) Per Band or 3) Per BC or 4) Per FS or 5) Per FSPC);**

|  |  |  |
| --- | --- | --- |
| **Company’s name** | **1) Per UE or**  **2) Per Band or**  **3) Per BC or**  **4) Per FS or**  **5) Per FSPC)** | **Comments, if any** |
| Intel | Per UE | If explicit capability signalling is needed. |
| InterDigital | Per UE |  |
| Samsung | Per UE |  |
| Xiaomi | Per UE? | Depends on 3-1 |
| OPPO | Per UE |  |

**3-3: If optional UE AS capability signalling is needed for TRS/CSI-RS in idle and inactive mode, companies are invited to provide your views on the Need of FDD/TDD differentiation for the capabilities;**

Note: as agreed in RAN2#116bis, FDD/TDD diff capability should be captured as per band signalling.

* From Rel-17 onwards, at least for new capabilities, if a UE capability requires at least FRx or at least Xdd differentiation, it is defined with both FRx and Xdd differentiation in per band signaling, i.e. no new UE capabilities will be defined in the FRX and XDD capability signaling branches.

|  |  |  |
| --- | --- | --- |
| **Company’s name** | **FDD/TDD diff or No** | **Comments, if any** |
| Intel | No | If explicit capability signalling is needed. |
| InterDigital | No |  |
| Samsung | No |  |
| Xiaomi | No |  |
| OPPO | No |  |

**3-4. If optional UE AS capability signalling is needed for TRS/CSI-RS in idle and inactive mode, companies are invited to provide your views on the Need of FR1/FR2 differentiation for the capabilities;**

Note: as agreed in RAN2#116bis, FR1/FR2 diff capability should be captured as per band signalling.

* From Rel-17 onwards, at least for new capabilities, if a UE capability requires at least FRx or at least Xdd differentiation, it is defined with both FRx and Xdd differentiation in per band signaling, i.e. no new UE capabilities will be defined in the FRX and XDD capability signaling branches.

|  |  |  |
| --- | --- | --- |
| **Company’s name** | **FR1/FR2 diff or No** | **Comments, if any** |
| Intel | No | If explicit capability signalling is needed. |
| InterDigital | No |  |
| Samsung | No |  |
| Xiaomi | No |  |
| OPPO | No |  |

# UE AS capabilities for RLM/BFD relaxation

In the last RAN2 meeting, the following is agreed:

*R2 assumes to use AS capability procedure to report UE capability of supporting RLM/BFD relaxation. Details FFS*

[1] proposed to introduce separate capability for RLM and BFD relaxation. [6] proposed separate optional per UE capability for RLM and BFD relaxation. [16] proposed using separate AS capability procedure to indicate UE capability of supporting RLM/BFD relaxation and both of them should be optional.

[8] on the other hand think it is not clear if NWs would be interested if UE support RLM/BFD relaxation feature with an intent to save UE power and proposed RAN2 to further discuss the presence/absence of UE capability for RLM/BFD relaxation feature.

[17] proposed one capability indicator of supporting RLM/BFD relaxation, finer granularity for UE capability is not needed.

Based on the above,

* 3 companies think separate capabilities are needed for RLM and BFD relaxation
* 1 company think 1 capability is sufficient
* 1 company wants to discuss further the need of UE capability

Note that RAN4 has also agreed to a single UE capability as in the following agreement (See LS R4-2202769):

Introduce a UE capability to indicate the support of RLM/BFD relaxation in general in Rel-17 feature table.

**4-1. Do companies see a need to have a single or two separate optional capability(-ies) signalling for RLM and BFD relaxation?**

|  |  |  |
| --- | --- | --- |
| **Companies** | **Single/Separate capability(-ies)** | **Comments** |
| Intel | Single | As per RAN4 agreement that a single optional capability signalling is sufficient. |
| InterDigital | Single |  |
| Samsung | Single |  |
| Xiaomi | separate capabilities | Note that RAN4 also said in the LS:   * “*The RLM/BFD relaxation is enabled by explicit signaling. The signaling design is left for RAN2.*   ”  So we do not think RAN4 has made the final decision.  For RLM procedure, the downlink radio quality of the primary cell is monitored by UE physical layer for the purpose of indicating out-of-sync/in-sync status to RRC layer while for BFD procedure, the downlink radio quality of each serving cell is monitored by UE physical layer for the purpose of indicating beam failure instance indication to MAC layer. Note that 38.306 also introduce the capability for SpCell BFR Enhancement. So We prefer RLM/BFD relaxation should be independent as well as UE’s AS capability. |
| OPPO | Separate | It would be flexible for UE to indicate as these are independent features. |

**4-2. Regardless of whether a single or two separate capability signalling for RLM and BFD relaxation, companies are invited to provide your views on Granularities for the capabilities e.g. 1) Per UE or 2) Per Band or 3) Per BC or 4) Per FS or 5) Per FSPC);**

|  |  |  |
| --- | --- | --- |
| **Company’s name** | **1) Per UE or**  **2) Per Band or**  **3) Per BC or**  **4) Per FS or**  **5) Per FSPC)** | **Comments, if any** |
| Intel | Per UE |  |
| InterDigital | Per UE |  |
| Samsung | Per UE |  |
| Xiaomi | Per UE |  |
| OPPO | Per UE as baseline |  |

**4-3: Regardless of whether a single or two separate capability signalling for RLM and BFD relaxation, companies are invited to provide your views on the Need of FDD/TDD differentiation for the capabilities;**

Note: as agreed in RAN2#116bis, FDD/TDD diff capability should be captured as per band signalling.

* From Rel-17 onwards, at least for new capabilities, if a UE capability requires at least FRx or at least xDD differentiation, it is defined with both FRx and xDD differentiation in per band signaling, i.e. no new UE capabilities will be defined in the FRX and XDD capability signaling branches.

|  |  |  |
| --- | --- | --- |
| **Company’s name** | **Yes/No** | **Comments, if any** |
| Intel | No |  |
| InterDigital | No |  |
| Samsung | No |  |
| Xiaomi | No |  |
| OPPO | No |  |

**4-4. Regardless of whether a single or two separate capability signalling for RLM and BFD relaxation, companies are invited to provide your views on the Need of FR1/FR2 differentiation for the capabilities;**

Note: as agreed in RAN2#116bis, FR1/FR2 diff capability should be captured as per band signalling.

* From Rel-17 onwards, at least for new capabilities, if a UE capability requires at least FRx or at least xDD differentiation, it is defined with both FRx and xDD differentiation in per band signaling, i.e. no new UE capabilities will be defined in the FRX and XDD capability signaling branches.

|  |  |  |
| --- | --- | --- |
| **Company’s name** | **Yes/No** | **Comments, if any** |
| Intel | No |  |
| InterDigital | No |  |
| Samsung | No |  |
| Xiaomi | No |  |
| OPPO | No |  |

# Conclusion

To be added latter

# References

[1] R2-2200242 Discussion on UE capabilities OPPO discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[2] R2-2200452 UE capability for Rel-17 UE power saving Intel Corporation discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[3] R2-2200453 Draft running CR to 38331 on UE capabilities for Rel-17 UE power saving Intel Corporation draftCR Rel-17 38.331 16.7.0 B NR\_UE\_pow\_sav\_enh-Core

[4] R2-2200454 Draft running CR to 38306 on UE capabilities for Rel-17 UE power saving Intel Corporation draftCR Rel-17 38.306 16.7.0 B NR\_UE\_pow\_sav\_enh-Core

[5] R2-2200463 Discussing on UE capability for Paging enhancement Beijing Xiaomi Mobile Softwar discussion

[6] R2-2200595 Discussion on capabilities for ePowSav vivo discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[7] R2-2201154 UE capability design for paging subgrouping Huawei, HiSilicon discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[8] R2-2201205 R17 NR UE Power Save UE capability aspects Apple discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[9] R2-2201221 Consideration on the UE capability for Paging Enhancement ZTE Corporation,Sanechips discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[10] R2-2200898 Considerations on remaining issues for paging subgrouping CMCC discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[11] R2-2201269 Consideration on Paging Sub-grouping CATT discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[12] R2-2201541 On the co-existence of UE-ID and CN assigned subgroups Interdigital, Inc. discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[13] R2-2201557 Paging Early Indication and Subgroups Ericsson other Rel-17 NR\_UE\_pow\_sav\_enh-Core

[14] R2-2201220 Further Consideration on TRS for Idle and Inactive UE ZTE Corporation,Sanechips discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core

[15] R2-2201556 TRS exposure Ericsson other Rel-17 NR\_UE\_pow\_sav\_enh-Core

[16] R2-2200465 Discussion on RLM\_BFD measurement relaxation Beijing Xiaomi Mobile Softwar discussion

[17] R2-2201156 Discussion on RLM/BFD relaxation and DCI-based power saving adaptation Huawei, HiSilicon discussion Rel-17 NR\_UE\_pow\_sav\_enh-Core