3GPP TR 38.823 V16.0.0 (2019-12)

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Study of further enhancement for disaggregated gNB
(Release 16)

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Contents

Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

In the present document, modal verbs have the following meanings:

shall indicates a mandatory requirement to do something

shall not indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

should indicates a recommendation to do something

should not indicates a recommendation not to do something

may indicates permission to do something

need not indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

can indicates that something is possible

cannot indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

will indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

will not indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

might indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

might not indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

is (or any other verb in the indicative mood) indicates a statement of fact

is not (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

1 Scope

The present document is related to the technical report of the study item " Study on Enhancement for Disaggregated gNB " [2].

This activity involves the Radio Access work area of the 3GPP studies and has impacts on the Access Network of the 3GPP systems.

The present document gathers all technical outcome of the study item, and draws a conclusion on the way forward.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] RP-191975, Revised SID: Enhancement for disaggregated gNB architecture, CATT

[3] 3GPP TS 38.300: "NR; Overall description; Stage-2"

[4] 3GPP TS 38.401: "NG-RAN; Architecture description"

[5] 3GPP TS 38.425:"NG-RAN; NR user plane protocol"

[6] R3-197333, pCR for TR 38.823: Transport Network Delay Compensation in Split gNB Architecture, Ericsson

[7] R3-197241, Evaluation of solutions for user plane enhancements, Huawei, CATT

[8] R3-197714, pCR for TR 38.823: Evaluation of flow control enhancements, Ericsson

[9] R3-197733, TP for TR 38.823: On reported DBS, Nokia, Nokia Shanghai Bell

[10] R3-197793, Solution on data compensation for transport network delay, Huawei

[11] R3-197736, pCR for TR 38.823: Evaluation of Solution 2 for Scenario 2, Ericsson

[12] R3-197738, Conclusion for Disaggregated gNB enhancement SI, CATT, China Telecom

[13] R3-194746, TP to TR 38.823 on user plane enhancement, CATT, CAICT, China Telecom

[14] R3-193694, Discussion on user plane enhancement, CATT, CAICT, China Telecom

[15] R3-194448, Considerations on retransmitted PDCP PDUs issue, Huawei

3 Definitions of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

gNB: as defined in 3GPP TS 38.300 [3]

gNB Central Unit (gNB-CU): as defined in 3GPP TS 38.401 [4]

gNB Distributed Unit (gNB-DU): as defined in 3GPP TS 38.401 [4]

gNB-CU-Control Plane (gNB-CU-CP): as defined in 3GPP TS 38.401 [4]

gNB-CU-User Plane (gNB-CU-UP): as defined in 3GPP TS 38.401 [4]

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

DDDS	Downlink Data Delivery Status
NR	NR Radio Access
TN	Transport Network

4 General

The objective of this study item is to investigate enhancements to disaggregated gNB scenario. At least the following topics should be studied:

1. Identifying detailed solutions for further enhancements on current flow control mechanism with the following aspects considered.

   - PDCP PDUs may be delivered in the Uu interface out of sequence.
   - The re-transmitted PDCP PDUs may arrive at DU out of order.
   - In DC scenario, data transmitted to UE from two legs may arrive out of order which in turn may result in out-of-order delivery to higher layer in case of re-ordering timer expiration.

Note1: The solution was required to be backward compatible (i.e. carefully consider the fact no criticality handling defined in U-plane protocol specification).

2. Identifying detailed solutions to support the scenario that one UE connects to several gNB-CU-UPs which belong to different security domains.

Note2: SA3 should be involved in this SI.

Note3: CP/UP separation and CU/DU split should be invisible to other nodes (especially UE should not be impacted).

5 Further Enhancements on Flow Control Mechanism

5.1 Scenario

5.1.1 Scenario 1

In Rel-15, fast retransmission was introduced. For this case, data unsuccessfully transmitted in one leg would be re-transmitted in another leg based on the DDDS from the corresponding node. The current DDDS reports the sequence number of the in-sequence successfully delivered PDCP PDUs, which may lead to re-transmission in another leg of some already delivered PDCP PDUs.

For example, Figure 5.1-1 depicts the transmission status for one specific UE in gNB-DU1, i.e. all PDCP PDU with sequence number below 207 are successfully sent to UE except for PDCP PDU with SN 201. In this case, the gNB-DU1 would only report to gNB-CU-UP that its highest in-sequence successful transmitted PDCP SN as 200 and gNB-

CU would request gNB-DU2 to re-transmit the PDCP PDU whose SN is above 200, among which some are already delivered to the UE.

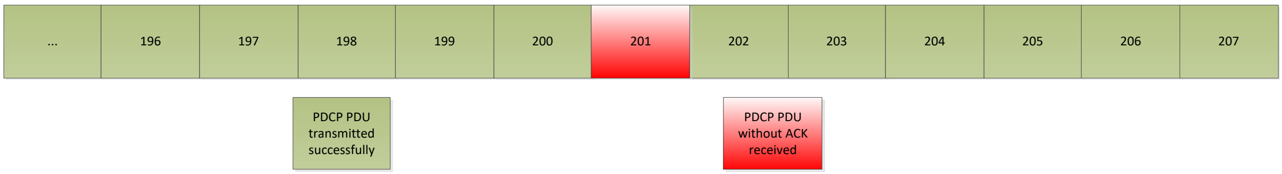

Figure 5.1-1: PDCP PDU transmission status in gNB-DU1 for Scenario 1

5.1.2 Scenario 2

For re-transmission, there may be two kinds of re-transmissions, i.e. retransmission because of the data missing on F1/Xn interface and fast re-transmission mechanism. When the two kinds of re-transmission data arrive at corresponding node, the corresponding node may do re-ordering while sending them to UE. At the same time, the data sent from hosting node may arrive at corresponding node out of order. In this case, the hosting node could not get the accurate information on the status of re-transmission packets.

In Rel-15, DDDS for retransmitted packets relies on reporting PDCP SN corresponding to the highest in-sequence NR-U SN. This was decided mainly due to backward compatibility and inter-operability.

For retransmitted packets, "retransmission" is flagged by CU. This is for prioritization at DU (i.e. re-ordering based on PDCP SN). Although not mandated, DU's re-ordering is critical to minimize service interruptions.

However, the current Rel-15 solution is suboptimal when DU performs re-ordering. For example, suppose that DU re-orders lower PDCP SN packets after successfully delivering SN #103 as in Figure 5.1.2-1 (assuming that SN #1, #2, arrives at DU before transmitting SN #104):

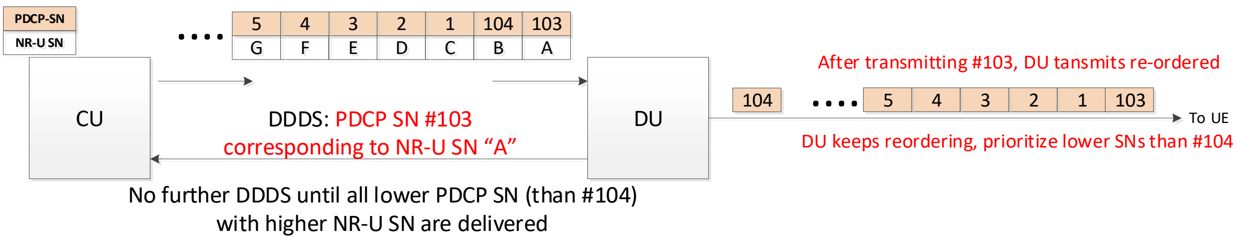

Figure 5.1.2-1: DU's re-ordering makes the current Rel-15 solution sub-optimal

- Reporting a PDCP SN corresponding to the highest in-sequence NR-U SN (current Rel-15) will be fixed to #103, until a next NR-U SN (i.e. corresponds to #104) is successfully delivered.
- In other words, there will not be any new feedback until all the retransmitted packets with lower PDCP SN than #104 (and higher NR-U SN than "B") are delivered successfully.
- If they are in large volume (e.g. the Centralized Retransmission scheme), this could result in a suboptimal behaviour for CU, because those large number of already delivered retransmitted packets cannot be freed up in a timely fashion.

In summary, the main issue with the current Rel-15 solution is as follows:

- DU's reordering based on PDCP SN could result in earlier NR-U SN packets (with higher PDCP SN) to be kept de-prioritized.
- Such de-prioritization could lead DDDS feedback sluggish and inefficient buffer management for CU.

5.1.3 Scenario 3

Typical delays on transport links between the node hosting the PDCP entity and the corresponding node may be up to several tens of milliseconds. Such large delays may lead to a discontinuity of packet arrivals at the corresponding node, meaning that the corresponding node buffer may often be empty because the packets transmitted by the node hosting the PDCP entity will spend significant amount of time traversing the transport network (Refer to [6]).

5.2 Possible Solutions

5.2.1 Solution for Scenario 1

For scenario 1, the possible solutions are listed as below:

Solution1: The corresponding node reports the highest successfully delivered PDCP SN in order and at the same time also reports all the other PDCP SN delivered successfully out of order. The corresponding node reports all PDCP SN which are delivered to UE successfully based on the request from hosting node (Refer to [14]). The update to DDDS and DL USER DATA is as follows:

<table>
<tr><th colspan="8">Bits</th><th rowspan="2">Number of Octets</th></tr>
<tr><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td colspan="4">PDU Type (=1)</td><td>Highest Transmitted NR PDCP SN Ind</td><td>Highest Delivered NR PDCP SN Ind</td><td>Final Frame Ind.</td><td>Lost Packet Report</td><td>1</td></tr>
<tr><td colspan="3">Spare</td><td>Delivered out of order NR PDCP SN Ind</td><td>Data rate Ind.</td><td>Retransmitted NR PDCP SN Ind</td><td>Delivered Retransmitted NR PDCP SN Ind</td><td>Cause Report</td><td>1</td></tr>
<tr><td colspan="8">Desired buffer size for the data radio bearer</td><td>4</td></tr>
<tr><td colspan="8">Desired Data Rate</td><td>0 or 4</td></tr>
<tr><td colspan="8">Number of lost NR-U Sequence Number ranges reported</td><td>0 or 1</td></tr>
<tr><td colspan="8">Start of lost NR-U Sequence Number range</td><td rowspan="2">0 or (6* Number of reported lost NR-U SN ranges)</td></tr>
<tr><td colspan="8">End of lost NR-U Sequence Number range</td></tr>
<tr><td colspan="8">Highest successfully delivered NR PDCP Sequence Number</td><td>0 or 3</td></tr>
<tr><td colspan="8">Highest transmitted NR PDCP Sequence Number</td><td>0 or 3</td></tr>
<tr><td colspan="8">Cause Value</td><td>0 or 1</td></tr>
<tr><td colspan="8">Successfully delivered retransmitted NR PDCP Sequence Number</td><td>0 or 3</td></tr>
<tr><td colspan="8">Retransmitted NR PDCP Sequence Number</td><td>0 or 3</td></tr>
<tr><td colspan="8">Number of NR PDCP successfully delivered out of order</td><td>0-3</td></tr>
<tr><td colspan="8">NR PDCP Sequence Number1 delivered out of order</td><td>0-3</td></tr>
<tr><td colspan="8">…</td><td></td></tr>
<tr><td colspan="8">NR PDCP Sequence Number N delivered out of order</td><td>0-3</td></tr>
</table>

Figure 5.2.1-1: Impact to DDDS for Solution 1

Bits								Number of Octets
7	6	5	4	3	2	1	0	
PDU Type (=0)				Full report indication	DL Discard Blocks	DL Flush	Report polling	1
Spare				Report Delivered	User data existence flag	Assistance Info. Report Polling Flag	Retransmission flag	1
NR-U Sequence Number								3
DL discard NR PDCP PDU SN								0 or 3
DL discard Number of blocks								0 or 1
DL discard NR PDCP PDU SN start (first block)								0 or 3
Discarded Block size (first block)								0 or 1
…								
DL discard NR PDCP PDU SN start (last block)								0 or 3
Discarded Block size (last block)								0 or 1
DL report NR PDCP PDU SN								0 or 3
Padding								0-3

Figure 5.2.1-2: Impact to DL USER DATA for Solution 1

Solution 2: The corresponding node reports the highest successfully delivered PDCP SN in order and the highest successfully delivered PDCP SN. At the same time, it reports the PDCP SN which is not delivered successfully between them. The corresponding node reports all PDCP SN which are delivered to UE successfully based on the request from hosting node (Refer to [14]). The update to DDDS and DL USER DATA is as follows:

Bits								Number of Octets
7	6	5	4	3	2	1	0	
PDU Type (=1)				Highest Transmitted NR PDCP SN Ind	Highest Delivered NR PDCP SN Ind	Final Frame Ind.	Lost Packet Report	1
Spare			Delivered out of order NR PDCP SN Ind	Data rate Ind.	Retransmitted NR PDCP SN Ind	Delivered Retransmitted NR PDCP SN Ind	Cause Report	1
Desired buffer size for the data radio bearer								4
Desired Data Rate								0 or 4
Number of lost NR-U Sequence Number ranges reported								0 or 1
Start of lost NR-U Sequence Number range								0 or (6* Number of reported lost NR-U SN ranges)
End of lost NR-U Sequence Number range								
Highest successfully delivered NR PDCP Sequence Number								0 or 3
Highest transmitted NR PDCP Sequence Number								0 or 3
Cause Value								0 or 1
Successfully delivered retransmitted NR PDCP Sequence Number								0 or 3
Retransmitted NR PDCP Sequence Number								0 or 3
Highest delivered NR PDCP Sequence Number (including out of order)								0-3
First missing NR PDCP Sequence Number1								0-3
…								
Last missing NR PDCP Sequence Number N								0-3

Figure 5.2.1-3: Impact to DDDS for Solution 2

Bits								Number of Octets
7	6	5	4	3	2	1	0	
PDU Type (=0)				Full report indication	DL Discard Blocks	DL Flush	Report polling	1
Spare				Report Delivered	User data existence flag	Assistance Info. Report Polling Flag	Retransmission flag	1
NR-U Sequence Number								3
DL discard NR PDCP PDU SN								0 or 3
DL discard Number of blocks								0 or 1
DL discard NR PDCP PDU SN start (first block)								0 or 3
Discarded Block size (first block)								0 or 1
...								
DL discard NR PDCP PDU SN start (last block)								0 or 3
Discarded Block size (last block)								0 or 1
DL report NR PDCP PDU SN								0 or 3
Padding								0-3

Figure 5.2.1-4: Impact to DL USER DATA for Solution 2

Solution 3: The indication of successfully delivered PDCP SN range(s) is introduced to indicate the status of the PDU after the highest successfully delivered PDCP PDU, where the successfully delivered PDCP SN range is defined by two parameters, i.e., start of successfully delivered PDCP SN and end of successfully delivered PDCP SN (Refer to [15]).

<table>
<tr><th colspan="8">Bits</th><th rowspan="2">Number of Octets</th></tr>
<tr><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td colspan="4">PDU Type (=1)</td><td>Highest Transmitted NR PDCP SN Ind</td><td>Highest Delivered NR PDCP SN Ind</td><td>Final Frame Ind.</td><td>Lost Packet Report</td><td>1</td></tr>
<tr><td colspan="3">Spare</td><td>Successfully Delivered NR PDCP SN Indicator</td><td>Data rate Ind.</td><td>Retransmitted NR PDCP SN Ind</td><td>Delivered Retransmitted NR PDCP SN Ind</td><td>Cause Report</td><td>1</td></tr>
<tr><td colspan="8">/** unchanged part is skipped**/</td><td></td></tr>
<tr><td colspan="8">Number of successfully delivered PDCP SN range</td><td>0 or 1</td></tr>
<tr><td colspan="8">Start of successfully delivered PDCP SN range</td><td>0 or 3</td></tr>
<tr><td colspan="8">End of successfully delivered PDCP SN range</td><td>0 or 3</td></tr>
<tr><td colspan="8">Padding</td><td>0-3</td></tr>
</table>

Figure 5.2.1-5: Impact to DDDS for Solution 3 to scenario 1

Solution 4: The existing DL discard mechanism from TS 38.425 is used [5].

Solution 5: The corresponding node was required to, if supported, send the report of out-of-sequence delivered PDCP PDU SNs when the node hosting the PDCP entity has set the *Full delivered PDCP PDU SN report flag*.

Bits								Number of Octets
7	6	5	4	3	2	1	0	
PDU Type (=0)				Spare	DL Discard Blocks	DL Flush	Report polling	1
Spare			Full delivered PDCP PDU SN report	Report Delivered	User data existence flag	Assistance Info. Report Polling Flag	Retransmission flag	1
NR-U Sequence Number								3
DL discard NR PDCP PDU SN								0 or 3
DL discard Number of blocks								0 or 1
DL discard NR PDCP PDU SN start (first block)								0 or 3
Discarded Block size (first block)								0 or 1
…								
DL discard NR PDCP PDU SN start (last block)								0 or 3
Discarded Block size (last block)								0 or 1
DL report NR PDCP PDU SN								0 or 3
Padding								0-3

Figure 5.2.1-6: Impact to DL User Data for Solution 5

Bits								Number of Octets
7	6	5	4	3	2	1	0	
PDU Type (=1)				Highest Transmitted NR PDCP SN Ind	Highest Delivered NR PDCP SN Ind	Final Frame Ind.	Lost Packet Report	1
Spare			Successfully Delivered PDCP PDU SN Blocks	Data rate Ind.	Retransmitted NR PDCP SN Ind	Delivered Retransmitted NR PDCP SN Ind	Cause Report	1
Desired buffer size for the data radio bearer								4
Desired Data Rate								0 or 4
Number of lost NR-U Sequence Number ranges reported								0 or 1
Start of lost NR-U Sequence Number range								0 or (6* Number of reported lost NR-U SN ranges)
End of lost NR-U Sequence Number range								
Highest successfully delivered NR PDCP Sequence Number								0 or 3
Highest transmitted NR PDCP Sequence Number								0 or 3
Cause Value								0 or 1
Successfully delivered retransmitted NR PDCP Sequence Number								0 or 3
Retransmitted NR PDCP Sequence Number								0 or 3
Number of successfully delivered NR PDCP PDU SN blocks								0 or 1
Successfully delivered NR PDCP PDU SN block start (first block)								0 or 3
Successfully delivered NR PDCP PDU SN block size (first block)								0 or 1
…								
Successfully delivered NR PDCP PDU SN block start (last block)								0 or 3
Successfully delivered NR PDCP PDU SN block size (last block)								0 or 1
Padding								0-3

Figure 5.2.1-7: Impact to DDDS for Solution 5

5.2.2 Solution for Scenario 2

Solution 1-5: Solutions for Scenario 1 could be reused for Scenario 2 with similar information introduced for re-transmission packets.

Solution 6: Highest PDCP SN approach with up to which NR-U SN. To mitigate this problem, the following solution is proposed for DDDS in TS 38.425 [5].

Bits								Number of Octets
7	6	5	4	3	2	1	0	
PDU Type (=1)				Highest Transmitted NR PDCP SN Ind	Highest Delivered NR PDCP SN Ind	Final Frame Ind.	Lost Packet Report	1
Highest Retransmitted End NR-U SN Ind	Highest Retransmitted NR PDCP SN Ind	Highest Delivered Retransmitted End NR-U SN Ind	Highest Delivered Retransmitted NR PDCP SN Ind	Data rate Ind.	Retransmitted NR PDCP SN Ind	Delivered Retransmitted NR PDCP SN Ind	Cause Report	1
Desired buffer size for the data radio bearer								4
Desired Data Rate								0 or 4
Number of lost NR-U Sequence Number ranges reported								0 or 1
Start of lost NR-U Sequence Number range								0 or (6* Number of reported lost NR-U SN ranges)
End of lost NR-U Sequence Number range								
Highest successfully delivered NR PDCP Sequence Number								0 or 3
Highest transmitted NR PDCP Sequence Number								0 or 3
Cause Value								0 or 1
Successfully delivered retransmitted NR PDCP Sequence Number								0 or 3
Retransmitted NR PDCP Sequence Number								0 or 3
Highest Successfully delivered retransmitted NR PDCP Sequence Number								0 or 3
End of NR-U Sequence Number for Highest Successfully delivered retransmitted NR PDCP Sequence Number								0 or 3
Highest Retransmitted NR PDCP Sequence Number								0 or 3
End of NR-U Sequence Number for Highest Retransmitted NR PDCP Sequence Number								0 or 3
Padding								0-3

Figure 5.2.2-1: Impact to DDDS for Solution 6

For Solution 6, the definition of the coding of information elements in frames are as follows:

Highest Delivered Retransmitted NR PDCP SN Ind

- **Description:** This parameter indicates the presence of highest successfully delivered retransmitted PDCP Sequence Number.
- **Value range:** {0= Highest Successfully delivered retransmitted NR PDCP Sequence Number not present, 1= Highest Successfully delivered retransmitted NR PDCP Sequence Number}.
- **Field length:** 1 bit.

Highest Delivered Retransmitted End NR-U SN Ind

- **Description:** This parameter indicates the presence of End of NR-U Sequence Number for Highest successfully delivered retransmitted NR PDCP Sequence Number.
- **Value range:** {0= End of NR-U Sequence Number for Highest Successfully delivered retransmitted NR PDCP Sequence Number not present, 1= End of NR-U Sequence Number for Highest Successfully delivered retransmitted NR PDCP Sequence Number}.
- **Field length:** 1 bit.

Highest Retransmitted NR PDCP SN Ind

- **Description:** This parameter indicates the presence of highest retransmitted PDCP Sequence Number.
- **Value range:** {0= Highest Retransmitted NR PDCP Sequence Number not present, 1= Highest Retransmitted NR PDCP Sequence Number present}.
- **Field length:** 1 bit.

Highest Retransmitted End NR-U SN Ind

- **Description:** This parameter indicates the presence of End of NR-U Sequence Number for Highest retransmitted NR PDCP Sequence Number.
- **Value range:** {0= End of NR-U Sequence Number for Highest Successfully delivered retransmitted NR PDCP Sequence Number not present, 1= End of NR-U Sequence Number for Highest Successfully delivered retransmitted NR PDCP Sequence Number}.
- **Field length:** 1 bit.

Highest Successfully delivered retransmitted NR PDCP Sequence Number

- **Description:** This parameter indicates highest successfully delivered NR PDCP SN in-sequence among retransmission NR PDCP PDUs.
- **Value range:** {0..218-1}.
- **Field length:** 3 octets.

End of NR-U Sequence Number for Highest successfully delivered retransmitted NR PDCP Sequence Number

- **Description:** This parameter indicates a NR-U sequence number up to which the reported Highest successfully delivered retransmitted NR PDCP Sequence Number should be applied for retransmission NR PDCP PDUs.
- **Value range:** {0..218-1}.
- **Field length:** 3 octets.

Highest retransmitted NR PDCP Sequence Number

- **Description:** This parameter indicates highest transmitted NR PDCP SN in-sequence among retransmission NR PDCP PDUs.
- **Value range:** {0..218-1}.

- **Field length:** 3 octets.

End of NR-U Sequence Number for Highest successfully delivered retransmitted NR PDCP Sequence Number

- **Description:** This parameter indicates a NR-U sequence number up to which the reported Highest retransmitted NR PDCP Sequence Number should be applied for retransmission NR PDCP PDUs.

- **Value range:** {0..218-1}.

- **Field length:** 3 octets.

The proposed solution has the following principles:

- Relying on "highest" PDCP SN feedback can embrace the advantage of freeing up CU's buffer for what has been successfully delivered based on PDCP SN.

- By giving "up to which NR-U SN" retransmitted packets have been already delivered to the UE and can be freed up by the reported "highest" SN, CU can confine a range of retransmitted packets for which the reported "highest" SN should be applied.

- The proposed solution is a generalized version of the current Rel-15 solution, where "up to which NR-U SN" is always fixed to that of the PDCP SN reported, thus cannot be worse than Rel-15.

For example, in Figure 5.2.2-2's scenario, CU is now able to know that "OK, among all the retransmitted packets whose PDCP SN lower than or equal to #103, only those up to NR-U SN "G" are successfully delivered", and thus free up #1, #2, #3, #4, #5, and #103 from its buffer as exactly intended:

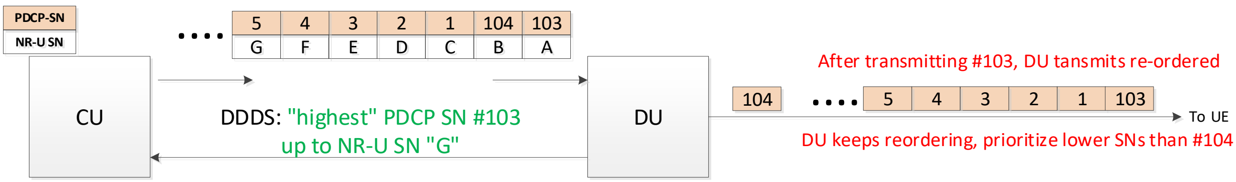

Figure 5.2.2-2: Proposed solution applied to the Figure 5.1.2-1's scenario

5.2.3 Solution for Scenario 3

Solution 1: According to TS 38.425, the amount of data per bearer that the node hosting the PDCP entity send to the corresponding node is upper-bounded by desired buffer size [5]. One way to address the problem in Scenario 3 and compensate for transport network delay is to allow the node hosting the PDCP entity to send additional amount of data on top of desired buffer size. This could be accommodated by introducing the following statement in clause 5.4.2.1 of TS 38.425: "*The hosting node may send additional amount of data to compensate for transport link delays.*"

Solution 2: In this solution, the corresponding node takes the transport network delay into account when it calculates the desired buffer size. That is, the corresponding node estimates the size of the additional amount of data to compensate for link delays, according to the transmission rate over air interface and the transport network delay which is received from the control plane message sent by the node hosting the PDCP entity. Subsequently, the corresponding node calculates the desired buffer size by considering the estimated size of the additional amount of data to compensate for link delays.

5.3 Evaluations

5.3.1 Overhead of message size evaluation

Regarding to the cost of the F1/Xn-U in case of Solution 1, Solution 2, Solution 3 and Solution 5 for scenario 1 from a message size perspective, the extra cost of the DDDS are listed as follows.

- Solution 1: For DDDS report, the cost is (1bit + 3 octets + *Number of NR PDCP successfully delivered out of order* * 3 octets), where the *Number of NR PDCP successfully delivered out of order* is ($2^{\text{SN length}}$ – 2) at most.

- Solution 2: For DDDS report, the cost is (1bit + 3 octets + Number of reported *missing NR PDCP* * 3 octets), where the *Number of missing NR PDCP* is ($2^{\text{SN length}}$ – 2) at most.

- Solution 3: For DDDS report, the cost is (1bit + 3 octets + *Number of successfully delivered PDCP SN range* * 6 octets), where the *Number of successfully delivered PDCP SN range* is ($2^{\text{SN length-1}}$ – 1) at most.

- Solution 5: For DDDS report, the cost is (1bit + 3 octets + *Number of successfully delivered NR PDCP PDU SN blocks* * 4 octets), where the *Number of successfully delivered NR PDCP PDU SN blocks* is ($2^{\text{SN length-1}}$ – 1) at most.

Note: to align among the above Solutions 1-3 when compare the cost, the field length of the number of the successfully delivered PDCP SN range is set to 3 octets as well, which is different from the Solution 3 and Solution 5 captured in the present document.

In the worst case, for all the above solutions, the extra cost of the F1/Xn-U is about 0.75MB and 12KB in case of SN-18 and SN-12, respectively, whereas for Solution 5, the extra cost is about 0.5MB and 8KB in case of SN-18 and SN-12 respectively. However, the worst case is normally rare, and the extra cost on the F1-U/Xn-U interface could be reduced and limited by the following mechanisms:

- Limit the reported size, i.e., the reported number of NR PDCP successfully delivered out of order for Solution 1, the reported number of missing NR PDCP Sequence for Solution 2, and the reported number of the successfully delivered PDCP SN range for Solution 3. For example, if the value rang of the number of the successfully delivered PDCP SN range is limited to 2^8 with field length 1 octet as captured in [13], then the cost of the Solution 3 could be reduced to 1.5KB, which is acceptable over the F1/Xn-U.

- As described in Solution1/2, the corresponding node could report all PDCP SN which are delivered to UE successfully based on the request from hosting node.

Regarding the selection of solution, it depends on the transmission status, e.g.,

- Case 1: if the *successfully delivered PDCP SN range* includes more than two PDU SNs, then the Solution 3 is better than Solution 1, i.e., the extra cost of the F1/Xn-U of Solution 3 is smaller than the Solution 1.

- Case 2: if the *successfully delivered PDCP SN range* includes two PDU SNs, then the extra cost of the F1/Xn-U of Solution 3 is equal to the Solution 1.

- Case 3: if the *successfully delivered PDCP SN range* includes only one PDU SN, then the extra cost of the F1/Xn-U of Solution 3 is larger than the Solution 1.

- Case 4: if the *successfully delivered NR PDCP PDU SN block size* for a certain block is larger than 256, then the Solution 5 is worse than Solution 3, i.e., the extra cost of the F1/Xn-U of Solution 5 is larger than the Solution 3.

- Case 5: if the *successfully delivered NR PDCP PDU SN block size* for a certain block is smaller than (or equal to) 256, then the extra cost of the F1/Xn-U of Solution 5 is smaller than the Solution 3.

- Case 6: if the *successfully delivered NR PDCP PDU SN block size* for a certain block is one, then the Solution 5 is worse than Solution 1, i.e., the extra cost of the F1/Xn-U of Solution 5 is larger than the Solution 1.

- Case 7: if the *successfully delivered NR PDCP PDU SN block size* for a certain block is larger than one, then the extra cost of F1/Xn-U of Solution 5 is better than Solution 1.

In conclusion, the cost of extra cost on the F1-U/Xn-U interface is acceptable, and the solutions for DDDS enhancement have to be adopted, and which one is chosen depends on the evaluation of the transmission status. Considering the Case 6 and Case 7, it seems that in the most case, the *successfully delivered NR PDCP PDU SN block size* is larger than one. Hence, compared with Solution 1 and Solution 2, Solution 5 is recommended [7].

With regards to Solution 4, since it reuses the existing DL discard mechanism, no extra signalling cost needs to be considered.

Regarding to the cost of the F1/Xn-U in case of solution for Scenario 2 as described in clause 5.2.2, the extra cost of the DDDS 2bit + 6 octets.

5.3.2 Practical relevance of the Scenarios 1 and 2

The changes to DDDS proposed in solutions 1-5 for Scenario 1 and Solutions 1-2 for Scenario 2 significantly change the current DDDS structure. Moreover, regarding the claimed benefits of the solution for duplication and fast retransmission, some properties of RLC need to be considered. First, when a packet is handed over to the RLC, its transmission cannot be recalled. Second, once a PDU is lost on RLC level, a meaningful RLC implementation will not attempt to send new PDUs (or at least not more than an extremely small number of new PDUs) to the UE until the missing PDU has been successfully delivered.

One claimed use case for detailed reporting of out-of-sequence delivered PDUs is centralized (i.e. fast) retransmission. The essence of fast retransmission feature is to temporarily suspend delivery in a leg that experiences delivery problems, where the benefit of (only) temporary suspension is that RLC context removal/reestablishment is avoided. In that respect, it is crucial that the RLC recognizes early that the problems with delivery are likely to occur (i.e. after one or two lost RLC PDUs) and initiates fast retransmission in the other leg. Since the DU will not wait for long to take action, this means that the number of out-of-sequence delivered PDUs to the UE is small. In other words, the number of out-of-sequence delivered PDUs to the UE will be extremely small, and any eventual retransmission in another leg will comprise an extremely small number of PDUs.

Regarding the use of aforementioned solutions for revoking packet transmissions in duplication, some companies expressed the following concern : it is expected that the duplicates are delivered to the UE within a reasonably short time period, meaning that, by the time an out-of-sequence delivery of a PDU from one leg is reported, the transmission of its duplicates in other legs cannot be recalled because the duplicates will most likely have entered the RLC on other legs and their transmission in these other legs cannot be recalled (i.e. discarded).

Having in mind the above, the benefits of the Solutions 1-5 for Scenario 1 and Solutions 1-2 for Scenario 2, compared with their inherent complexity are questioned by some companies.

The Solution 2 for Scenario 2 does not support the reporting for the scenario where multiple sets of retransmission blocks (caused by e.g. TN loss or poor conditions in the other leg) are sent along with first-time transmissions [11].

The DU may perform full or partial reordering, where the CU cannot know if and how much reordering has been done. The Solution 2 for Scenario 2 does not take this into account (refer to [8]).

The Solution 2 for Scenario 2 is rather costly because not only that it requires the use of 4 spare bits + up to 12 octets in the DDDS, but this alternative also requires storage of NR-U SNs at the DU until their respective PDUs are acknowledged, which may heavily load the memory.

The fundamental trait of fast retransmission is the ability to predict that the link is bound to fail, which implies that fast retransmission usually deals with small number of packets. Hence, it is concluded that the benefits of the solution are marginal since the scenario in question will likely involve a small number of retransmitted PDUs.

For the reasons explained above, the solution is not recommended for normative work.

5.3.3 Evaluation of Solutions for Scenario 3

The essence of Scenario 3 is transport network (TN) delay compensation. Accurate compensation requires accurate estimation of DL TN delay. Although DL TN delay estimation is not an integral part of the Scenario 3, it is worth mentioning that this delay can be measured in several different ways:

- A proprietary method
- One possibility would be to consider using the GTP-U echo to measure the RTT and divide it by 2 or some other number calculated in a proprietary way.
- Another option would be to use timestamps and report from the DU the PDU reception time.
- Yet another option could be to measure RTT for a poll (i.e. time between sending a request and receiving a reply).
- RAN3 recently approved SA5 measurements for F1-U DL based on RTT. The RTT measurements are based on DDDS, where it is assumed that total internal DU delay is known and that is subtracted from the RTT. The remainder is divided by 2 to get the DL estimation. In case the DDDS refers to multiple packets, the measurement starts from the last packet that pertains to the DDDS [9].

Although a portion of a buffer size at a receiver may be spent to account for network delay as described in Scenario 3, a solution which disregards DBS (e.g., Solution 1) is likely to incur interoperability issues. For such mechanism to operate, there is an underlying assumption that a reliable way to determine network delay between transmitter and receiver is accurate and available. However, this cannot be guaranteed. Therefore, situations in which a transmitter node estimates a delay that is not representative, or which fluctuates, will make the estimation at the transmitter no longer deterministic or accurate. Hence, it will result in sending an amount of data that the receiver cannot handle, leading to buffer overflow, lost packets and retransmissions. Thus, for a multi-vendor scenario to properly operate, it is more appropriate for the transmitter has to respect the upper limit determined by the DBS (as defined in TS 38.425 [5]) and not to exceed it based on an estimation of the network delay over the interface.

Likewise, by means of implementation it is still possible to have the network delay accounted for in the DBS value provided by the receiver without changes to the existing TS 38.425 specification [5].

Compared to Solution 1, Solution 2 can be considered more accurate, since the corresponding node (e.g., gNB-DU) obtains the channel state information and knows the transmission rate over the air interface for each TTI (e.g., 1ms), whereas the node hosting the PDCP entity can only speculate the transmission rate over the air interface by DDR (which indicates the expected data rate of the corresponding node in 1s). Moreover, in Solution 2 the corresponding node can also use the transport network delay for scheduling to meet the QoS requirements, especially for the TSN [10].

6 Support for UE Connection to Several gNB-CU-UPs from Different Security Domains

6.1 Scenario

The support for CU-UPs located in different security domains can be useful for certain deployment scenarios in which there may be a security concern.

- An operator may not wish to share the same key with 3rd party application providers (e.g., applications used in specific slices or CU-UPs). This security concern exists irrespective of whether the CU-UPs are in the same location or not. For example, consider Figure 6.1-1, In this example CU-UP1, and CU-UP2 are located in the same virtualized centralized environment. However, the level of trust for CU-UP1 and CU-UP2 is not the same. This may be due to having a 3rd party application provider handling specific slices at the CU-UP2 or even controlling the whole CU-UP2. Thus, a security breach in CU-UP2 would compromise CU-UP1. In Figure 6.1-2, a similar scenario is depicted, in which CU-UP1 and CU-UP2 are both still in centralized environments, however, at different location. The security concern for this scenario is the same. Thus, to address this security concern, it is beneficial to have CU-UP1 and CU-UP2 belong to different security domains.

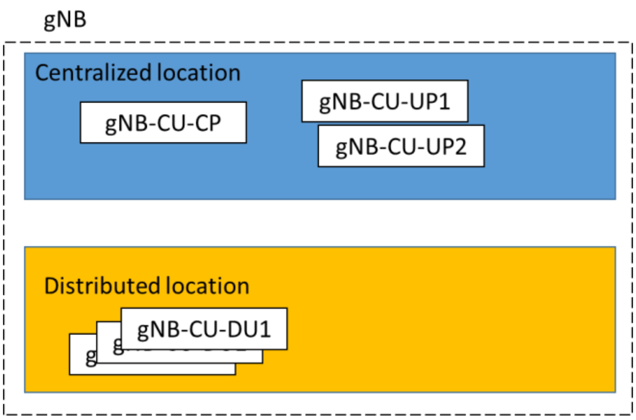

Figure 6.1-1: gNB with gNB-CU-UP centralized

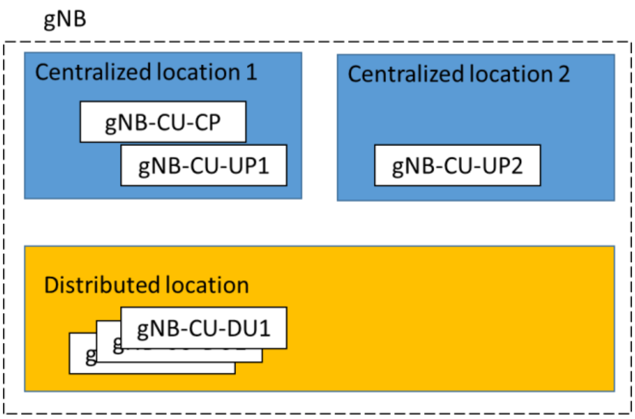

Figure 6.1-2: gNB with gNB-CU-UP centralized at different locations

- The location of certain CU-UP under a gNB may be a security concern. Consider Figure 6.1-3, in which CU-UP2 is located at a distributed location and CU-UP1 at a centralized one. If the distributed location is not well secured, tampering at the site will compromise CU-UP1. This security concern exists irrespective of whether CU-UP2 is handled by the same operator or a 3rd party.

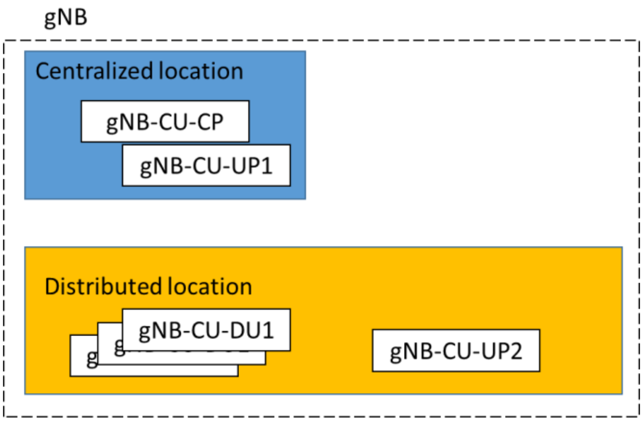

Figure 6.1-3: gNB with gNB-CU-UP centralized and gNB-CU-UP distributed

6.2 Possible Solutions

void

6.2 Evaluations

void

7 Conclusion

RAN3 analysed various scenario and solutions as per the objectives described in [2] and the conclusions and recommendations are provided below for each of these objectives respectively.

Enhancements on Flow Control Mechanism:

- During the discussion, 4 scenarios are proposed among which 3 scenarios are identified in clause 5.1 and one scenario are precluded. Possible solutions for the 3 scenarios are provided in clause 5.2. There has been evaluation on different solutions from several aspects including Overhead of message size, Radio resources efficiency, relevance of the scenario which is captured in clause 5.3.

- RAN3 acknowledged that Solution 5 can be beneficial in at least some scenarios, e.g. Industrial IoT (packet duplication). This solution is currently being discussed in the scope of an ongoing Rel-16 Work Item on

Industrial IoT and is considered beneficial in this latter scope. For this reason, it is recommended to pursue this solution for scenario 1 in that scope.

- Further enhancements of Solution 5 targeting Scenario 2 may be specified during normative phase, provided that gains can be confirmed with a reasonable complexity. Some companies see the benefits of solutions for Scenario 3, but there is no consensus on this issue in RAN3 [12].

Support for UE Connection to Several gNB-CU-UPs from Different Security Domains:

- The scenario was identified and agreed as useful to be supported. Likewise, an LS was sent to SA3 requesting feedback on solutions for this scenario. Therefore, a solution could be specified during normative phase based on the feedback from SA3 [12].

Annex (Informative): Change history

Change history							
Date	Meeting	TDoc	CR	Rev	Cat	Subject/Comment	New version
2019-08	RAN3#105	R3-194531				TR skeleton	0.0.1
2019-08	RAN3#105					Update the progress in RAN3#105 to TR: Scenarios and solutions for flow control enhancement	0.1.0
2019-10	RAN3#105bis					Reflected the agreed TPs from RAN3#105bis	0.2.0
2019-11	RAN3#106					Reflected the agreed TPs from RAN3#106 and including some editorial changes	0.3.0
2019-12	RAN#86					One step approval	1.0.0
2019-12	RAN#86					TR approved by TSG RAN plenary	16.0.0