3GPP TSG-RAN WG2 Meeting #125 Tdoc R2-24xxxxx

Athens, Greece, February 26th - March 1st, 2024

Source: Ericsson (rapporteur)

Title: [POST125][017][XR] PDCP report

Agenda item: 7.5.3.3

Document for: Discussion, Decision

# 1 Introduction

This contribution intends to provide a report for the post meeting discussion as below:

* [POST125][017][XR] PDCP report (Ericsson)

Intended outcome: Start with joint paper proposal to get further inputs from companies that haven’t yet provided their views, suggest and review the TP.

Deadline: Long

This email discussion will be organized in two phases. In the 1st phase, we will collect company views on the leftover joint proposals from [2]. In the 2nd phase, based on the outcome of the 1st phase, we will provide a set of proposals and corresponding TPs for perusal and further comments.

The deadline for providing company views are as follows:

|  |  |
| --- | --- |
| 1st Phase | 22nd March 2024, 10 UTC |
| 2nd Phase | 29th March 2024, 10 UTC |

# 2 List of Joint Proposals

The following are the agreements from the RAN2#125 meeting [18]:

**Agreements**

1. To define a mechanism for PDCP Transmitter to report to PDCP Receiver about the gap on the PDCP SN (i.e., transmitting PDCP entity can inform the receiving PDCP entity about the discarded SDUs).

2 To agree that the usage of a PDCP SN gap report is under network control (i.e. network configures UE whether/when PDCP SN gap report can be used). The UE should report only if there gaps (i.e. if the UE does re-association and there are not gaps, the UE is not required to transmit).

3 Define a new UE capability to indicate the support of PDCP SN Gap reporting.

The intended outcome as stated above is to get further input from companies on these joint proposals. Further, also gather company inputs on the related TPs. The proposals from the joint contribution [2] are as shown below, given that P1/P2 and part of P4 have already been agreed, we will focus on the other set of proposals.

***Proposal 1.*** *To define a mechanism for PDCP Transmitter to report to PDCP Receiver about the gap on the PDCP SN (i.e., transmitting PDCP entity can inform the receiving PDCP entity about the discarded SDUs).*

***Proposal 2.*** *To agree that the usage of a PDCP SN gap report is under network control (i.e. network configures UE whether/when PDCP SN gap report can be used).*

***Proposal 2.1.*** *To confirm that the usage of a PDCP SN gap reporting is dependent or applicable only when outOfOrderDelivery is not configured.*

***Proposal 3.*** *To agree on PDCP control PDU approach for transmitter to provide PDCP SN Gap reporting to receiver.*

***Proposal 3.1.*** *To discuss whether to enable PDCP SN Gap reporting via: option (A.1) bitmap kind of information, or option (A.2) range kind of information.*

***Proposal 3.2.*** *To discuss whether/which rules needs to be defined in PDCP transmitter entity to trigger PDCP SDU discard report considering e.g. (1) the PDCP entity discards SDU(s) which have not been transmitted (for UM DRBs) or acknowledged (for AM DRBs), due to the expiry of PDCP discard timer; and (2) there is a buffered SDU associated with an SN higher than the SN of the discarded SDU(s), as well as, related TPs included in R2-2401420, R2-2400748 and R2-2313923.*

***Proposal 3.3.*** *To consider the related TPs included in R2-2401420, R2-2400748 and R2-2313923.*

***Proposal 4.*** *To discuss whether to define a new UE capability to indicate the support of PDCP SN Gap reporting. If so, to discuss whether UE supporting PDCP SN Gap reporting shall also support pdu-SetDiscard-r18 and/or psi-BasedDiscard-r18.*

# 3 Discussion

## 3.1 PDCP SN Gap Reporting for *OutofOrderDelivery*

*that the usage of a PDCP SN gap reporting is dependent or applicable only when outOfOrderDelivery is not configured.*

This is a straightforward proposal where if the UE is configured with *OutofOrderDelivery*, then the reordering delays are not applicable. But would be good to confirm company’s views on this proposal.

**Is the PDCP SN gap reporting applicable only when outOfOrderDelivery is not configured?**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| LGE | Yes |  |
| Futurewei | – | Agree that reordering delay isn’t a concern when OOD is configured. However, we may need to study the following case as well:  It is known that peak data rate of XR video (at least DL) can be as high as 150 Mbps, which translates into 12500 1500-byte SDUs per second. When PDU Set transmissions are uninterrupted, 12-bit PDCP SN can very well handle the HFN derivation for this case. However, if PSI-based SDU discard with a non-zero discardTimerForLowImportance is configured and the congestion causes the transmitter to consecutively discard more than 1/6 of a second of video PDUs, a PDCP SN gap greater than 2048 is created at the receiving PDCP entity, which may cause HFN desynchronization, when a next PDU Set (a high-importance one) is transmitted and received. In this case, if the transmitting PDCP entity reports the SN gap, the receiving PDCP entity updates its RX\_DELIV before deriving HFN for the next received PDU and hence avoids HFN desynchronization. The transmitting PDCP entity doesn’t have to report the SN gap each time SDU discarding occurs. It just needs to report when the size of the contiguous SN gap becomes very close to the size of one half of the PDCP SN space.  The alternative is to configure 18-bit PDCP SN, but with a price of one extra byte of overhead for every PDCP data PDU constantly, i.e., even when there is no congestion. |
| Xiaomi | Yes | As for issues mentioned by Futurewei, we think 18-bit PDCP SN can resolve the potential issue. Considering that 1500-byte typical PDCP SDU size (as mentioned by Futurewei), the overhead of 1 byte is only 1/1500 = 0.067%, which is negligible. |
| CATT | Yes | In case outOfOrderDelivery is configured, the receiving PDCP entity shall deliver the resulting PDCP SDU to upper layers after performing header decompression using EHC. There is no PDCP SN gap issue needs to be handled under that case. |
| Huawei, HiSilicon | Yes |  |
| Apple | Yes |  |
| Ericsson | Yes |  |
| Intel | Yes |  |
| HONOR | Yes | When OutofOrderDelivery is configured for receiving side, once the PDCP SDU is successfully received from lower layer, it will forward to upper layer without any re-ordering delay. Thus no extra mechnism is needed in such case. |
| Lenovo | Yes |  |
| Fujitsu | See comment | Agree with the intention.  We think the current outOfOrderDelivery configuration is used for delivery of downlink data. For uplink data, it’s up to the network implementation whether in-order delivery is needed.  PDCP SN reporting can be used for both DL and UL. For DL, if outOfOrderDelivery is not configured, UE will expect to receive PDCP SN report from network. For UL, it may be better to define a new configuration to indicate whether UE should enable PDCP SN reporting. |
| ZTE | Yes |  |
| Nokia | Yes |  |
| Qualcomm | Yes |  |
| Samsung | Yes |  |
| OPPO | Yes |  |
| ITRI | Yes |  |
|  |  |  |

## 3.2 PDCP Control PDU for PDCP SN Gap Reporting

*On PDCP control PDU approach for transmitter to provide PDCP SN Gap reporting to receiver.*

[3][5][8][9][12][13][14][15] believe a new PDCP Control PDU is the simplest way to perform the PDCP SN gap reporting as the headers of the PDCP data PDU are not impacted [3] and, that it was agreed to not introduce in-band marking in Rel-18 XR [15]. Further, as detailed in [9], using the headers of the data PDU could result in a unwarranted size of the PDCP data PDU and due to preprocessing of the header, any changes would require manipulation of the already processed PDCP PDU header resulting in implementation complexities.

[6] on the other hand, suggests that the control PDU is poorly suited for this type of notification as in-band reception can inform the receiver as soon as possible hence, using the header of the data PDU.

So, based on the majority view, we would like to check company’s views on the use of a new PDCP control PDU to perform the PDCP SN gap reporting as a baseline.

**As the baseline, should a new PDCP Control PDU be used for PDCP SN gap reporting?**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| LGE | No | Using a header-only PDU (i.e. PDU without payload) is simple with following reasons:   * PDCP Control PDU can be transmitted only after all the buffered data are transmitted. There is no PDCP Control PDU prioritization rule in current specification. Thus, there is no real benefit to use PDCP Control PDU. * Header-only PDU does not change any state variable handling in Rx operation. On the other hand, with PDCP Control PDU, a new state variable handling operation should be introduced in Rx side.   Futurewei>> we respectfully disagree with this bullet. The whole purpose of providing the SN gap report st o enable the receiving PDCP entity to update ist state variable such as RX\_DELIV when needed, so that: 1) HFN desynchronization can be avoided 2) any PDCP SDUs after the old RX\_DELIV and having been received and stored in the reordering buffer can be delivered to upper layer and the receiving window can slide forward, like what happens after the re-ordering timer expires today. Even if header-based approach is adopted, we expect that state variable handling in the data PDU Rx operation is still needed, potentially complicating the existing data PDU Rx operation significantly. On the other hand, if using PDCP control PDU, the control PDU Rx operation described in [1], [8], and [15] are very similar st o data PDU Rx operation today.  [LGE] You seem to misunderstand the header-only PDU. It is different from Data PDU header indication described in [6].  The header-only PDU contains only SN without any payload. As the SNs are attached to each PDCP PDU, the RX operation is same as legacy, i.e. the RX state variables are updated based on the SN of the header-only PDU.  The change is simple, e.g. just adding a text “**if SN gap would occur due to discard of a PDCP SDU, the PDCP entity discards the payload of the PDCP PDU instead of discarding the PDCP SDU**”.  The Control PDU solution requires additional handling of RX state variables based on the Control PDU, and thus it complicates the RX operation.   * The Tx operation with header-only PDU is simple. When a PDCP report is triggered, the UE just removes the payload from the discardTimer-expired PDUs.   Futurewei>> we respectfully disagree with this bullet. It will significantly complicate the data PDU Tx and Rx operations when all details are considered. Please see point #3 in our analysis below.  [LGE] Still you seem to misunderstand the header-only PDU. There is no change in Tx and Rx operation with header-only PDU.   * If the header-only PDU is used, further discussion such as 3.2.1 and 3.2.2 are not needed. |
| Futurewei | Yes | There are a number of issues with PDCP data PDU header based approaches, as follows:   1. Using PDCP data PDU header to report the SN gap is slower than using PDCP control PDU because the PDCP data PDU is submitted st o RLC entity in-sequence while the PDCP control PDU is prioritized over any PDCP data PDUs that has not been submitted st o RLC entity yet, according st o following text from 38.323:     [LGE] PDCP Control PDU is prioritized over PDCP Data PDU in PDCP entity, but it is not prioritized in RLC entity. The SN gap reporting is triggered when PDCP SDUs are discarded in the RLC entity and following PDCP SDUs are stored in the RLC buffer. Thus, the PDCP Control PDU can be transmitted only after all PDCP SDUs stored in the RLC buffer are transmitted.  And, the PDCP control PDU can be generated and submitted st o RLC as soon as the transmitting PDCP entity, after having discarded some low-importance PDU Set(s), determines that the next PDU Set is a high-importance one, i.e., as soon as the first PDCP SDU st o high-importance PDU Set arrives. But if using PDCP data PDU header, one st o wait until the first PDCP SDU st o high-importance PDU Set has finished the header compression, integrity protection, and cyphering, and all PDCP data PDUs queued before it have been cleared.   1. According to [6], the SN gap is reported by inserting the number of contiguous SNs being discarded immedicately prior st o PDCP SN st o current PDCP data PDU. First, as we described in our response to Q3.1, consecutively discarding more than 1/6 of a second of video PDUs may cause HFN desynchronization if 12-bit PDCP SN is configured. If the COUNT value st o current PDCP data PDU cannot be correctly reconstructed in the first place, the discarded COUNT values cannot be correctly indicated either with the number of consecutively discarded SNs. Secondly, even without HFN desynchronization, design in [6] works only if the discarded PDCP SNs are always contiguous. However, the LS (R2-2400088) we just received from SA4 indicates that packets may arrive out of order. E.g., a base layer PDU Set (persumably with high-importance) and a spatial enhancement layer PDU Set (persumably with low-importance) generated from a same video picture may arrive at the gNB out-of-order and interleaved and hence their COUNT values may be interleaved. When the spatial enhancement layer PDU Set is discarded due to PSI based discarding under congestion, there is no guarantee that the discarded PDCP SNs are always contiguous.   [LGE] Header-only PDU is different from Data PDU header indication described in [6]. Such problem does not occur in header-only PDU.   1. Since the SN gap report is not always present in the PDCP data PDUs, there must be an indication bit in every PDCP data PDU header to indicate the presence or absence st o SN gap report. But because discarding may occur after the integrity protection and cyphering has been done, this presence bit (as well as the inserted SN gap report) must be excluded from the computation of integrity protection and cyphering, and the receiving PDCP entity must mask this presence bit when performing decyphering and integrity verification. If the SN gap report is inserted as a new field in the PDCP header, not as a trailer st o PDU (i.e., after the MAC-I field), the receiving PDCP entity also needs to remove the SN gap report before performing decyphering and integrity verification. All these extra steps significantly complicate the data PDU Tx and Rx operations.   [LGE] Header-only PDU is different from Data PDU header indication described in [6]. Such problem does not occur in header-only PDU.  On the other hand, if PDCP control PDU is used, the control PDU Rx operations described in [1], [8], and [15] are very similar st o data PDU Rx operation today. Except the triggers, the control PDU Tx operations described in [8] and [15] are very similar st o Status Report Tx operation today. The data PDU Tx operations remain completely intact and the data PDU Rx operations almost remain intact, as described in [8] and [15]. Hence, we support using PDCP control PDU to report SN gap. |
| Xiaomi | Yes |  |
| CATT | Yes | We see the similarity between SN gap reporting and status reporting, it is preferred to reuse a new PDCP Control PDU for PDCP SN gap reporting. |
| Huawei, HiSilicon | Yes | As mentioned by the rapporteur, using UP packets to carry this information would violate previous agreements which were made to avoid substantial impacts to UP processing and implementation, so this is not a proper way to handle this. In addition st o reasons introduced by the rapporteur, we think control PDU should be used because:   1. This is control data so using user packet header is not appropriate. 2. For C-PDU we can easily inherit the design from PDCP SR.   [LGE] You seem to misunderstand the header-only PDU. It is different from Data PDU header indication described in [6].  The header-only PDU does not contain any control data but only contains SN without any payload. As the SNs are attached to each PDCP PDU, the RX operation is same as legacy, i.e. the RX state variables are updated based on the SN of the header-only PDU.  To reply to LGE’s comments:   * Priority of C-PDU: this is up to UE implementaiton so a smart UE would send it as soon as possible.   [LGE] In PDCP specification, it is specified that the Control PDU is prioritized over Data PDCP. But, in RLC, there is no such prioritization specified. The RLC does not differentiate the contents of RLC SDUs, and only transmits in the receiving order, i.e. first-in-first-out.   * We do not see how the solution can work without changing state variables at the receiver side. The whole point st o solution st o avoid reoredring delay and avoid window stalling. Hence updating the variables is necessary.   [LGE] You seem to misunderstand the header-only PDU. It is different from Data PDU header indication described in [6]. Updating the state variable is definitely necessary. With header-only PDU, the RX state variables are updated same as legacy.   * Of course we need to discuss how the discarded SNs are provided for both solutions, so we are not sure about the last point from LGE * If the intention st o send all discarded PDUs with just an SN number, then we are concerned about the delay of providing this information as well as ist overhead. |
| Apple | Yes | To notify the receiver which SDUs are discarded, we think it is more generalized and straightforward to report a bitmap. Since the existing PDCP control PDUs already have fields based on bitmap structures, we believe a new control PDU reusing such bitmap structure for discarding notification seems to be a simpler approach. |
| Ericsson | See comments | From a specification standpoint, we believe that the header-only PDU looks like a reasonable solution as described by LGE. Even with the header-only solution, the state variables (RX\_NEXT and RX\_DELIV) would need to be updated, I assume what LGE meant by “no change“ is that the state variables update would be based on the current receive operation as described in Section 5.2.2 with the addition of handling the header-only PDU with zero data size. From an implementation standpoint also we think the header-only PDU is a good solution and as the reception is in-band (i.e., no prioritization needed) this has least impact on implementation. Even for the case when the PDCP PDUs are preprocessed, since the headers are not ciphered, the RLC can peek into the SNs of the PDUs to perform the removal of the data part of the PDU and retain the header.  The specification impact would be restricted to a new section for e.g., 5.2.2.4 and something like the following: 5.2.2.4          Actions when <discard indication header-only> is received When a <discard indication header-only> is received, the receiving PDCP entity shall:  -    perform actions in 5.2.2.1 for an PDCP Data PDU with the assumed SN as indicated in the < received header-only > and assumed empty payload. Methods for decompression, deciphering and delivery don’t apply to this PDU.  For FWs comment on the the transmission as the first PDCP PDU, it should be noted that the current PDCP SR is sent only in cases of reestablishment/data recovery. However, the PDCP SN gap reporting is under steady state conditions.  For HWs comment, we believe this has least impact to UP processing/implementation. |
| Intel | Yes | We have slightly preference to use a new PDCP Control PDU not to impact PDCP Data headers of any kind of traffic and because it is unclear whether the discarded PDUs will always be in sequence. Said this, if there is a large support to use PDCP Data header, we could accept it with the understanding that the Tx might need to flag the SN skipped multiple times if those SNs are not allocated sequencially. |
| HONOR | Yes | We prefer using PDCP control PDU which is similar to current PDCP status report. |
| Lenovo | Yes with comment | We would be also open for the header-only solution suggested by LGE. We also think that specification impact would be reasonably low, since the “normal” receiving operation could be used. |
| Fujitsu | Yes | No matter a control PDU-based or data PDU-based approach is used, the receiving operation on SN report will be similar. However, data PDU with the header indication will affect normal data PDU receiving operation, which increases the receiver complexity. |
| ZTE | Yes with comment | Our preference is for control PDU based solution, but we are also open to the header-only solution suggested by LGE. |
| Nokia | Yes with comment | Also open to header-only solution. |
| Qualcomm | Yes | We have a slight preference for a new PDCP Control PDU, as header-only solution has more impact on UE implementation. |
| Samsung | Yes | We think a Control PDU is better suited as the discard information primarily can be consisting of one or two sets of first discarded SDU SN and number of consecutively discarded SDUs (depending on discardTimer expiry and/or discardTimerLowImportance expiry causing discard). Incorporating such information to a header-only data PDU has significant impact. |
| OPPO | Yes | As what we want is to provide the status information to the peer entity, the most straightforward way is to introduce a new control PDU using a bitmap structure. |
| ITRI | Yes with comment | Our preference is PDCP control PDU similar to current PDCP status report based on bitmap structures, but we are also open to the header-only solution. |
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### 3.2.1 Indication of Discarded PDCP SNs

*whether to enable PDCP SN Gap reporting via: option (A.1) bitmap kind of information, or option (A.2) range kind of information*

From the contributions, [3][5][8][12][13] alluded to a bitmap-based indication. On the other hand, a couple of other companies prefer the range indication. With [14] mentioning that discarding PDUs in blocks as an entire PDU-set can result in 100 PDUs being discarded if a single PDU is dropped. In [12], suggests three different indications i.e., bitmap-based, two COUNTs and first discard Count + number of SDUs.

Drawing from the options in [12] and based on our understanding of the requirements, at the PDCP Rx entity, it should be sufficient to consider all SNs in the reordering window SN >= RX\_DELIV AND < RX\_NEXT as discarded based on the PDCP SN gap report. In which case, RX\_DELIV would be set to the next non-delivered SN (not discarded) and RX\_NEXT would be set to the COUNT value of the indicated SN in the PDCP SN gap report. Further, it would be sufficient to indicate using a single SN in the PDCP SN gap report. Furthermore, this would also have minimal specification impact and in terms of overhead, the simple mechanism has a fixed length and at most two octets i.e., low overhead.

**For the new PDCP Control PDU, do companies think a simple mechanism of “considering all SNs in the reordering window (i.e., >= RX\_DELIV AND < RX\_NEXT) as discarded by using a single SN in the PDCP Control PDU” is sufficient?**

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| --- | --- | --- |
| Company | Yes/No | Comments |
| LGE | Comment | Note that if header-only PDU is used, this discussion is not needed.  But, if PDCP Control PDU is used, the triggering event should be discussed first.    If SN Gap reporting is triggered when SDUs are discarded discontinuously, FMC + BITMAP is desirable.    But, if SN Gap reporting is triggered when SDUs are discarded continuously, only a single value (i.e. highest COUNT among discarded SDUs) is sufficient.  However, we think SN Gap reporting is not beneficial when SDUs are discarded continuously, as explained in R2-2401863.  Thus, if PDCP Control PDU is used, FMC + BITMAP is better. |
| Futurewei | No | First, SNs in the reordering window may include both SNs discarded and SNs not discarded yet (e.g., an earlier low-importance PDU Set is discarded while a later high-importance PDU Set isn’t). We shouldn’t throw the baby out with the bathwater. SDUs stored and after the RX\_DELIV should be delivered to upper layer, similar to the expiry of reordering timer today.  [Ericsson] To clarify, with this report, the Rx entity does not discard all PDUs in the reordering queue, it only discards the ones which have not been received yet. The rest (already received) it can submit to the upper layers.  Secondly, there may be less impact to the data PDU Rx operation by treating the discarded PDUs “as if received and delivered to upper layers“ than treating them “as discarded“. E.g., when updating RX\_DELIV, no change is needed if the discarded PDUs are treated “as if received and delivered to upper layers“.  Third, as a part of the control PDU RX operation, 1) RX\_DELIV should be updated when condition is met, to prevent HFN desynchronization due to consecutive discarding; 2) RX\_NEXT should be updated when condition is met, to move the receiving window forward; 3) RX\_REORD should be updated according to the updated RX\_DELIV and RX\_NEXT. All three steps are very similar to (if not the same as) the existing behaviours in the data RX operation. |
| Xiaomi | No | Multiple QoS flows can be mapped to a single DRB. Discarding a PDU set in one QoS flow should not impact other QoS flows mapped in the same DRB. Therefore we think such mechanism impacts the performance of other QoS flows. It would be straightforward to reuse existing PDCP status report (with a bitmap) to indicate the discarded PDCP COUNTS. |
| CATT | No | It is possible that more than one PDU Sets are discarded and their SNs are not continuous, hence, bitmap method is more proper. |
| Huawei | No | As commented by LGE, the proposed mechanism does not work in all scenarios. We should have a possibility to indicate the discarded PDUs even if they are not consecutive and for this a bitmap is most suitable. One example where discontinous discard can easily happen is when PSI-based discarding is enabled. Furthermore, with bitmpa approach, we can simply reuse the design from PDCP SR, which makes specification and implementation simpler. |
| Apple | No | When discarding happens, not necessarily all SDUs in the reordering window are being discarded. Such approach is not able to support the cases where some SDUs within the window are discarded while some others are not discarded. |
| Ericsson | Yes | With the assumption that for XR traffic, if all the PDUs within the PDU set are “associated“, discarding one of the PDUs would result in all of them being discarded. Hence, at the Rx entity, all PDUs (yet to be received) within the range of >=RX\_DELIV and < RX\_NEXT would have been discarded at the Tx entity even if one of them were discarded. It is also most appropriate that the PDU sets are transmitted in order unless the jitter associated is really large, but this is unlikely. The specification impact would also be limited to something like the following (similar to the header-only PDU case): 5.2.2.4          Actions when <discard indication control PDU> is received When a <discard indication control PDU> is received, the receiving PDCP entity shall:  -    perform actions in 5.2.2.1 for an PDCP Data PDU with the assumed SN as indicated in the < received control PDU > and assumed empty payload. Methods for decompression, deciphering and delivery don’t apply to this PDU.  For FWs comment, with this indication, the Rx entity should only discard the PDUs not yet received and submit the rest (i.e., already in the reordering queue) to the upper layers.  Further, this is also applicable for discontinguous discarding, the Tx entity can always indicate the highest SN > RX\_DELIV. |
| Intel | See comment | This approach would require that SN assigned/discarded are allocated in sequence or that a control PDU is sent for each set of in-sequence PDCP SN that is discarded. It is indeed a simple approach and might be sufficient although it is unclear whether this approach is enough considering the different range of XR applications (i.e., PDUs may not always be discarded in sequence ). On summary, maybe it is ok as a first step/enhancement. |
| HONOR | No | Considering PDU set discard and PSI based discard, PDCP discard may happen for more than one SDU and inconsecutively. Only one SN in PDCP control PDU can not be sufficient for such cases. |
| Lenovo | No | This approach only works in certain conditions. But we also don’t think that all SDUs in the reordering window need to be necessarily discarded. Such approach is not able to support the cases where some SDUs within the window are discarded while some others are not discarded. |
| Fujitsu | No | A single SN may not be enough. A PDU Set may be discarded, e.g., due to its low importance, while some earlier PDU Sets may still be waiting for transmission. In this case, these earlier PDU Sets should not be considered as discarded. |
| ZTE | No | As explained by others, this doesn’t work in all scenarios. |
| Nokia | No | Agree with LGE. |
| Qualcomm | No | Agree with the comments by others |
| Samsung | No | Non-contaguous discard can happen due to PSI based SDU discard being enabled. |
| OPPO | No | Agree with others, it would be possible that the discarded PDUs are not continuous, thus, bitmap is useful. |
| ITRI | No | Agree with LGE. |
|  |  |  |

For the bitmap indication, the PDCP Tx entity needs to compile the report on the first discarded SN and each discarded SN within the window into a bitmap. The PDCP Rx entity then delivers all stored SDUs from the COUNT = RX\_DELIV except the SDUs which are not considered discarded and then the state variables need to be updated accordingly. This is not beneficial for PDUs discarded within a PDU sets. [12] also calculates the overhead for the bitmap indication for a maximum data packet size (140625 bytes) is at most 16 bytes with a variable length. The same is applicable for the range indication in terms of the processing required at the PDCP Tx and Rx entity.

Considering the aspect of complexity and in the interest of introducing a solution with minimal spec impact during the maintenance of Rel-18, we would like companies to provide their inputs on whether such complex indications as bitmap or range is necessary as opposed to using the simple mechanism described above.

**For the new PDCP Control PDU, do companies believe it is necessary to use a bitmap or range indication over the simple mechanism described above?**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments (bitmap or range) |
| LGE | Comment | It should be discussed first in which case the SN Gap reporting is triggered. |
| Futurewei | Yes | Bitmap is more flexible and bullet-proof. Although it may incur more overhead, those extreme cases are relatively rare. Range incurs less overhead but works only if the discarded SNs are contiguous, which cannot be guaranteed according to the SA4 LS (R2-2400088). We may be OK to support both mechanisms. But if only one is to be specified, we prefer the bitmap to ensure that all cases can be covered. |
| Xiaomi | Yes for bitmap | As bitmap approach can reuse existing PDCP status report, we think the specification impact is minimal. |
| CATT | Yes for bitmap | During the maintenance of Rel-18, we think the bitmap manner is more easy and acceptable to reach consensus. |
| Huawei, HiSilicon | Yes for bitmap | Bitmap should be used, as mentioned above. |
| Apple | Yes for bitmap | As commented previously, we think it is more generalized and straightforward to report a bitmap for discarding notification, which also allows us to reuse the existing control PDU structure. |
| Ericsson | See comments | Prefer the single SN or the header-only indication as we believe it has least impact on the specification.  Futurewei>> We wonder whether the single SN in the header-only approach has assumed that the discarded SNs are always contiguous, while SA4 LS (R2-2400088) indicates that packets may arrive out of order. We wonder how the single SN in the header-only approach would work in the scenario illustrated below, where packets of PDU Sets have arrived interleaved and the low-importance PDU Set is discarded due to a non-zero shorter discard timer value: |
| Intel | Maybe | In general, we are open on the actual mechanism used as long as it provides the optimum/required means for PDCP TX to inform RX of the SN gap.  Bitmap approach is aligned to PCPC Status Report although it might not be ideal with a PDU Set containing a large number of PDUs. Range approach is aligned to RLC Status Report and could allow reporting of multiple ranges of SNs.  On other hand, we also acknowledge that the discarded of PDUs belonging to one PDU Set may have sequential SNs and so a simpler indication may be sufficient.  Considering the limited time that we have to conclude on the details of the solution, we suggest enabling the one with the largest support (i.e., bitmap approach). If there is equal support for the options, as an alternative to consider defining two approaches dependent on UE support and network configuration (e.g., PDCP Control PDU with bitmap approach, or PDCP Data PDU where , one of the reserve bits indicates that SNs up to this one are discarded). |
| HONOR | Yes for bitmap | If we consider inconsecuitve SDU discard, bitmap method has relative low overhead compared to COUNT+range. |
| Lenovo |  | We are open on the detailed mechanism to be used. Some range indication may be sufficient. |
| Fujitsu | Yes for range | Range indication may have less signaling overhead than the bitmap indication considering PDU Set discard very likely have continuous SN. |
| ZTE | Yes for bitmap | We prefer bitmap solution which is similar to the existing mechanism for PDCP control SR. |
| Nokia | Yes (both) | For the discard of PDUs in sequence, range is more attractive. If PDUs of a PDU set happen to be interleaved with other PDUs, bitmap is more attractive. |
| Qualcomm | Yes for bitmap | Either approach can work. We have a slight preference for bitmap as it is more flexible and also more in line with the format of the status report |
| Samsung | Yes for range | For discard signalling, only relevant information is the indication for discarded SDUs SN and it is not similar to bitmap in SR as the bits not set to 1 (not yet discarded SDUs) do not convey any real action to receiver. That is, not yet discarded SDUs are still subject to discard. Then, it is preferable to only limit the discard information for the discarded SDUs (i.e. one or more sets of FDC and range of SDUs). Moreover, with range approach, transmitting PDCP entity would be required to send discard information only once for a given PDCP SDU to the receiving PDCP entity, whereas, bitmap may cause repetition and/or update of discard of a given PDCP SDU in two different discard signalling. This causes additonal processing for receiving PDCP entity. |
| OPPO | Yes for bitmap | Bitmap is more proper for the case where SDUs are discarded discontinuously. This way is similar to the existing mechanism for PDCP control PDU. |
| ITRI | Yes for bitmap | We prefer reusing the bitmap solution. |
|  |  |  |

### 3.2.2 Usage of SN or COUNT

This was not discussed in detail during the previous meetings. [15] mentions that COUNT should be used as indication for the first discarded SDU and by reusing the design of the PDCP SR, there would not be too much work.

As explained in [9], the PDCP SN gap reporting is a different type of signaling i.e., originating at the PDCP Tx entity and this is used to indicate to the PDCP Rx entity to not wait for certain SN(s) in cases where the SN >= RX\_DELIV AND < RX\_NEXT. Given that the PDCP Tx entity and PDCP Rx entity are synchronized (i.e., operating under steady state conditions), it is sufficient to include the SN in the new PDCP control PDU as the Rx entity derives the corresponding HFN by operating on the received SNs. On the contrary, the current PDCP SR is used under conditions of reestablishment or data recovery i.e., the PDCP Tx entity and PDCP Rx entity have lost synchronization. Therefore, we would like companies to comment on this aspect.

**For the new PDCP Control PDU, do companies have a preference in using SN or COUNT for indicating discarded PDCP SDUs?**

|  |  |  |
| --- | --- | --- |
| Company | SN or COUNT | Comments |
| LGE | COUNT | But, it is not urgent, and thus can be discussed later. |
| Futurewei | COUNT | We think 12-bit PDCP SN is efficient in term of signaling overhead and sufficient for uniquely identifying XR video packets for the highest data rate (150 Mbps) within a period about 166 ms, which is much longer than the PDB/PSDB of XR video traffic. However, as we described in our response to Q3.1, HFN desynchronization may occur when consecutively discarding more than 166 ms of video data of a video stream with 150 Mbps data rate.  To overcome that, 18-bit PDCP SN can be configured but with a price of one extra byte in PDCP header for every single PDCP data PDU, e.g., 12500 extra bytes per second for a video stream of 150 Mbps data rate. In comparison, sending the full COUNT value in the SN gap report, but doing so only occasionally, is far more economic. |
| Xiaomi | COUNT | We prefer to use COUNT to avoid any ambiguity. Also with COUNT, we can reuse PDCP Status Report as much as possible. |
| CATT | COUNT | Same view as Xiaomi. |
| Huawei, HiSilicon | COUNT | We think we can reuse PDCP SR principles as much as possible, but we do not have a strong view here in case we would like to save some overhead. However, we think we need to make a decision already to have complete CRs for the next meeting. |
| Apple | COUNT | It is simpler to just follow the existing status report design, by having a field indicates the COUNT value of the first discarde PDCP SDU in the discarding notification. |
| Ericsson | See comments | The solution for indication should be decided first, the details can be worked out later. |
| Intel | SN < COUNT | Both can work but we agree with the explanation provided by [9]. |
| HONOR | COUNT | If we go with bitmap method, only one COUNT/SN is needed in each PDCP SN Gap report, thus we should use COUNT to avoid potential ambiguity. |
| Lenovo | COUNT |  |
| Fujitsu | COUNT |  |
| ZTE | COUNT |  |
| Nokia | COUNT |  |
| Qualcomm | COUNT | We are fine with either COUNT or SN. Both can be made to work. We have a slight preference for COUNT because it is more in line with the current format of status report. |
| Samsung | COUNT |  |
| OPPO | See comments | We see either SN or COUNT can work, but COUNT is preferred to avoid any ambiguity. |
| ITRI | COUNT |  |
|  |  |  |

## 3.3 Triggering of the PDCP SN Gap Report

*whether/which rules needs to be defined in PDCP transmitter entity to trigger PDCP SDU discard report considering e.g. (1) the PDCP entity discards SDU(s) which have not been transmitted (for UM DRBs) or acknowledged (for AM DRBs), due to the expiry of PDCP discard timer; and (2) there is a buffered SDU associated with an SN higher than the SN of the discarded SDU(s), as well as, related TPs included in R2-2401420, R2-2400748 and R2-2313923*.

In [15], when the SDUs are discarded in the PDCP buffer and at the tail of the buffer, the Tx entity could perform (re-)association of the SNs to the SDUs that arrive later. This has already been covered in the agreement and such (re-)association is up to implementation.

[15] also details the scenario where the PDCP Tx entity can trigger the report based on the conditions in the proposal above. In our understanding, the underlying trigger is the same in both cases, in the RLC buffer, if there are PDCP PDUs not transmitted in UM DRBs or acknowledged in AM DRBs and in the PDCP buffer, if the corresponding SDU associated with a lower SN is discarded (due to the expiry of the discard timer) whilst a SDU associated with a higher SN is buffered, this would trigger the PDCP SN gap report. In essence, the discarding of lower SNs (in the presence of higher SNs) in the PDCP buffer will create gaps in SNs. The dependence on the RLC status of the PDCP PDUs is a precursor for discard but not the trigger for the PDCP SN gap report nor will it affect the gap in the PDCP SNs.

Therefore, the trigger at the PDCP Tx entity is basically an “arbitration” of whether the discard will create a gap at the PDCP Rx entity. Hence, we comebine the two triggering conditions and would like to check company’s views on the same.

**Do companies agree that the PDCP Tx entity triggers the PDCP SN gap report when there is a buffered SDU associated with an SN higher than the SN of the discarded SDU(s) (discarded due to expiry of the discard timer) and these SDU(s) have not been transmitted (for UM DRBs) or acknowledged (for AM DRBs)?**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| LGE | No | Even for AM DRBs, the condition should be same as UM DRBs, i.e. “these SDU(s) have not been transmitted“.  The “not acknodwledged“ SDU includes SDUs already transmitted. In AM RLC, once a segment is transmitted, the AM RLC entity will keep retransmitting the SDU. Thus, there is no need to report SN Gap. |
| Futurewei | – | 1. OK with the part of “**when there is a buffered SDU associated with an SN higher than the SN of the discarded SDU(s)**“. Agree with LGE on the part of “not been transmitted“ for both UMD and AMD. In addition, this is the trigger when OOD isn‘t configured. 2. We also need to consider a trigger when OOD is configured and the size of a contiguous SN gap is getting close to one half of the PDCP SN space, to prevent HFN desynchronization. |
| Xiaomi | No | Agree with LGE that we should use the same condition “these SDU(s) have not been transmitted“ for both AM and UM. |
| CATT | No | Same view as LG. |
| Huawei, HiSilicon | Yes | For AM, we need to also indicate those PDUs which have been transmitted but not acknowledged yet, because these PDUs are outdated already and the Rx PDCP entity can move the receiving window and not wait for the RLC retransmissions of such PDUs, to speed up the delivery of the subsequent PDUs. Otherwise, we are delaying the delivery of data by waiting for RLC retransmissions which are useless in this situation. |
| Apple | No | We should use the same condition for both AM and UM. In principle, the trigger condition would be fulfilled whenever the transmitter introduces an SN gap due to SDU discarding (from the perspective of the PDCP receiver). A discard notification may be sent when a) these SDU(s) have not been transmitted and b) there is a PDCP SDU already associated with an SN higher than the SN of the discarded SDU(s). |
| Ericsson | Yes for the higher SN in the queue | As explained in the discussion, the trigger is related to when the PDCP Tx entity expects a SN gap at the Rx entity. This is most likely when there is a higher SN in the queue and lower SNs are discarded. For AM, it would be easier to keep the not transmitted condition. |
| Intel | Yes |  |
| HONOR | Yes | For AM DRBs, we see some benefits if also send the nofication for discarded SDUs transmitted but not acknowledged. Since the PDCP re-ordering window could also be forwarded in advance in some cases. Besides, it is better to keep PDCP independent based on its current discard operation. |
| Lenovo |  | Agree with Ericsson comment |
| Fujitsu | No | Discard due to discardTimer is a legacy behavior which does not need to trigger a PDCP SN report, otherwise the report will be too frequent. We think that the PDCP SN report is better to be triggered by PDU Set discard/PSI-based discard and there is a buffered SDU associated with an SN higher than the SN of the discarded SDU(s) and these SDU(s) have not been transmitted. |
| ZTE | Yes | In general the condition seems fine. But, we don’t think the addtional restriction “and these SDU(s) have not been transmitted (for UM DRBs) or acknowledged (for AM DRBs)“ is needed. |
| Nokia | ~ | Agree with Ericsson |
| Qualcomm | No | Agree with LGE |
| Samsung | No | Same view as LGE |
| OPPO | No | Agree with LGE |
| ITRI |  | Agree with Ericsson |
|  |  |  |

## 3.4 New UE-capability for PDCP SN Gap Reporting and Other Discarding Capabilities

To discuss whether to define a new UE capability to indicate the support of PDCP SN Gap reporting. If so, to discuss whether UE supporting PDCP SN Gap reporting shall also support pdu-SetDiscard-r18 and/or psi-BasedDiscard-r18.

The highlighted part of the proposal was not discussed during the meeting. Dependencies between discard capabilities was brought up during the coordination of the summary paper [2], specifically around the question if capability to do PDU Set discard would also mandate the capability to do PDCP SN gap reporting. Earlier discussion around PDCP SN gap reporting has raised the concern that there may be more discards happen when utilizing PDU Set discarding. Hence, we would like companies to provide their views on the relationship between PDCP SN gap reporting and other discarding capabilities.

**Do companies think that there should be any dependencies between the UE capability to support PDCP SN Gap reporting and support pdu-SetDiscard-r18/psi-BasedDiscard-r18?**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| LGE | Yes | As explained in our paper (R2-2401863), the SN Gap reporting is beneficial only when RLC SDUs stored in RLC Tx buffer are discarded discontinuously. This case happens in following conditions:   * pdu-SetDiscard is configured * PDU sets arrive at PDCP buffer with interleaving * Lots of PDCP SDUs are pre-processed and stored in RLC Tx buffer * RLC SDUs are not transmitted until the discard timer expires   For other cases (i.e. continuous discard case), SN re-association or relying on t-Reordering is sufficient.  Thus, the SN Gap reporting should be used only when pdu-SetDiscard is configured. |
| Futurewei | Yes and No | pdu-SetDiscard-r18 and psi-BasedDiscard-r18 indicates UE’s capability of discarding UL packets. So, UE’s capability of sending PDCP SN Gap report on the UL can be dependent on pdu-SetDiscard-r18 and psi-BasedDiscard-r18.  However, UE’s capability of receiving PDCP SN Gap report and responding to it (such as updating RX\_DELIV accordingly) should be independent from pdu-SetDiscard-r18 or psi-BasedDiscard-r18. In a CU-DU split gNB architecture, for security reason, the CU cannot reuse a discarded COUNT value on another SDU if the discarded PDCP PDU has been submitted to the RLC entity. So, if the CU discards consecutive PDCP PDUs spanning one half of the PDCP SN space or more, the transmitting PDCP entity in the CU may send a PDCP SN Gap report to the receiving PDCP entity in the UE, if knowing the UE is capable of receiving PDCP SN Gap report, to avoid HFN desynchronization. |
| Xiaomi | No strong view. | If we want to define the dependency, it might be sufficient to specify that a UE supporting PDCP SN gap reporting shall also support *pdu-SetDiscard-r18*. |
| CATT | Yes | Agree with LG, the SN Gap reporting should be used only when pdu-SetDiscard is configured. |
| Huawei, HiSilicon | No | SN gap reporting can be used also when PDU set discarding is not enabled, i.e. for normal discarding operation. PDCP specifications does not even have to distinguish these two cases and the transmitter/receiver behaviour can be exactly the same in both cases. Hence, there is no need to introduce any capability inter-dependencies and it can be a network decision whether to configure it together with PDU Set discarding or also in other cases. |
| Apple | Comment | Ok to have such a prerequisite. Moreover, if the UE supports a re-adjustment of the reordering window due to PDCP discard then a PDCP transmitter may use the Discard Notification in downlink as well. The gNB may only use that if the UE supports the SN gap reporting (which implies a) bi-directional operation and b) that the capability for SN gap reporting encompasses the receiver behavior too). |
| Ericsson | No | We dont agree with LG that this feature is only beneficial when PDU Set discarding is used. As HW point out there is no real dependencies between the features, they work independently of each other and thus there is no need to introduce any artifical dependency. It should be left up to network to decide which features it want to be configured together. |
| Intel | No | It was possible that PDCP SN gap occurs even before Rel-18 discard enhancements as stated in the following note captured in TS 38.323.  NOTE 2: Discarding a PDCP SDU already associated with a PDCP SN causes a SN gap in the transmitted PDCP Data PDUs, which increases PDCP reordering delay in the receiving PDCP entity. It is up to UE implementation how to minimize SN gap after SDU discard.  Therefore we have slight preference to define this functionality without any dependencies.  At most, we wonder whether RAN2 should discuss whether a UE supporting *pdu-SetDiscard-r18* (or *psi-BasedDiscard-r18*) shall always support PDCP SN Gap. If so, PDCP SN Gap feature can be supported by itself but if a UE supports *pdu-SetDiscard-r18* (or *psi-BasedDiscard-r18*), this UE shall always support PDCP SN Gap feature. |
| HONOR | Yes | The PDCP SN Gap reporting capability shoud be based on UE supporting either pdu-SetDiscard-r18 or psi-BasedDiscard-r18, ie if UE only support legacy PDCP discard, the PDCP SN Gap reporting should not be supported. |
| Fujitsu | Yes | UE capability to support PDCP SN Gap reporting should support pdu-SetDiscard-r18 or psi-BasedDiscard-r18. This capability is only for UL PDCP SN reporting. |
| ZTE | No strong view | We are okay to keep this as an independent capability. |
| Nokia | Yes | UE supporting pdu-SetDiscard-r18 or psi-BasedDiscard-r18 shall also support SN-Gap reporting.  Discontinuous discarding becomes possible also with PSI-based discarding, when discard timers of successive SDUs have different durations. |
| Qualcomm | No | We can’t agree with the view that the association between the two features shall be mandated. First, gap reporting does not need to depend on the support for XR PDU set. Second, if a UE supports PDU set discard or PSI based discard, it does not need to implement gap indication if it always assigns PDCP SN in the very last moment (hence there is no gap). |
| Samsung | No | There seems no real dependency between these features, so it is preferable to leave this to network configuration. |
| OPPO | No | We do not see tight-dependency in-between. |
| ITRI | No strong view | There is no explicit dependency between these capabilities. |
|  |  |  |

## 3.5 Receiver Behaviour

In [15], the behaviour is described for when the PDCP SN gap report is received at the PDCP Rx entity. For the upper bound of the reordering window, if RX\_NEXT is not larger than the max COUNT indicated as discarded, it should be updated to the max COUNT + 1 and for the lower bound, if the RX\_DELIV corresponds to an SDU which has been discarded, the receiving PDCP entity shall deliver subsequent received SNs consecutively and skip the discarded SNs and update RX\_DELIV to the COUNT which has not been discarded or delivered.

As a baseline, we would like to get company views on the receiver behaviour up on receiving the PDCP SN gap report.

**Do companies agree that RX\_DELIV and RX\_NEXT should be updated at the PDCP Rx entity when the PDCP SN gap report is received?**

|  |  |  |
| --- | --- | --- |
| Company | Yes/No | Comments |
| Futurewei | Yes | [8] and [15] describe essentially the same behavior for RX\_NEXT update.  In [8], because discarded SDUs are treated as if “delivered to upper layers”, the RX\_DELIV update procedure is slightly simpler than [15], including less impact to the legacy data PDU RX operation.  In addition, RX\_REORD should be updated according to the updated RX\_DELIV and RX\_NEXT, like what is done today after the expiry of reordering timer. |
| Xiaomi | Yes with comments | Our understanding is that PDCP state variables (RX\_DELIV, RX\_NEXT, RE\_REORD) might be updated (following the principle as in TS 38.323 clause 5.2.2.1) if discarded SDUs are treated as delivered to upper layers. Which state variable is update depends on receiver state and discarded SDUs. |
| CATT | Yes | The push window + t\_reording mechanism can work appropriately with RX\_DELIV and RX\_NEXT updation at the PDCP Rx entity when the PDCP SN gap report is received. |
| Huawei, HiSilicon | Yes | For the mechanism to work, we need to clarify how the variables need to be updated at the receiver upon obtaining the discarding report. |
| Apple | Yes with comments | Following reception of a discard indication the receiver treats the last PDU before and the first PDU after the range of discarded SNs as in-sequence. This implies that the receiver updates RX\_DELIV (if t-reordering is not running) and RX\_REORD (if t-Reordering is running). RX\_NEXT can be updated based on RCVD\_COUNT, so perhaps nothing much is needed for RX\_NEXT. |
| Ericsson | Yes, see comments | To answer the question at face-value, we believe the status variables at the Rx would need to be updated. But depending on the solution, it would be possible to re-use the existing receiver operation section in the spec for e.g., when using the header-only PDU or single-SN indication. |
| Intel | Yes |  |
| HONOR | Yes | RX\_DELIV and RX\_NEXT could be updated accordingly if the PDCP SN Gap report is received based on current principle in TS38.323. And considering inconsecutive discard, for each time the above varibale need to be updated, it should check with the previous recived SN Gap report to forward the window further. |
| Lenovo | Yes |  |
| Fujitsu | Yes | How to update the state variables depends on the PDCP SN report information and the relation of the reported SN number compared with the current state variables. The detailed RX operation may be discussed in next meeting based on contributions. |
| ZTE | Yes | This will be needed for the control PDU based solution but not needed (i.e. no changes) for header only solution proposed above. |
| Nokia | Yes |  |
| Qualcomm | Yes |  |
| Samsung | Yes, see comment | We understand PDCP state variables (RX\_DELIV, RX\_NEXT, RE\_REORD) should be updated based on discard information. In addition, receiving PDCP entity can be benefitted by “considering” each of the discarded SDU included in the discard information as if already received. |
| LGE | Yes |  |
| OPPO | Yes, see Comments | Similar view as Samsung. |
| ITRI | Yes |  |
|  |  |  |

## 3.6 Related TPs (Phase 2, TODO)

As the TPs are be based on the outcome of the above discussion, we will provide different versions of the TPs to cover all the proposals in the 2nd phase of the email discussion as explained in the introduction.

# 4 References

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18. Chair notes, RAN2#125, Athens, Greece, February 2024.