**3GPP TSG-RAN2 Meeting #127bis *R2-240xxxx***

**Hefei, China, 14th October 2024 - 18th October 2024**

Agenda Item: 8.5.4

Source: OPPO

Title: Summary of [109]

Document for: Discussion, Decision

1. Introduction

This is to discuss the offline as follows.

* **[POST127][109][NES] (OPPO)**

 **Scope:** For each direction (N extension vs PF bundling): 1) List proposed options, 2) Discuss to understand each option better, 3) Down select options, 4) Discuss pros and cons for each direction or down-selected options (with the consideration of UE impacts, system impacts and specification job). F2F offline discussion in Brk3 room. => It is extended to long email discussion to continue detailed analysis of pros and cons for each direction.

 **Intended outcome:** Discussion summary in R2-2407598. => Updated discussion summary

**Deadline:** Long email discussion.

1. Stage-1 Discussion

In this section, the defined scope of the post email discussion is further expanded to dig into details.

**2.1 Issue-1: List proposed options**

Based on the conclusion from 125bis

For adaptation of paging occasions in time domain, RAN2 to study
a) bundle paging frames and
b) extend the values of N to have increased interval between PFs (e.g. T/64, T/128 ...) and compensating decrease in number of PFs by increasing POs per PF.

For option-a), as discussed during AT-127 [109], there are multiple sub-options of approach a), for which there is one left issue, i.e.,

Proposal 2 For option-a), R2 further discuss whether to allow gaps between bundled PFs.

* Can be discussed as part of long email discussion.

**Q1-1: for option-a), do you agree to allow gaps between bundled PFs?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Agree/Disagree** | **Comment** |
| Nokia | Agree | This is useful to address potential PO overlap of two adjacent PFs.  |
| Lenovo | Disagree | The MAIN intention of this work is to save network energy by allowing it to sleep as much as possible. This is possible by minimizing paging transmissions and by trying to make transmissions in “one shot” as far as possible. The gap will not allow the network RF to go into deeper sleep state, as it would need to wake up soon for the *next* PF transmission.In our study, collected from various field logs, in R2-2406890, is clear that on an average network has only about 2 UEs (records) to page in a DRX Cycle. So, just one PF (and one PO) is sufficient. Waking up the network unnecessarily is going against energy saving aim. How many POs in each PF will be there is configurable and also the nrofPDCCH-MonitoringOccasionPerSSB-InPO is configurable. |
| vivo | No strong view | We understand the gap is needed to avoid PO overlapping between two consecutive PFs. However, the NES mode is likely to be applied when the cell load is low, and thus the chance for potential PO overlapping issue may be little. |
| CATT | Agree | Share the view with Nokia.it is necessary to avoid the PO overlapping. |
| III | Agree | Potential POs overlapping can be avoided between two consecutive PFs |
| Apple | Agree | Same view as Nokia. It is possible that two adjacent PFs may have PO overlapping, as illustrated in Qualcomm’s contribution (R2-2407163). The related figure is copied below for readiness:The above issue case can be resolved via allowing configurable gap between bundled PF. Thus, we need this NW flexibility to avoid potential PO overlap of two adjacent PFs.  |
| Huawei, HiSilicon | Agree | In general, we agree to allow the flexibility. |
| LGE | Agree | We agree with Nokia’s view. Otherwise, current specification regarding starting point of a PO should be changed. |
| InterDigital | Agree | How short/long the gaps can be left for network configuration. The example provided by Nokia/Apple (to avoid overlapping POs) is a valid reason. |
| Qualcomm | No with comment | We **agree** on the overlapping issue with the adjacent PFs (bundled PFs). However, the size of the gap may vary depending on the number of POs (UEs camped on the NES cell). If the gap is not large enough, then the overlapping cannot be avoided completely; if the gap is too large, it defeats the purpose of bundling the PFs together so that a NES cell may have more deep sleeping time.Additionally, if no impact to legacy UEs, the PFs still need to be distributed for legacy UEs.  |
| Ericsson | Agree | We think having gaps between bundled PFs can be beneficial. One should also consider other features such as PEI when designing these mechanisms, i.e., the coexistence of PEI and bundled PF/POs. In particular, the issue may appear if POs are separated less than when PEI is supposed to be transmitted prior to its associated PO. Otherwise, there can be an overlap.Regarding the value range for those gaps, we do not think there is a need to have large gaps due to its impact on network energy consumption. Furthermore, it should also be possible to configure a bundle of PFs without gaps, i.e. gap = 0 |
| Xiaomi  | Disagree  | If there is gap, we wonder the power saving gain.  |

For option-a), as discussed during AT-127 [109], there are multiple sub-options, it was a bit difficult to make down-selection between sub-options due to the limited time. So now the attempt as follows to see if any possibility to converge.

|  |  |  |  |
| --- | --- | --- | --- |
| **Option** | **Source** | **Formula** | **Comment** |
| **a-1** | **Intel, 6471** | **(SFN + PF\_offset) mod T = G\*(UE\_ID mod L)** | **L: the number of consecutive PFs within a PF bundle (i.e., PF bundle size)****G: the frame gap between consecutive PFs** |
| **a-2** | **Apple, 6671** | **(SFN + PF\_offset) mod T = (T div N)\*(~~UE\_ID~~ SubGroup\_ID mod N)** |  |
| **a-3** | **Apple, 6671** | **(SFN + PF\_offset) mod T = ~~(T div N)\*~~(UE\_ID Mod N)** |  |
| **a-4** | **CATT, 7004** | **(SFN + PF\_offset) mod T = G\*(UE\_ID mod N)** | **G: the frame gap between consecutive PFs.** |
| **a-5** | **Vivo, 6723** | **(SFN + PF\_offset) mod T = SFN [(UE\_ID mod N)]** |  |
| **a-6** | **Vivo, 6723** | **Rel-19 PF = legacy PF +[ (UE\_ID mod (N\_new/N+factor)) – (factor-1)]** |  |
| **a-7** | **Lenovo, 6809** | **only one fixed PO is used in a cell specific Paging DRX Cycle** | Lenovo: This is also option-b) in our understanding. Please see our responses below. |
| **a-8** | **Samsung, 6348** | **(SFN +PF\_Offset) mod T = (D div N) \* (UE\_ID mod N).** | **N (#of PFs in duration D at the beginning of DRX cycle) = D, D/2, D/4, D/8 ,..** |
| **a-9** | **III, 7531** |  |  |

**Q1-2: For option-a), which sub-option you prefer?**

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| --- | --- | --- |
| **Company** | **Preferred sub-option** | **Comment** |
| Nokia | a-1 | We prefer the options, which provide a gap between adjacent PFs. Options a-4 and a-8 also work as long as N can be configured differently from the legacy N for legacy paging. Additionally it might be worthwhile to consider having possibility for two (or more) PF bundles per paging cycle in order ensure sufficient capacity.  |
| Lenovo | a-7 | We think a-7 can also be counted as option-b i.e., extend the values of N to have increased interval between PFs (e.g. T/64, T/128 …T/N). It will lead to just one PF in the DRX cycle. And since this is just “one” PF, in that sense we have successfully bundled the PFs in this “one” PF. So, its technically also option a. The companies worried about “capacity” should show a need first. We do not think that number of UEs are substantially (like 10-fold) increase in Rel. 19. |
| Vivo | a-1/a-3/a-5 | We are OK with a-1/a-3 and the selection between them depends on the conclusion of Q1-1. We would like to also support a-5 (as proponent) as it can indicate the Rel-19 PFs position (e.g., list of SFNs) directly. UE finds the corresponding index of entry in the SFN list based on its UE ID, and then finds the corresponding SFN value based on its index. |
| CATT | a-4 | It allows gaps between bundled PFs when G >1. And N can be configured differently from the N for legacy paging if separate paging parameters are configured for legacy paging and Rel-19 NES paging daptation. |
| III | a-1 | a-1,a-4, a-8 provide gap consideration in the bundling PFs. And a-1 is more general form than a-4 and a-8. |
| Apple | a-1or a-3 (if majority view is not to consider gap between bundled PFs) | Same view as Nokia on configurable gap.On a-1 vs a-8, we think they are essentially same. To make progress, we suggest to use a-1 for further evaluation.On a-4, we think it actually doesn’t work. You can try some values as example. If the gap term is changed (i.e. T div N->G), you have to also correspondingly change the term N in (**UE\_ID mod N).**  |
| Huawei, HiSilicon | None | Among the options, a-1 seems to be most compatible with legacy formulation: use G to replace (T div N) and use L to replace N. We understand that the agreement “*RAN2 observe that the option-a) and option-b) can be designed to configure the Pos at same time position*” is based on a-1, and RAN2 has not inspected carefully whether this agreement applies to other options.However, all of the options will cause R19 NES Ues and legacy Ues to use different formulae, it is unclear whether the PFs calculated by new formula and the PFs calculated by legacy formula will have some overlap and whether there would be any risk with this. On the other hand, if the two sets for PFs are totally non-overlapping, the gNB power consumption will be increased rather than decreased.  |
| LGE | a-4 | We prefer the option a-4. The options which provide a gap between adjacent PFs can be a candidate option. There isn’t a major performance difference among candidate options. There are only preference differences. For option a-4, it reuses most of legacy equation. It only applies one new parameter “G” to express the concept “gap” which is the frame gap between consecutive PFs. |
| Samsung | a-8  | Prefer to have formula similar to legacy formula. Legacy formula distributes PFs over duration T whereas intention of PF bundling is to enable distribution over a short interval (D) at the beginning of T. So just replacing (T div N) by (D div N) is sufficient. Number of PFs (N) for PF bundling can be signalled similar to legacy i.e. , D/2, D/4, D/8 ,..in place of , T/2, T/4, T/8 ,.. |
| InterDigital | a-1/a-2/a-8 | a-1 can achieve configurability of gaps between PFs. A-2 and a-8 can be considered alternatively. All options indeed result in a formula change. |
| Qualcomm | none | As commented to Q1-1, a configured gap may not be optimal, i.e. trade-off between overlapping and power saving.Additionally, as concluded from the offline “*RAN2 observe that the option-a) and option-b) can be designed to configure the Pos at same time position*”, where option-a has spec impact (i.e., the equations are under discussion here) and option-b has least spec impact. At such late stage of NR, don’t see good reason to go to the option with more spec work. |
| Ericsson | a-1 or a-4 (assuming that N can be configured separately for legacy and Rel-19 Ues) in principle | The value range for parameter G needs more discussion. We should clarify whether the term “frame gap” implies that parameter G is one or multiple frames long. We do not see the need for such as it should be possible to configure a gap in order of slot(s). Note that long gaps may diminish the purpose of PF bundling and minimize the number of opportunities for the network to sleep. As we mentioned above, it should be possible to configure these gaps to zero, i.e., there are no gaps between PFs in a bundle.Another aspect that needs to be considered is the possibility to configure the PF/Pos so that some Rel-19 Ues can share the PF/Pos with legacy Ues. |
| Xiaomi  | None  | We disagree the gap. |

On the other hand, there seems no much further details to clarify for option-b).

Overall, it is good to understand if there is any major issue missing, in order to clarify either option.

**Q1-3: Besides the issues above, any major issue remains, in order to clarify the key idea for either option-a) or option-b)?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Any major left issue?****Yes/No** | **Comment** |
| Nokia | Yes | When we have bundled paging occasions then likely we would need to also accommodate PRACH resources so that they are “aligned” with bundle. |
| Lenovo | No | In Rel. 19 we do not want to have any further enhancements. This is because:1. Network can “spread” paging across cycles, keeping the cycle length short if required. Paging is anyway hit and trial (network does not know where the UE is inside of its RA).
2. The field operation must even today be capable to handle 4-5 MO calls being established in the same short time period…even assuming 10 UEs being paged in rf128 paging cycle.
 |
| CATT | Yes | In RAN2#125bis, it was agreed:1. *From the UE point of view, UE will monitor one PEI/PO every paging DRX cycle, i.e. the UE doesn’t skip PO in paging DRX cycle.*

We need to discuss how to ensure UE will monitor one PO every paging DRX cycle with option-b). For example: T is 64 radio frames while N is T/64 is broadcasting system information for option-b). The T of a UE is 32 radio frames as T in the UE is determined by the shortest of the UE specific DRX value configured by RRC (if any), the UE specific DRX value configured by upper layers (if any), and a default DRX value broadcast in system information. Then N is 1/2 for the UE with option-b) which means there may be no PF in every paging DRX cycle. In order to ensure UE monitors one PO every paging DRX cycle, we can clarify that the UE can return to legacy paging mechanism if suitable legacy paging parameters for network power saving are configured or N can be equal to 1 in this case. |
| III | Yes | Option-a will lead to SSB period change if the interval of PFs was reduced due to bundling. Option-b may increase more Pos(more than 4) in one PF(N=1), the signalling overhead and associated PMOs should be checked. |
| Apple | No major issue, but with comments | * On Nokia comments, we are confused why RACH makes difference. RACH resource is configured by the Network. Thus, NW implementation can already flexibly allocate RACH resource, considering possible paging collision. Meanwhile, RAN1 has introduced RACH adaptation via additional RO set. If NW has concern, it can just dynamically activate additional RO set in bundled PF frames. Maybe Nokia can further clarify the issue.
* On Lenovo comment, we do not agree to challenge motivation of paging adaptation. First, it is WID objective to specify paging adaptation rather than “study”. If any concern on motivation, company should raise it in RAN plenary to revise WID objective rather than WG. Secondly, as far as we know, >99% RRC candidate parameters are not used in practical 5G deployment, but it doesn’t mean these are useless because 3GPP needs to consider worst case.
* On III comment, we are also confused why option-a lead to SSB period change. We understand SSB period configuration is independent of paging configuration. Maybe III can further clarify the issue.

  |
| LGE | No | Selecting simple sub-option of option-a is needed since time budget for NES is only 1 TU in Rel-19. |
| Qualcomm | No | At such late stage of NR, selecting a least spec impact option is more realistic with only 1 TU time allocation. |
| Ericsson | Yes | We have a similar opinion with Nokia regarding the need to adapt PRACH resources so that random access occasions can be bundled with paging occasion bundles. As Apple mentioned above, RAN1 has agreed to introduce adaptive PRACH resources so it would be good to check/confirm that the proposed adaptation can address such need. |
| Xiaomi  | No  | Support to do down selection in phase 2.  |

**2.2 Issue-2: Discuss to understand each option better**

It seems the scope is the same as issue-1 above.

**2.3 Issue-4: Discuss pros and cons for each direction or down-selected options (with the consideration of UE impacts, system impacts and specification job)**

Although this is the last bullet in email scope, it seems helpful to discuss this first, before going to the 3rd bullet here.

From email rapporteur perspective, it seems clearer that option-b) has requires less specification effort since it aims at keeping the legacy formula as it was, and the effort comes from the additional value range for the corresponding parameters. While option-a) would come with a revised formula.

**Q2-1: Given that option-b) tends to keep the legacy formula as it was but just extended value range, while option-a) tends to go for a revised formula, do you agree that the specification job for option-b) is less?**

|  |  |  |
| --- | --- | --- |
| **Company** | **Agree/Disagree** | **Comment** |
| OPPO | Agree | For the comments on additional RRC signaling: 1. For the configuration of PMO location, based on Figure-1, the PMO location of different PFs is actually repetitive, i.e., same offset applies PMO w.r.t each associated PF. So, the need of additional RRC signaling of option-b) essentially comes from whether one wants to allow configurability for each PMO, or a repetitive pattern is also acceptable.
2. For the configuration of PMI-O location, similar situation as for PMO. Furthermore, we disagree that a higher *po-numPerPEI* value would decrease the performance, since each PEI would contain per-PO and per-subgroup bit, so there is false alarm issue to the UEs. On the contrary, single PEI transmission helps the network to save power, so actually higher *po-numPerPEI* value improves the system performance in our view.
 |
| Nokia | Agree |  |
| Lenovo | Agree, and… | We would like the solution A-7 to be counted in option-b) as well (or more option-b than a). |
| CATT | Agree |  |
| III | Agree, but | Option-b seems no impact to formula of PF, but the increasing POs and related PMOs to SSB mapping may need more discussion. |
| Apple | Yes for TS 38.304FFS for TS 38.331 and RAN1 spec | On TS 38.331, we identify at least below two spec changes needed for option a:1. RRC needs to extend existing PCCH-config to add new values on *nAndPagingFrameOffset*, *Ns* and *firstPDCCH-MonitoringOccasionOfPO*

On *firstPDCCH-MonitoringOccasionOfPO*, please note that existing value depends on max Ns (i.e. maxPO-perPF is 4 in legacy):firstPDCCH-MonitoringOccasionOfPO CHOICE { sCS15KHZoneT SEQUENCE (SIZE (1..maxPO-perPF)) OF INTEGER (0..139),1. Because existing PEI only allow up to 4 PO in one PF to assocaite with one PEI-O and 8 PO in 2 PFs to associte with one PEI-O, RRC needs to also extend existing PEI configuration to add new valuse on *po-NumPerPEI-r17* and *pei-ConfigBWP-r17.*

On *pei-ConfigBWP-r17,* please note that existing value depends on max Ns (i.e. *maxPEI-perPF-r17* is 4 in legacy):pei-ConfigBWP-r17 SEQUENCE { pei-SearchSpace-r17 SearchSpaceId, firstPDCCH-MonitoringOccasionOfPEI-O-r17 CHOICE { sCS15KHZoneT SEQUENCE (SIZE (1..maxPEI-perPF-r17)) OF INTEGER (0..139),So, if Ns is increased to 8, it means PEI-O can only associate with first 4 POs in PF with Ns=8 if *po-numPerPEI* =1, or only supporting *po-numPerPEI* >=2, which will decrease PEI performance. This issue will become worse if Ns is increased more than 8 (e.g. 16).  |
| Huawei, HiSilicon | Agree |  |
| LGE | Agree |  |
| Samsung | Agree |  |
| InterDigital | Agree |  |
| Qualcomm | Agree |  |
| Ericsson | Somewhat agree | While it may be straightforward to extend the value range, the potential issue with option-b) is how to allocate UEs to those POs associated with a single PF. In particular, the question is whether the existing scheme can address this potential issue with no update/change, especially considering that there should be no impact on legacy UEs. This may eventually make option-b) more/as complicated than/as option- a). |
| Xiaomi  | Agree  |  |

And then the option-a) would be motivated only if there is a major performance difference. While during AT-127, as clarified and concluded



**Figure 1 Option-a) vs. Option-b) in terms of PO location in time domain (discussed in AT-127 [109])**

As clarified in 304 as follows:

NOTE 1: A PO associated with a PF may start in the PF or after the PF.

NOTE 2: The PDCCH monitoring occasions for a PO can span multiple radio frames. When *SearchSpaceId* other than 0 is configured for *paging-SearchSpace* the PDCCH monitoring occasions for a PO can span multiple periods of the paging search space.

And thus 127 agreed that

Proposal 3 R2 observe that the option-a) and option-b) can be designed to configure the PO:s at same time position.

**Q2-2: Given clarification (as concluded in R2#127) that PO does not have to be limited to the time period of the corresponding PF, and thus option-b) can reach same time position for POs, do you think there would be a major difference for the system performance of the two options? If Yes, please clarify the difference in your view.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Any major performance difference? Yes/No?** | **Comment** |
| OPPO | No | Based on same time position for the PO:s, we have not understood the reason for a performance difference between the two options. More details: 1. For the impact to PMO availability: As calculated by Apple below, if squeeze all POs into a single PF, it would lead to the consequence that no available PMO for non-paging usage. But (also clarified by Apple), if following the distribution by Figure-1, there would be no such paging-PMO congestion issue, i.e., it is up to network implementation.
2. For the signaling overhead due to additional RRC signaling: As replied in Q2-1, the necessity of it depends on whether repetitive pattern (similar to option-a) is acceptable or not (should be so if one prefers option-a)). Furthermore, the calculation for option-b) based on 32 radio-frames is too much, since the original intention is to restrict the frames with PO, rather than scattering it in the whole T radio frames…
 |
| Nokia | No | We have not identified any major difference between options – with appropriate parameter selection they can look rather same. |
| vivo |  | We have some concern on opt.b for that it may have signalling overhead issue in some cases as it needs more bits in the SI to indicate *firstPDCCH-MonitoringOccasionOfPO* for additional POs of opt.b. In the table below, we analyze the additional signaling overhead of opt.b compared to opt.a when SCS is 30kHz and T is 320ms for instance.【vivo2】：Revise the table. |
| CATT | No |  |
| III | No | When configureing the PO:s at same time position, this make no difference for option-and option-b.  |
| Apple | No major difference, but it does have difference. | First, we think there is one difference between option a and b: compared with option b, option a provides more flexibility / balance of common CORESET / SearchSpace distribution / usage in PF. For example, we assume that there are totally 60 PMOs in one PF and 4 POs (i.e. Ns=4) will occupy 32 PMOs (e.g. 8 SSB) in legacy. Then, it will make below difference between option a and b:* Option a: it will result in that PF has 32 PMO occupied for paging and remaining 28 PMOs can be used by NW for SI/PWS or other common signalling. And the adjacent is bundled PF which also has 32 PMO occupied for paging (i.e. same as previous PF).
* Option b: assuming Ns is increased to 8 (i.e. 8 PO), it will result in that PF has all 60 PMO occupied for paging, and the adjacent frame has 4 PMO occupied for paging. It also implies PF may not have common CORESET / SearchSpace for SI/PWS because all PMOs are used for paging due to Ns increasing to 8.

In above example, option a can achieve more balanced PMO allocation in PF and adjacent frame. But we tend to think this issue can also be addressed by smart NW implementation. So, it seems not a major issue.We also agree with vivo to study the signaling overhead impacts. Meanwhile, we need to consider legacy UE impacts. If legacy UEs have to co-exist with Rel-19 UEs, we also think there are some differences, which need further analysis.  |
| Huawei, HiSilicon | No |  |
| LGE | No | However, there would be a minor difference for the system performance depending on each option’s detail. |
| Samsung | No | We do not see any difference in performance. Do not agree with Apple’s analysis. By proper configuration of *firstPDCCH-MonitoringOccasionOfPO,* both options will have same usage of PMOs.On signalling overhead:* For option a, max number of POs per PF is 4. So *firstPDCCH-MonitoringOccasionOfPO* is signalled 4 times.
* For option b, *firstPDCCH-MonitoringOccasionOfPO* is signalled X times, X is number of POs per PF where X can be greater than 4.
* In option a), there is no flexibility in allocating starting PMO independently for each PO in the bundle. In option b), there is flexibility in allocating starting PMO independently for each PO. In our view, it is good to this additional flexibility.
 |
| InterDigital | No | Similar system performance can be achieved with both options.  |
| Qualcomm | No | For power saving and latency, no difference. |
| Ericsson | Not in terms of performance but | We observe that by only relying on option-b) one may need to increase the value range of Ns significantly in order to provide sufficient paging capacity. Introducing excessive values for parameter Ns may result in many new parameters (e.g., one new firstPDCCH-MonitoringOccasionOfPO would have to be introduced for each PO since all POs are associated to a single PF), and hence a complicated configuration. This needs further discussion. |
| Xiaomi  | No  | There is no difference for energy saving gain and paging latency, but option b has less spec impact.  |

1. Stage-2 Discussion

**2.4 Issue-3: Down select options**

Given the clarification during 127 and the discussion above, it would be helpful to understand companies view, regarding the two options.

1. Conclusion

Based on the offline, we reached the following WF