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Technical Specification

KT PyeongChang 5G Special Interest Group (KT 5G-SIG); KT 5th Generation Radio Access; Radio Link Control (RLC); Protocol specification (Release 1)

Ericsson, Intel Corp., Nokia, Qualcomm Technologies Inc., Samsung Electronics & KT

Document History

Version	Date	Change
0.1	2016-04-29	First Draft Version
1.0	2016-07-13	Final Version
1.1	2016-08-24	Clarification of RLC operation related to segmentation

Contents

Foreword

This Technical Specification has been produced by the KT PyeongChang 5G Special Interest Group (KT 5G-SIG).

1 Scope

The present document provides the description of the Radio Link Control (RLC) protocol for the PyeongChang 5G trial (P5G).

2 References

[1] TS 5G.300: " PyeongChang 5th Generation Radio Access; Overall Description".

[2] TS 5G.331: "5G Radio Access (5G RA); Resource Control (5G-RRC); Protocol Specification".

[3] TS 5G.323: "5G Radio Access (5G RA); Packet Data Convergence Protocol (5G-PDCP) protocol specification".

[4] TS 5G.321: "5G Radio Access (5G RA); Medium Access Control (5G-MAC) protocol specification".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AM	Acknowledged Mode
AMD	AM Data
ARQ	Automatic Repeat reQuest
xBCCH	5G Broadcast Control CHannel
xCCCH	5G Common Control CHannel
xDCCH	5G Dedicated Control CHannel
DL	DownLink
xDL-SCH	5G DL-Shared CHannel
xDTCH	5G Dedicated Traffic CHannel
E	Extension bit
5G Node-B	5G Node B
5G RA	5G Radio Access
5G RAN	5G Radio Access Network
FI	Framing Info
HARQ	Hybrid ARQ
LI	Length Indicator
LSF	Last Segment Flag
MAC	Medium Access Control
PDU	Protocol Data Unit
RLC	Radio Link Control
RRC	Radio Resource Control
SAP	Service Access Point
SDU	Service Data Unit
SN	Sequence Number
SO	Segment Offset
TB	Transport Block
TM	Transparent Mode
TMD	TM Data
UE	User Equipment
UL	UpLink

UM	Unacknowledged Mode
UMD	UM Data

4 General

4.1 Introduction

The objective is to describe the 5G-RLC architecture and the 5G-RLC entities from a functional point of view.

4.2 5G-RLC architecture

4.2.1 5G-RLC entities

The description in this sub clause is a model and does not specify or restrict implementations.

5G-RRC is generally in control of the 5G-RLC configuration.

Functions of the 5G-RLC sub layer are performed by 5G-RLC entities. For a 5G-RLC entity configured at the 5G Node, there is a peer 5G-RLC entity configured at the 5G UE and vice versa.

A 5G-RLC entity receives/delivers 5G-RLC SDUs from/to upper layer and sends/receives 5G-RLC PDUs to/from its peer 5G-RLC entity via lower layers. A 5G-RLC PDU can either be a 5G-RLC data PDU (see sub clause 6.1.1) or a 5G-RLC control PDU (see sub clause 6.1.2). If a 5G-RLC entity receives 5G-RLC SDUs from upper layer, it receives them through a single SAP between 5G-RLC and upper layer, and after forming 5G-RLC data PDUs from the received 5G-RLC SDUs, the 5G-RLC entity delivers the 5G-RLC data PDUs to lower layer through a single logical channel. If an 5G-RLC entity receives 5G-RLC data PDUs from lower layer, it receives them through a single logical channel, and after forming 5G-RLC SDUs from the received 5G-RLC data PDUs, the 5G-RLC entity delivers the 5G-RLC SDUs to upper layer through a single SAP between 5G-RLC and upper layer. If a 5G-RLC entity delivers/receives 5G-RLC control PDUs to/from lower layer, it delivers/receives them through the same logical channel it delivers/receives the 5G-RLC data PDUs through.

A 5G-RLC entity can be configured to perform data transfer in one of the following three modes: Transparent Mode (TM), Unacknowledged Mode (UM) or Acknowledged Mode (AM). Consequently, a 5G-RLC entity is categorized as a TM 5G-RLC entity, an UM 5G-RLC entity or an AM 5G-RLC entity depending on the mode of data transfer that the RLC entity is configured to provide.

A TM 5G-RLC entity is configured either as a transmitting TM 5G-RLC entity or a receiving TM 5G-RLC entity. The transmitting TM 5G-RLC entity receives 5G-RLC SDUs from upper layer and sends 5G-RLC PDUs to its peer receiving TM 5G-RLC entity via lower layers. The receiving TM 5G-RLC entity delivers 5G-RLC SDUs to upper layer and receives 5G-RLC PDUs from its peer transmitting TM 5G-RLC entity via lower layers.

An UM 5G-RLC entity is configured either as a transmitting UM 5G-RLC entity or a receiving UM 5G-RLC entity. The transmitting UM 5G-RLC entity receives 5G-RLC SDUs from upper layer and sends 5G-RLC PDUs to its peer receiving UM 5G-RLC entity via lower layers. The receiving UM 5G-RLC entity delivers 5G-RLC SDUs to upper layer and receives 5G-RLC PDUs from its peer transmitting UM 5G-RLC entity via lower layers.

An AM 5G-RLC entity consists of a transmitting side and a receiving side. The transmitting side of an AM 5G-RLC entity receives 5G-RLC SDUs from upper layer and sends 5G-RLC PDUs to its peer AM 5G-RLC entity via lower layers. The receiving side of an AM 5G-RLC entity delivers 5G-RLC SDUs to upper layer and receives 5G-RLC PDUs from its peer AM 5G-RLC entity via lower layers.

Figure 1 illustrates the overview model of the 5G-RLC sub layer.

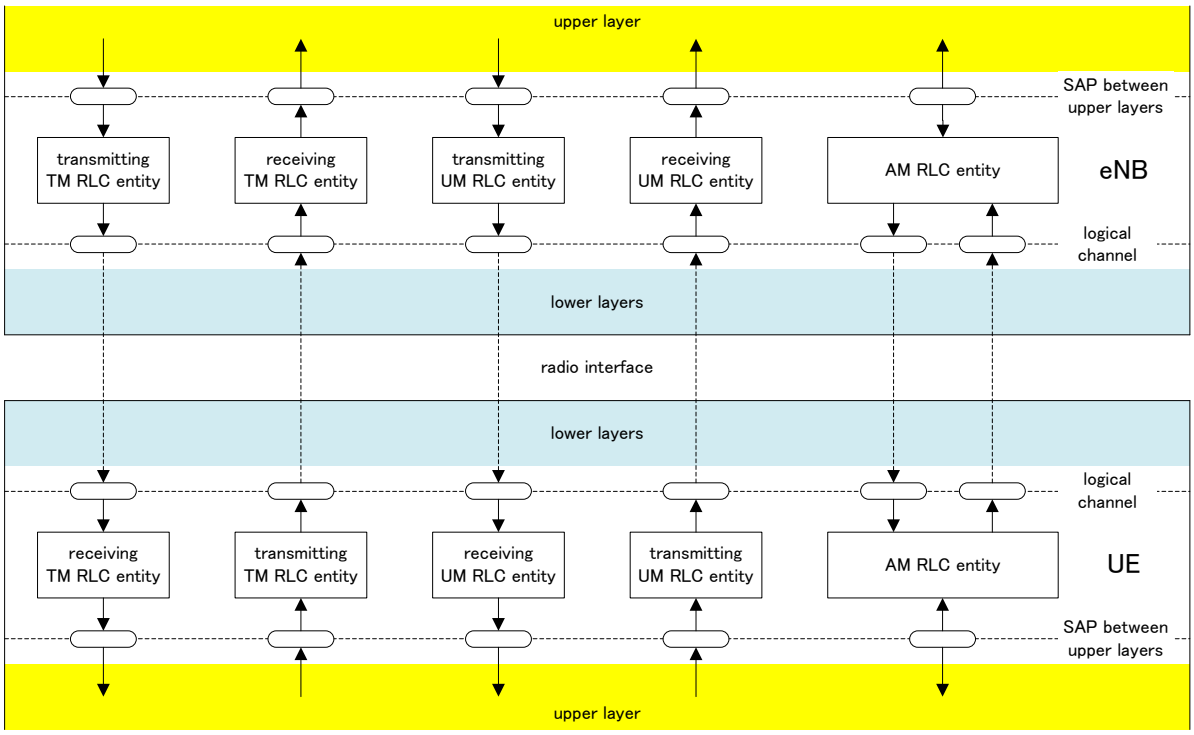

Figure 4.2.1-1: Overview model of the 5G-RLC sub layer

The following applies to all RLC entity types (i.e. TM, UM and AM RLC entity):

- RLC SDUs of variable sizes which are byte aligned (i.e. multiple of 8 bits) are supported;
- RLC PDUs are formed only when a transmission opportunity has been notified by lower layer (i.e. by MAC) and are then delivered to lower layer.

Description of different RLC entity types are provided below.

4.2.1.1 TM 5G-RLC entity

4.2.1.1.1 General

A TM 5G-RLC entity can be configured to deliver/receive 5G-RLC PDUs through the following 5G logical channels:

- xBCCH.
- In standalone mode, xBCCH, DL/UL xCCCH and xPCCH(TBD).

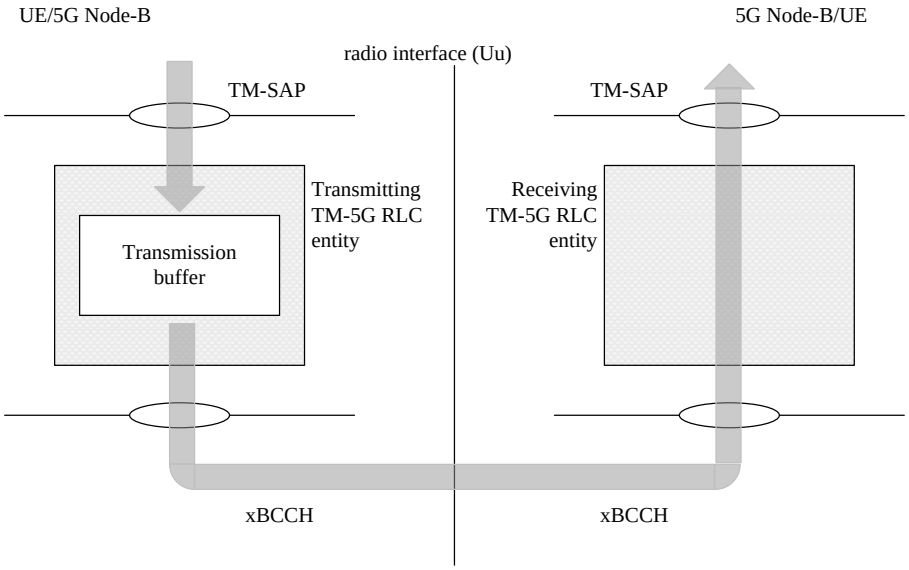

Figure 4.2.1.1.1-1: Model of two transparent mode peer entities

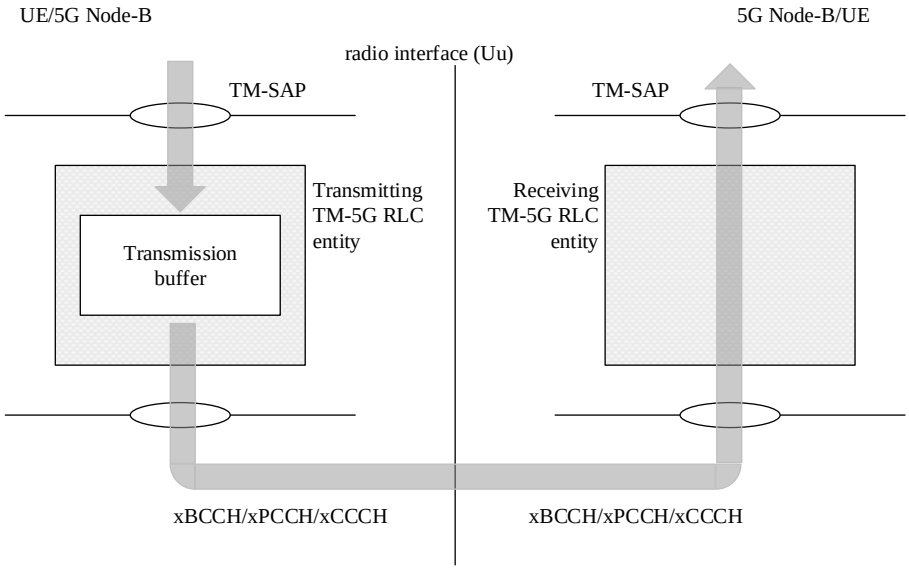

Figure 4.2.1.1.1-1a: Model of two transparent mode peer entities in standalone mode

A TM 5G RLC entity delivers/receives the following 5G RLC data PDU:

- TMD PDU.

4.2.1.1.2 Transmitting TM 5G RLC entity

When a transmitting TM 5G RLC entity forms TMD PDUs from 5G RLC SDUs, it shall:

- not segment nor concatenate the 5G RLC SDUs;
- not include any 5G RLC headers in the TMD PDUs.

4.2.1.1.3 Receiving TM 5G RLC entity

When a receiving TM 5G RLC entity receives TMD PDUs, it shall:

- deliver the TMD PDUs (which are just 5G RLC SDUs) to upper layer.

4.2.1.2 UM RLC entity

4.2.1.2.1 General

An UM 5G-RLC entity can be configured to deliver/receive 5G-RLC PDUs through the following logical channels:

- DL/UL xDTCH.

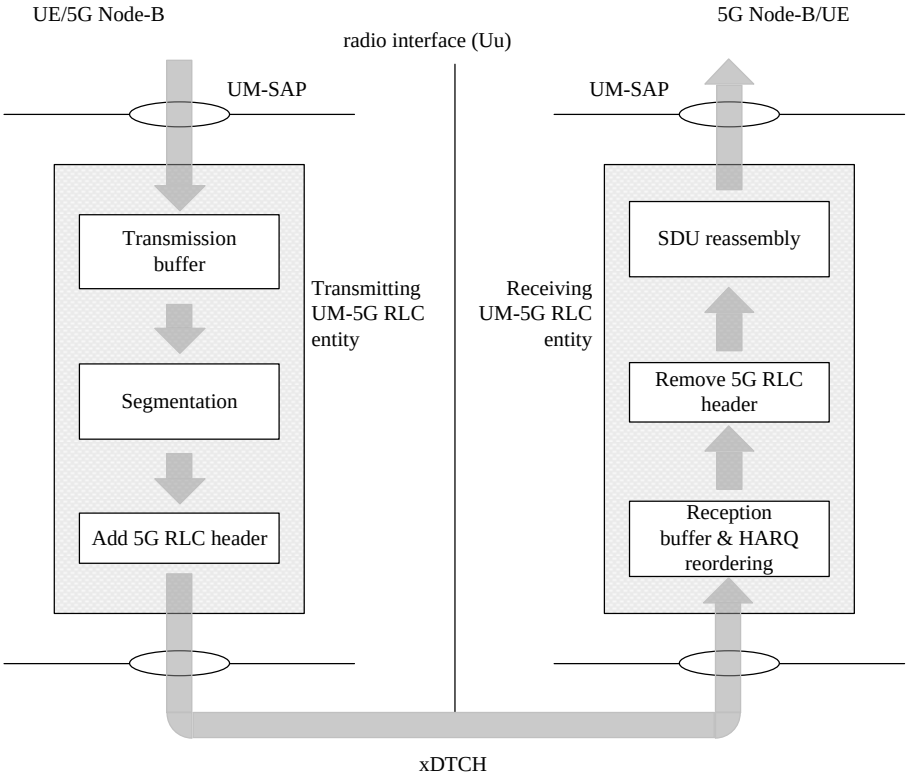

Figure 4.2.1.2.1-1: Model of two unacknowledged mode peer entities

An UM 5G-RLC entity delivers/receives the following 5G-RLC data PDUs:

- UMD PDU.
- UMD PDU segment.

4.2.1.2.2 Transmitting UM 5G-RLC entity

When a transmitting UM 5G-RLC entity forms UMD PDUs from 5G-RLC SDUs, it shall:

- segment the 5G-RLC SDUs so that the UMD PDUs fit within the total size of 5G-RLC PDU(s);
- include relevant RLC headers in the UMD PDU/UMD PDU segment.

4.2.1.2.3 Receiving UM RLC entity

When a receiving UM RLC entity receives UMD PDUs, it shall:

- detect whether or not the UMD PDUs have been received in duplication, and discard duplicated UMD PDUs;
- reorder the UMD PDUs if they are received out of sequence;
- detect the loss of UMD PDUs at lower layers and avoid excessive reordering delays;

- reassemble 5G-RLC SDUs from the reordered UMD PDUs (not accounting for 5G-RLC PDUs for which losses have been detected) and deliver the 5G-RLC SDUs to upper layer in ascending order of the 5G-RLC SN;
- discard received UMD PDUs that cannot be re-assembled into a RLC SDU due to loss at lower layers of an UMD PDU which belonged to the particular 5G-RLC SDU.

At the time of 5G-RLC re-establishment, the receiving UM 5G-RLC entity shall:

- if possible, reassemble 5G-RLC SDUs from the UMD PDUs that are received out of sequence and deliver them to upper layer;
- discard any remaining UMD PDUs that could not be reassembled into 5G-RLC SDUs;
- initialize relevant state variables and stop relevant timers.

4.2.1.3 AM RLC entity

4.2.1.3.1 General

An AM RLC entity can be configured to deliver/receive 5G-RLC PDUs through the following logical channels:

- DL/UL xDTCH.
- In standalone mode, DL/UL xDCCH or DL/UL xDTCH.

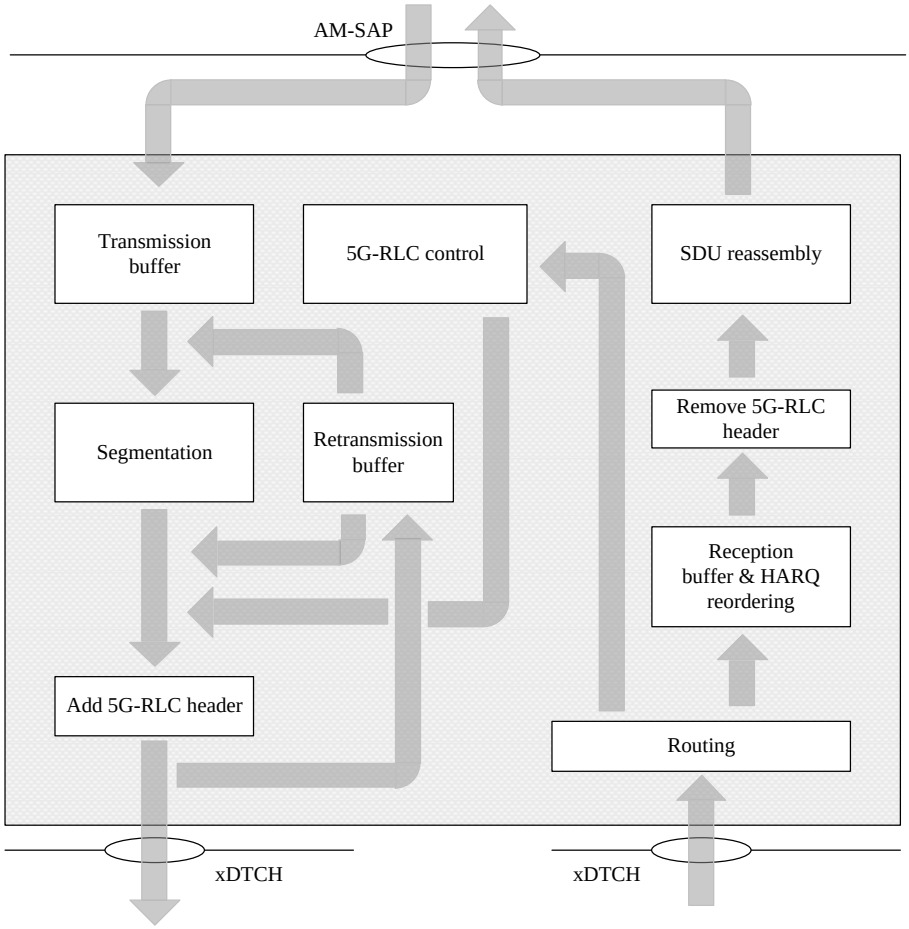

Figure 4.2.1.3.1-1: Model of an acknowledged mode entity

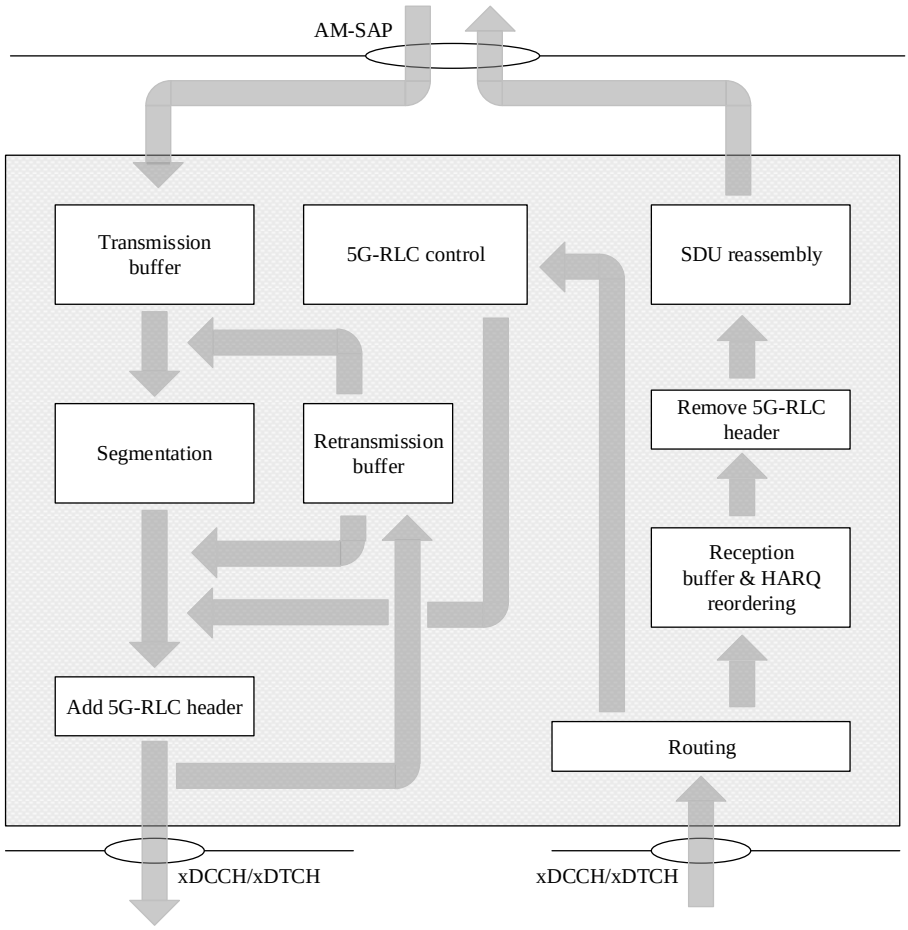

Figure 4.2.1.3.1-1a: Model of an acknowledged mode entity in standalone mode

An AM 5G-RLC entity delivers/receives the following 5G-RLC data PDUs:

- AMD PDU;
- AMD PDU segment.

An AM 5G-RLC entity delivers/receives the following 5G-RLC control PDU:

- STATUS PDU.

4.2.1.3.2 Transmitting side

When the transmitting side of an AM 5G-RLC entity forms AMD PDUs from 5G-RLC SDUs, it shall:

- segment the 5G-RLC SDUs so that the AMD PDUs fit within the total size of 5G-RLC PDU(s) indicated by lower layer at the particular transmission opportunity notified by lower layer.

The transmitting side of an AM 5G-RLC entity supports retransmission of 5G-RLC data PDUs (ARQ):

- if the 5G-RLC data PDU to be retransmitted does not fit within the total size of 5G-RLC PDU(s) indicated by lower layer at the particular transmission opportunity notified by lower layer, the AM 5G-RLC entity can re-segment the 5G-RLC data PDU into AMD PDU segments;
- the number of re-segmentation is not limited.

When the transmitting side of an AM 5G-RLC entity forms AMD PDUs from 5G-RLC SDUs received from upper layer or AMD PDU segments from 5G-RLC data PDUs to be retransmitted, it shall:

- include relevant 5G-RLC headers in the 5G-RLC data PDU/PDU segment.

4.2.1.3.3 Receiving side

When the receiving side of an AM 5G-RLC entity receives 5G-RLC data PDUs, it shall:

- detect whether or not the 5G-RLC data PDUs have been received in duplication, and discard duplicated 5G-RLC data PDUs;
- reorder the 5G-RLC data PDUs if they are received out of sequence;
- detect the loss of 5G-RLC data PDUs at lower layers and request retransmissions to its peer AM 5G-RLC entity;
- reassemble 5G-RLC SDUs from the reordered 5G-RLC data PDUs and deliver the 5G-RLC SDUs to upper layer in sequence.

At the time of 5G-RLC re-establishment, the receiving side of an AM 5G-RLC entity shall:

- if possible, reassemble 5G-RLC SDUs from the 5G-RLC data PDUs that are received out of sequence and deliver them to upper layer;
- discard any remaining 5G-RLC data PDUs that could not be reassembled into 5G-RLC SDUs;
- initialize relevant state variables and stop relevant timers.

4.3 Services

4.3.1 Services provided to upper layers

The following services are provided by RLC to upper layer:

- TM data transfer;
- UM data transfer;
- AM data transfer, including indication of successful delivery of upper layers PDUs.

4.3.2 Services expected from lower layers

The following services are expected by 5G-RLC from lower layer (i.e. 5G-MAC):

- data transfer;
- notification of a transmission opportunity, together with the total size of the 5G-RLC PDU(s) to be transmitted in the transmission opportunity.

4.4 Functions

The following functions are supported by the RLC sub layer:

- transfer of upper layer PDUs;
- error correction through ARQ (only for AM data transfer);
- segmentation and reassembly of 5G-RLC SDUs (only for UM and AM data transfer);
- re-segmentation of RLC data PDUs (only for AM data transfer);
- reordering of 5G-RLC data PDUs (only for UM and AM data transfer);
- duplicate detection (only for UM and AM data transfer);
- 5G-RLC SDU discard (only for UM and AM data transfer);
- 5G-RLC re-establishment;
- Protocol error detection (only for AM data transfer).

4.5 Data available for transmission

For the purpose of MAC buffer status reporting, the UE shall consider the following as data available for transmission in the 5G-RLC layer:

- 5G-RLC SDUs, or segments thereof, that have not yet been included in a 5G-RLC data PDU;
- 5G-RLC data PDUs, or portions thereof, that are pending for retransmission (RLC AM).

In addition, if a STATUS PDU has been triggered and *t-StatusProhibit* is not running or has expired, the UE shall estimate the size of the STATUS PDU that will be transmitted in the next transmission opportunity, and consider this as data available for transmission in the 5G-RLC layer.

5 Procedures

5.1 Data transfer procedures

5.1.1 TM data transfer

5.1.1.1 Transmit operations

5.1.1.1.1 General

When submitting a new TMD PDU to lower layer, the transmitting TM 5G-RLC entity shall:

- submit a 5G-RLC SDU without any modification to lower layer.

5.1.1.2 Receive operations

5.1.1.2.1 General

When receiving a new TMD PDU from lower layer, the receiving TM 5G-RLC entity shall:

- deliver the TMD PDU without any modification to upper layer.

5.1.2 UM data transfer

5.1.2.1 Transmit operations

5.1.2.1.1 General

When delivering a new UMD PDU to lower layer, the transmitting UM 5G-RLC entity shall:

- set the SN of the UMD PDU to VT(US), and then increment VT(US) by one.

When delivering a new UMD PDU segment to lower layer and if all the UMD PDU segments from the same UMD SDU are delivered to lower layer, the transmitting UM 5G-RLC entity shall:

- set the SN of the UMD PDU segment to VT(US), and then increment VT(US) by one.

When delivering a new UMD PDU segment to lower layer and if any UMD PDU segment from the same UMD SDU is not delivered to lower layer yet, the transmitting UM 5G-RLC entity shall:

- set the SN of the UMD PDU segment to VT(US).

5.1.2.2 Receive operations

5.1.2.2.1 General

The receiving UM 5G-RLC entity shall maintain a reordering window according to state variable VR(UH) as follows:

- a SN falls within the reordering window if (VR(UH) – UM_Window_Size) <= SN < VR(UH);

- a SN falls outside of the reordering window otherwise.

When receiving an UMD PDU from lower layer, the receiving UM 5G-RLC entity shall:

- either discard the received UMD PDU or place it in the reception buffer (see sub clause 5.1.2.2.2);
- if the received UMD PDU was placed in the reception buffer:
  - update state variables, reassemble and deliver 5G-RLC SDUs to upper layer and start/stop *t-Reordering* as needed (see sub clause 5.1.2.2.3);

When *t-Reordering* expires, the receiving UM 5G-RLC entity shall:

- update state variables, reassemble and deliver RLC SDUs to upper layer and start *t-Reordering* as needed (see sub clause 5.1.2.2.4).

5.1.2.2.2 Actions when an UMD PDU is received from lower layer

When an UMD PDU with SN = x is received from lower layer, the receiving UM 5G-RLC entity shall:

- if VR(UR) < x < VR(UH) and the UMD PDU with SN = x has been received before; or
- if (VR(UH) – UM_Window_Size) <= x < VR(UR); or
  - if byte segment numbers y to z of the UMD PDU with SN=x have been received before:- discard the received UMD PDU;
- else:
  - place the received UMD PDU in the reception buffer.
  - if some byte segments of the UMD PDU contained in the 5G-RLC data PDU have been received before:
    - discard the duplicate byte segments.

5.1.2.2.3 Actions when an UMD PDU is placed in the reception buffer

When an UMD PDU with SN = x is placed in the reception buffer, the receiving UM RLC entity shall:

- if x falls outside of the reordering window:
  - update VR(UH) to x + 1;
  - reassemble 5G-RLC SDUs from any byte segment of UMD PDUs with SN that falls outside of the reordering window, remove 5G-RLC headers when doing so and deliver the reassembled 5G-RLC SDUs to upper layer in ascending order of the 5G-RLC SN if not delivered before;
  - if VR(UR) falls outside of the reordering window:
    - set VR(UR) to (VR(UH) – UM_Window_Size);
- if the reception buffer contains an UMD PDU with SN = VR(UR):
  - update VR(UR) to the SN of the first UMD PDU with SN > current VR(UR) that has not been received;
  - reassemble 5G-RLC SDUs from any byte segment of UMD PDUs with SN < updated VR(UR), remove 5G-RLC headers when doing so and deliver the reassembled 5G-RLC SDUs to upper layer in ascending order of the 5G-RLC SN if not delivered before;
- if *t-Reordering* is running:
  - if VR(UX) <= VR(UR); or
  - if VR(UX) falls outside of the reordering window and VR(UX) is not equal to VR(UH)::
    - stop and reset *t-Reordering*;
- if *t-Reordering* is not running (includes the case when *t-Reordering* is stopped due to actions above):

- if VR(UH) > VR(UR):
  - start *t-Reordering*;
  - set VR(UX) to VR(UH).

5.1.2.2.4 Actions when *t-Reordering* expires

When *t-Reordering* expires, the receiving UM 5G-RLC entity shall:

- update VR(UR) to the SN of the first UMD PDU with SN >= VR(UX) that has not been received;
- reassemble 5G-RLC SDUs from any UMD PDUs with SN < updated VR(UR), remove 5G-RLC headers when doing so and deliver the reassembled 5G-RLC SDUs to upper layer in ascending order of the 5G-RLC SN if not delivered before;
- if VR(UH) > VR(UR):
  - start *t-Reordering*;
  - set VR(UX) to VR(UH).

5.1.3 AM data transfer

5.1.3.1 Transmit operations

5.1.3.1.1 General

The transmitting side of an AM 5G-RLC entity shall prioritize transmission of 5G-RLC control PDUs over 5G-RLC data PDUs. The transmitting side of an AM 5G-RLC entity shall prioritize retransmission of 5G-RLC data PDUs over transmission of new AMD PDUs.

The transmitting side of an AM 5G-RLC entity shall maintain a transmitting window according to state variables VT(A) and VT(MS) as follows:

- a SN falls within the transmitting window if VT(A) <= SN < VT(MS);
- a SN falls outside of the transmitting window otherwise.

The transmitting side of an AM 5G-RLC entity shall not deliver to lower layer any 5G-RLC data PDU whose SN falls outside of the transmitting window.

When delivering a new AMD PDU to lower layer, the transmitting side of an AM 5G-RLC entity shall:

- set the SN of the AMD PDU to VT(S), and then increment VT(S) by one.

When delivering a new AMD PDU segment to lower layer and if all the AMD PDU segment from the same AMD SDU are delivered to lower layer, the transmitting side of an AM 5G-RLC entity shall:

- set the SN of the AMD PDU segment to VT(S), and then increment VT(S) by one.

When delivering a new AMD PDU segment to lower layer and if any AMD PDU segment from the same AMD SDU is not delivered to lower layer yet, the transmitting side of an AM 5G-RLC entity shall:

– set the SN of the AMD PDU segment to VT(S).The transmitting side of an AM 5G-RLC entity can receive a positive acknowledgement (confirmation of successful reception by its peer AM 5G-RLC entity) for a 5G-RLC data PDU by the following:

- STATUS PDU from its peer AM 5G-RLC entity.

When receiving a positive acknowledgement for an AMD PDU with SN = VT(A), the transmitting side of an AM 5G-RLC entity shall:

- set VT(A) equal to the SN of the AMD PDU with the smallest SN, whose SN falls within the range VT(A) <= SN <= VT(S) and for which a positive acknowledgment has not been received yet.

- if positive acknowledgements have been received for all AMD PDUs associated with a transmitted 5G-RLC SDU:
  - send an indication to the upper layers of successful delivery of the 5G-RLC SDU.

5.1.3.2 Receive operations

5.1.3.2.1 General

The receiving side of an AM 5G-RLC entity shall maintain a receiving window according to state variables VR(R) and VR(MR) as follows:

- a SN falls within the receiving window if VR(R) <= SN < VR(MR);
- a SN falls outside of the receiving window otherwise.

When receiving a 5G-RLC data PDU from lower layer, the receiving side of an AM 5G-RLC entity shall:

- either discard the received 5G-RLC data PDU or place it in the reception buffer (see sub clause 5.1.3.2.2);
- if the received 5G-RLC data PDU was placed in the reception buffer:
  - update state variables, reassemble and deliver 5G-RLC SDUs to upper layer and start/stop *t-Reordering* as needed (see sub clause 5.1.3.2.3).

When *t-Reordering* expires, the receiving side of an AM 5G-RLC entity shall:

- update state variables and start *t-Reordering* as needed (see sub clause 5.1.3.2.4).

5.1.3.2.2 Actions when a 5G-RLC data PDU is received from lower layer

When a RLC data PDU is received from lower layer, where the RLC data PDU contains byte segment numbers y to z of an AMD PDU with SN = x, the receiving side of an AM RLC entity shall:

- if x falls outside of the receiving window; or
- if byte segment numbers y to z of the AMD PDU with SN = x have been received before:
  - discard the received RLC data PDU;
- else:
  - place the received RLC data PDU in the reception buffer;
  - if some byte segments of the AMD PDU contained in the 5G-RLC data PDU have been received before:
    - discard the duplicate byte segments.

5.1.3.2.3 Actions when a 5G-RLC data PDU is placed in the reception buffer

When a 5G-RLC data PDU with SN = x is placed in the reception buffer, the receiving side of an AM 5G-RLC entity shall:

- if x >= VR(H)
  - update VR(H) to x+ 1;
- if all byte segments of the AMD PDU with SN = VR(MS) are received:
  - update VR(MS) to the SN of the first AMD PDU with SN > current VR(MS) for which not all byte segments have been received;
- if x = VR(R):
  - if all byte segments of the AMD PDU with SN = VR(R) are received:
    - update VR(R) to the SN of the first AMD PDU with SN > current VR(R) for which not all byte segments have been received;

- update VR(MR) to the updated VR(R) + AM_Window_Size;

- reassemble RLC SDUs from any byte segments of AMD PDUs with SN that falls outside of the receiving window and in-sequence byte segments of the AMD PDU with SN = VR(R), remove RLC headers when doing so and deliver the reassembled RLC SDUs to upper layer in sequence if not delivered before;

- if *t-Reordering* is running:

  - if VR(X) = VR(R); or

  - if VR(X) falls outside of the receiving window and VR(X) is not equal to VR(MR):

    - stop and reset *t-Reordering*;

- if *t-Reordering* is not running (includes the case *t-Reordering* is stopped due to actions above):

  - if VR (H) > VR(R):

    - start *t-Reordering*;

    - set VR(X) to VR(H).

5.1.3.2.4 Actions when *t-Reordering* expires

When *t-Reordering* expires, the receiving side of an AM 5G-RLC entity shall:

- update VR(MS) to the SN of the first AMD PDU with SN >= VR(X) for which not all byte segments have been received;

- if VR(H) > VR(MS):

  - start *t-Reordering*;

  - set VR(X) to VR(H).

5.2 ARQ procedures

ARQ procedures are only performed by an AM 5G-RLC entity.

5.2.1 Retransmission

The transmitting side of an AM 5G-RLC entity can receive a negative acknowledgement (notification of reception failure by its peer AM 5G-RLC entity) for an AMD PDU or a portion of an AMD PDU by the following:

- STATUS PDU from its peer AM 5G-RLC entity.

When receiving a negative acknowledgement for an AMD PDU or a portion of an AMD PDU by a STATUS PDU from its peer AM 5G-RLC entity, the transmitting side of the AM RLC entity shall:

- if the SN of the corresponding AMD PDU falls within the range VT(A) <= SN < VT(S):

  - consider the AMD PDU or the portion of the AMD PDU for which a negative acknowledgement was received for retransmission.

When an AMD PDU or a portion of an AMD PDU is considered for retransmission, the transmitting side of the AM 5G-RLC entity shall:

- if the AMD PDU is considered for retransmission for the first time:

  - set the RETX_COUNT associated with the AMD PDU to zero;

- else, if it (the AMD PDU or the portion of the AMD PDU that is considered for retransmission) is not pending for retransmission already, or a portion of it is not pending for retransmission already:

  - increment the RETX_COUNT;

- if RETX_COUNT = *maxRetxThreshold*:

- indicate to upper layers that max retransmission has been reached.

When retransmitting an AMD PDU, the transmitting side of an AM 5G-RLC entity shall:

- if the AMD PDU can entirely fit within the total size of 5G-RLC PDU(s) indicated by lower layer at the particular transmission opportunity:
  - deliver the AMD PDU as it is except for the P field (the P field should be set according to sub clause 5.2.2) to lower layer;
- otherwise:
  - segment the AMD PDU, form a new AMD PDU segment which will fit within the total size of 5G-RLC PDU(s) indicated by lower layer at the particular transmission opportunity and deliver the new AMD PDU segment to lower layer.

When retransmitting a portion of an AMD PDU, the transmitting side of an AM RLC entity shall:

- segment the portion of the AMD PDU as necessary, form a new AMD PDU segment which will fit within the total size of 5G-RLC PDU(s) indicated by lower layer at the particular transmission opportunity and deliver the new AMD PDU segment to lower layer.

When forming a new AMD PDU segment, the transmitting side of an AM RLC entity shall:

- only map the Data field of the original AMD PDU to the Data field of the new AMD PDU segment;
- set the header of the new AMD PDU segment in accordance with the description in sub clause 6.;
- set the P field according to sub clause 5.2.2.

5.2.2 Polling

An AM 5G-RLC entity can poll its peer AM 5G-RLC entity in order to trigger STATUS reporting at the peer AM 5G-RLC entity.

5.2.2.1 Transmission of a AMD PDU or AMD PDU segment

Upon assembly of a new AMD PDU, the transmitting side of an AM 5G-RLC entity shall:

- increment PDU_WITHOUT_POLL by one;
- increment BYTE_WITHOUT_POLL by every new byte of Data field element that it maps to the Data field of the 5G-RLC data PDU;
- if PDU_WITHOUT_POLL >= *pollPDU*; or
- if BYTE_WITHOUT_POLL >= *pollByte*;
  - include a poll in the 5G-RLC data PDU as described below.

Upon assembly of an AMD PDU or AMD PDU segment, the transmitting side of an AM 5G-RLC entity shall:

- if both the transmission buffer and the retransmission buffer becomes empty (excluding transmitted 5G-RLC data PDU awaiting for acknowledgements) after the transmission of the 5G-RLC data PDU; or
- if no new 5G-RLC data PDU can be transmitted after the transmission of the 5G-RLC data PDU (e.g. due to window stalling);
  - include a poll in the 5G-RLC data PDU as described below.

NOTE: Empty 5G-RLC buffer (excluding transmitted 5G-RLC data PDU awaiting for acknowledgements) should not lead to unnecessary polling when data awaits in the upper layer. Details are left up to UE implementation.

To include a poll in a 5G-RLC data PDU, the transmitting side of an AM RLC entity shall:

- set the P field of the RLC data PDU to "1";

- set PDU_WITHOUT_POLL to 0;
- set BYTE_WITHOUT_POLL to 0;

After delivering a 5G-RLC data PDU including a poll to lower layer and after incrementing of VT(S) if necessary, the transmitting side of an AM 5G-RLC entity shall:

- set POLL_SN to VT(S) – 1;
- if *t-PollRetransmit* is not running:
  - start *t-PollRetransmit*;
- else:
  - restart *t-PollRetransmit*;

5.2.2.2 Reception of a STATUS report

Upon reception of a STATUS report from the receiving 5G-RLC AM entity the transmitting side of an AM 5G-RLC entity shall:

- if the STATUS report comprises a positive or negative acknowledgement for the 5G-RLC data PDU with sequence number equal to POLL_SN:
  - if *t-PollRetransmit* is running:
    - stop and reset *t-PollRetransmit*.

5.2.2.3 Expiry of *t-PollRetransmit*

Upon expiry of *t-PollRetransmit*, the transmitting side of an AM 5G-RLC entity shall:

- if both the transmission buffer and the retransmission buffer are empty (excluding transmitted 5G-RLC data PDU awaiting for acknowledgements); or
- if no new 5G-RLC data PDU can be transmitted (e.g. due to window stalling):
  - consider the AMD PDU with SN = VT(S) – 1 for retransmission; or
  - consider any AMD PDU which has not been positively acknowledged for retransmission;
- include a poll in a 5G-RLC data PDU as described in section 5.2.2.1.

5.2.3 Status reporting

An AM 5G-RLC entity sends STATUS PDUs to its peer AM 5G-RLC entity in order to provide positive and/or negative acknowledgements of 5G-RLC PDUs (or portions of them).

RRC configures whether or not the status prohibit function is to be used for an AM 5G-RLC entity.

Triggers to initiate STATUS reporting include:

- Polling from its peer AM 5G-RLC entity:
  - When a 5G-RLC data PDU with SN = x and the P field set to “1” is received from lower layer, the receiving side of an AM 5G-RLC entity shall:
    - if the PDU is to be discarded as specified in subclause 5.1.3.2.2; or
    - if x < VR(MS) or x >= VR(MR):
      - trigger a STATUS report;
    - else:
      - delay triggering the STATUS report until x < VR(MS) or x >= VR(MR).

NOTE 1: This ensures that the 5G-RLC Status report is transmitted after HARQ reordering.

- Detection of reception failure of an 5G-RLC data PDU:
  - The receiving side of an AM 5G-RLC entity shall trigger a STATUS report when *t-Reordering* expires.

NOTE 2: The expiry of *t-Reordering* triggers both VR(MS) to be updated and a STATUS report to be triggered, but the STATUS report shall be triggered after VR(MS) is updated.

When STATUS reporting has been triggered, the receiving side of an AM 5G-RLC entity shall:

- if *t-StatusProhibit* is not running:
  - at the first transmission opportunity indicated by lower layer, construct a STATUS PDU and deliver it to lower layer;
- else:
  - at the first transmission opportunity indicated by lower layer after *t-StatusProhibit* expires, construct a single STATUS PDU even if status reporting was triggered several times while *t-StatusProhibit* was running and deliver it to lower layer;

When a STATUS PDU has been delivered to lower layer, the receiving side of an AM 5G-RLC entity shall:

- start *t-StatusProhibit*.

When constructing a STATUS PDU, the AM 5G-RLC entity shall:

- for the AMD PDUs with SN such that VR(R) <= SN < VR(MS) that has not been completely received yet, in increasing SN order of PDUs and increasing byte segment order within PDUs, starting with SN = VR(R) up to the point where the resulting STATUS PDU still fits to the total size of 5G-RLC PDU(s) indicated by lower layer:
  - for an AMD PDU for which no byte segments have been received yet::
    - include in the STATUS PDU a NACK_SN which is set to the SN of the AMD PDU;
  - for a continuous sequence of byte segments of a partly received AMD PDU that have not been received yet:
    - include in the STATUS PDU a set of NACK_SN, SOstart and SOend
- for the AMD PDUs with consecutive SNs which should be reported as lost
  - if the first byte of the AMD PDU with the highest SN in the consecutive SNs has not been received yet;
  - and if the last byte of the AMD PDU with the lowest SN in the consecutive SNs has not been received yet;
  - and if all byte segments for neither the highest SN nor lowest SN have not been received yet:
    - include in the STATUS PDU a NACK_SN which is set to the largest SN in the consecutive SN;
    - include in the STATUS PDU a NACK_Length which is set to (number of the consecutive SN) -1;
    - if the first byte of the AMD PDU with the lowest SN in the consecutive SNs has been received yet;or
    - if the last byte of the AMD PDU with the highest SN in the consecutive SNs has been received yet:
- include in the STATUS PDU a set SOstart and SOend- set the ACK_SN to the SN of the next not received 5G-RLC Data PDU which is not indicated as missing in the resulting STATUS PDU.

5.3 SDU discard procedures

When indicated from upper layer (i.e. 5G PDCP) to discard a particular 5G RLC SDU, the transmitting side of an AM RLC entity or the transmitting UM 5G RLC entity shall discard the indicated 5G RLC SDU if no segment of the 5G RLC SDU has been mapped to a 5G RLC data PDU yet.

5.4 Re-establishment procedure

5G-RLC re-establishment is performed upon request by 5G-RRC, and the function is applicable for AM, UM and TM 5G-RLC entities.

When 5G-RRC indicates that an 5G-RLC entity should be re-established, the 5G-RLC entity shall:

-
- if it is a transmitting TM 5G-RLC entity:
  - discard all 5G-RLC SDUs;
- if it is a receiving UM 5G-RLC entity:
  - when possible, reassemble 5G-RLC SDUs from UMD PDUs with SN < VR(UH), remove 5G-RLC headers when doing so and deliver all reassembled 5G-RLC SDUs to upper layer in ascending order of the 5G-RLC SN, if not delivered before;
  - discard all remaining UMD PDUs and byte segment of UMD PDU;
- if it is a transmitting UM 5G-RLC entity:
  - discard all 5G-RLC SDUs, UMD PDUs and UMD PDU segments;
- if it is an AM 5G-RLC entity:
  - when possible, reassemble 5G-RLC SDUs from any byte segments of AMD PDUs with SN < VR(MR) in the receiving side, remove 5G-RLC headers when doing so and deliver all reassembled 5G-RLC SDUs to upper layer in ascending order of the 5G-RLC SN, if not delivered before;
  - discard the remaining AMD PDUs and byte segments of AMD PDUs in the receiving side;
  - discard all 5G-RLC SDUs and AMD PDUs in the transmitting side;
  - discard all 5G-RLC control PDUs.
- stop and reset all timers;
- reset all state variables to their initial values.

5.5 Handling of unknown, unforeseen and erroneous protocol data

5.5.1 Reception of PDU with reserved or invalid values

When an 5G-RLC entity receives an 5G-RLC PDU that contains reserved or invalid values, the 5G-RLC entity shall:

- discard the received PDU.

6 Protocol data units, formats and parameters

6.1 Protocol data units

5G-RLC PDUs can be categorized into 5G-RLC data PDUs and 5G-RLC control PDUs. 5G-RLC data PDUs in sub clause 6.1.1 are used by TM, UM and AM 5G-RLC entities to transfer upper layer PDUs (i.e. 5G-RLC SDUs). 5G-RLC control PDUs in sub clause 6.1.2 are used by AM 5G-RLC entity to perform ARQ procedures.

6.1.1 5G-RLC data PDU

a) TMD PDU

TMD PDU is used to transfer upper layer PDUs by a TM 5G-RLC entity.

b) UMD PDU

UMD PDU is used to transfer upper layer PDUs by an UM 5G-RLC entity.

c) UMD PDU segment

UMD PDU segment is used to transfer upper layer PDUs by an UM 5G-RLC entity. It is used when the UM 5G-RLC entity needs to transmit a portion of an UMD PDU

d) AMD PDU

AMD PDU is used to transfer upper layer PDUs by an AM 5G-RLC entity. It is used when the AM 5G-RLC entity transmits (part of) the 5G-RLC SDU for the first time, or when the AM 5G-RLC entity retransmits an AMD PDU without having to perform re-segmentation.

e) AMD PDU segment

AMD PDU segment is used to transfer upper layer PDUs by an AM 5G-RLC entity. It is used when the AM 5G-RLC entity needs to retransmit a portion of an AMD PDU.

6.1.2 5G-RLC control PDU

a) STATUS PDU

STATUS PDU is used by the receiving side of an AM 5G-RLC entity to inform the peer AM 5G-RLC entity about 5G-RLC data PDUs that are received successfully, and 5G-RLC data PDUs that are detected to be lost by the receiving side of an AM 5G-RLC entity.

6.2 Formats and parameters

The formats of 5G-RLC PDUs are described in sub clause 6.2.1 and their parameters are described in sub clause 6.2.2.

6.2.1 Formats

6.2.1.1 General

5G-RLC PDU is a bit string. In the figures in sub clause 6.2.1.2 to 6.2.1.7, bit strings are represented by tables in which the first and most significant bit is the left most bit of the first line of the table, the last and least significant bit is the rightmost bit of the last line of the table, and more generally the bit string is to be read from left to right and then in the reading order of the lines.

5G-RLC SDUs are bit strings that are byte aligned (i.e. multiple of 8 bits) in length. An 5G-RLC SDU is included into an 5G-RLC PDU from first bit onward.

6.2.1.2 TMD PDU

TMD PDU consists only of a Data field and does not consist of any 5G-RLC headers.

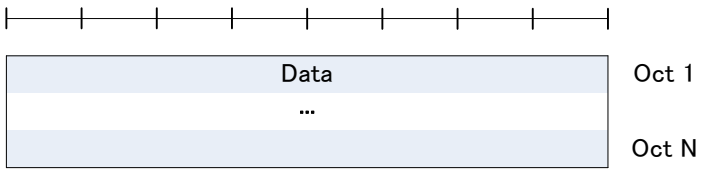

Figure 6.2.1.2-1: TMD PDU

6.2.1.3 UMD PDU

UMD PDU consists of a Data field and an UMD PDU header.

UMD PDU header consists of a fixed part (fields that are present for every UMD PDU). The UMD PDU header itself is byte aligned and consists of a SN. The fixed part of the UMD PDU header is identical to the fixed part of the AMD PDU header, except for D/C and P fields all being replaced with R1 fields.

UM RLC uses 18-bit SN. The length of the UMD PDU header is three bytes.

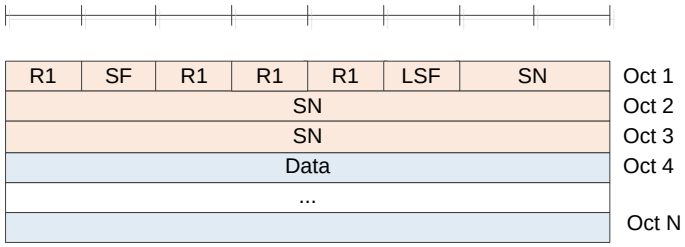

Figure 6.2.1.3-1: UMD PDU

6.2.1.4 UMD PDU segment

UMD PDU segment is generated when segmentation of UMD SDU is necessary. UMD PDU segment consists of a Data field and an UMD PDU segment header.

UMD PDU segment header consists of a fixed part fields. The UMD PDU segment header itself is byte aligned and consists of a SF, a SN, a LSF and a SO.

UM RLC uses 18-bit SN. The length of the UMD PDU segment header is five bytes.

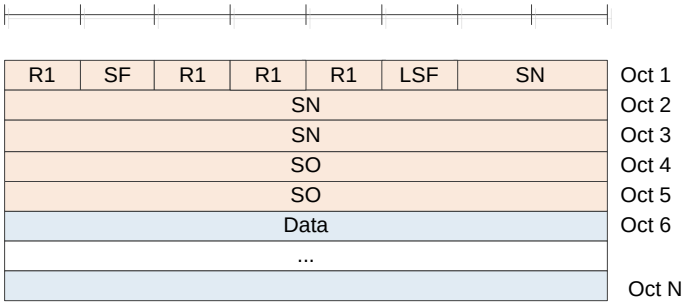

Figure 6.2.1.4-1: UMD PDU segment

6.2.1.5 AMD PDU

AMD PDU consists of a Data field and an AMD PDU header.

AMD PDU header consists of a fixed part (fields that are present for every AMD PDU). The AMD PDU header itself is byte aligned and consists of a D/C, a SF, a P, a LSF, and a SN.

AM RLC uses 18-bit SN. The length of the AMD PDU header is three bytes.

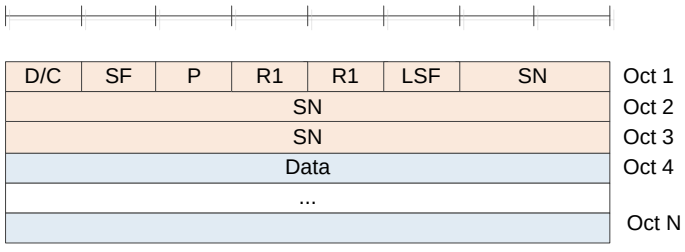

Figure 6.2.1.5-1: AMD PDU

6.2.1.6 AMD PDU segment

AMD PDU segment is generated when segmentation or resegmentation of AMD SDU is necessary. AMD PDU segment consists of a Data field and an AMD PDU segment header.

AMD PDU segment header consists of a fixed part (fields that are present for every AMD PDU segment). The AMD PDU segment header itself is byte aligned and consists of a D/C, a SF, a P,a SN, a LSF and a SO. AM RLC uses 18-bit SN. The length of the AMD PDU segment header is five bytes.

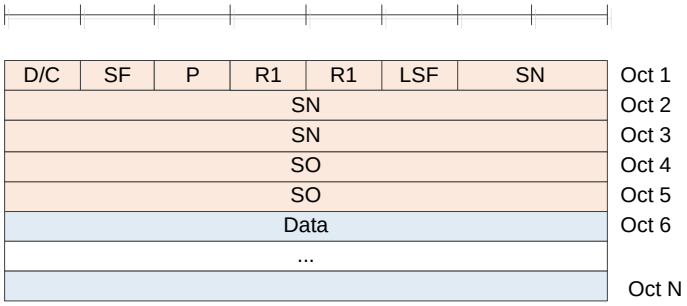

Figure 6.2.1.6-1: AMD PDU segment

6.2.1.7 STATUS PDU

STATUS PDU consists of a STATUS PDU payload and a RLC control PDU header.

5G-RLC control PDU header consists of a D/C and a CPT field.

The STATUS PDU payload starts from the first bit following the RLC control PDU header, and it consists of one ACK_SN and one E1, zero or more sets of a NACK_SN, an E1, an E2, and an E3, possibly a NACK_Length for consecutive NACK_SNs, and possibly a set of a SOstart and a SOend for a NACK_SN and a NACK_Length. When necessary one to seven padding bits are included in the end of the STATUS PDU to achieve octet alignment.

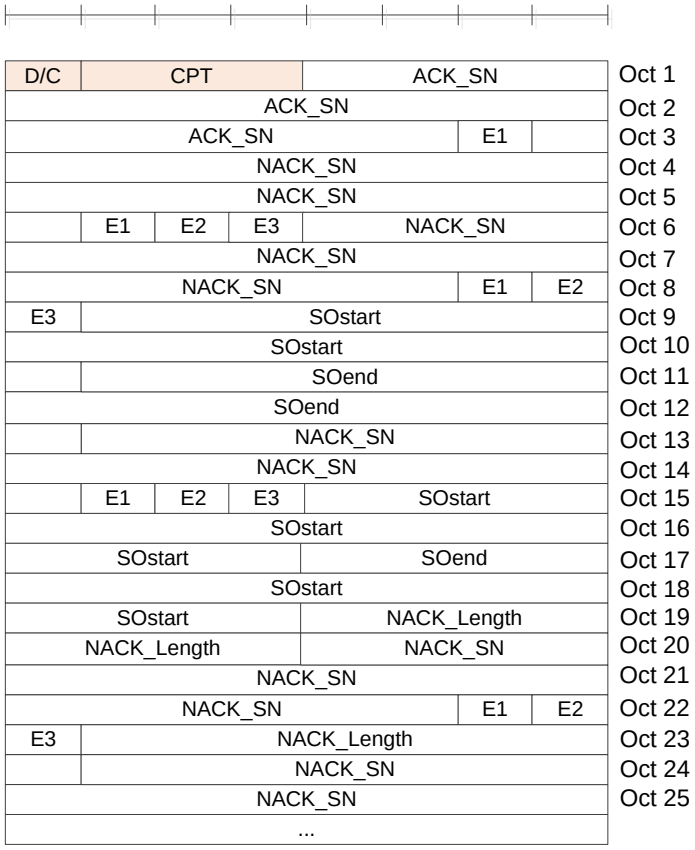

Figure 6.2.1.7-1: STATUS PDU

6.2.2 Parameters

6.2.2.1 General

In the definition of each field in sub clauses 6.2.2.2 to 6.2.2.18, the bits in the parameters are represented in which the first and most significant bit is the left most bit and the last and least significant bit is the rightmost bit. Unless mentioned otherwise, integers are encoded in standard binary encoding for unsigned integers.

6.2.2.2 Data field

Data field elements are mapped to the Data field in the order which they arrive to the RLC entity at the transmitter.

ForTMD PDU, UMD PDU and AMD PDU:

- The granularity of the Data field size is one byte;
- The maximum Data field size is the maximum TB size minus the sum of minimum 5G-MAC PDU header size and minimum 5G-RLC PDU header size.

For TMD PDU:

- Only one 5G-RLC SDU can be mapped to the Data field of one TMD PDU

For UMD PDU, UMD PDU segment, AMD PDU and AMD PDU segment:

- The following can be mapped to the Data field of one UMD PDU, or AMD PDU:
  - One 5G-RLC SDU
  - One or more 5G-RLC SDUs:

6.2.2.3 Sequence Number (SN) field

Length: 18 bits.

The SN field indicates the sequence number of the corresponding UMD or AMD PDU. For a UMD PDU segment or an AMD PDU segment, the SN field indicates the sequence number of the original UMD PDU or AMD PDU from which the UMD PDU segment or AMD PDU segment was constructed from. The sequence number is incremented by one for every UMD or AMD PDU.

6.2.2.4 Segment Offset (SO) field

Length: 16 bits

The SO field indicates the position of the UMD PDU segment or AMD PDU segment in bytes within the original SDU. Specifically, the SO field indicates the position within the Data field of the original SDU to which the first byte of the Data field of the UMD PDU segment or AMD PDU segment corresponds to. The first byte in the Data field of the original UMD PDU or AMD PDU is referred by the SO field value "0000000000000000", i.e., numbering starts at zero.

6.2.2.5 Last Segment Flag (LSF) field

Length: 1 bit.

The LSF field indicates whether or not the last byte of UMD PDU segment or the AMD PDU segment corresponds to the last byte of an UMD PDU or an AMD PDU. The interpretation of the LSF field is provided in Table 6.2.2.5-1.

Table 6.2.2.5-1: LSF field interpretation

Value	Description
0	Last byte of the UMD PDU segment or AMD PDU segment does not correspond to the last byte of an UMD PDU or an AMD PDU.
1	Last byte of the UMD PDU segment or AMD PDU segment corresponds to the last byte of an UMD PDU or an AMD PDU.

6.2.2.6 Data/Control (D/C) field

Length: 1 bit.

The D/C field indicates whether the 5G-RLC PDU is a 5G-RLC data PDU or 5G-RLC control PDU. The interpretation of the D/C field is provided in Table 6.2.2.6-1.

Table 6.2.2.6-1: D/C field interpretation

Value	Description
0	Control PDU
1	Data PDU

6.2.2.7 Segmentation Flag (SF) field

Length: 1 bit.

The SF field indicates whether the 5G-RLC PDU is an UMD/AMD PDU or UMD/AMD PDU segment. The interpretation of the SF field is provided in Table 6.2.2.7-1.

Table 6.2.2.7-1: RF field interpretation

Value	Description
0	UMD PDU or AMD PDU
1	UMD PDU segment or AMD PDU segment

6.2.2.8 Polling bit (P) field

Length: 1 bit.

The P field indicates whether or not the transmitting side of an AM 5G-RLC entity requests a STATUS report from its peer AM 5G-RLC entity. The interpretation of the P field is provided in Table 6.2.2.8-1.

Table 6.2.2.8-1: P field interpretation

Value	Description
0	Status report not requested
1	Status report is requested

6.2.2.9 Reserved 1 (R1) field

Length: 1 bit.

The R1 field is a reserved field for this release of the protocol. The transmitting entity shall set the R1 field to "0". The receiving entity shall ignore this field.

6.2.2.10 Control PDU Type (CPT) field

Length: 3 bits.

The CPT field indicates the type of the 5G-RLC control PDU. The interpretation of the CPT field is provided in Table 6.2.2.10-1.

Table 6.2.2.10-1: CPT field interpretation

Value	Description
000	STATUS PDU
001-111	Reserved (PDUs with this coding will be discarded by the receiving entity for this release of the protocol)

6.2.2.11 Acknowledgement SN (ACK_SN) field

Length: 18 bits.

The ACK_SN field indicates the SN of the next not received 5G-RLC Data PDU which is not reported as missing in the STATUS PDU. When the transmitting side of an AM 5G-RLC entity receives a STATUS PDU, it interprets that all AMD PDUs up to but not including the AMD PDU with SN = ACK_SN have been received by its peer AM 5G-RLC entity, excluding those AMD PDUs indicated in the STATUS PDU with NACK_SN and portions of AMD PDUs indicated in the STATUS PDU with NACK_SN, SOstart and SOend.

6.2.2.12 Extension bit 1 (E1) field

Length: 1 bit.

The E1 field indicates whether or not a set of NACK_SN, E1,E2 and E3 follows. The interpretation of the E1 field is provided in Table 6.2.2.12-1.

Table 6.2.2.12-1: E1 field interpretation

Value	Description
0	A set of NACK_SN, E1, E2 and E3 does not follow.
1	A set of NACK_SN, E1, E2 and E3 follows.

6.2.2.13 Negative Acknowledgement SN (NACK_SN) field

Length: 18 bits.

The NACK_SN field indicates the SN of the AMD PDU (or portions of it) that has been detected as lost at the receiving side of the AM RLC entity. If there are serveral AMD PDUs of consecutive SNs (including portion of it) that have been

detected as lost, the NACK_SN field indicates the highest SNs of the AMD PDUs. In this case, the value of E3 field for this NACK_SN should be set to 1.

6.2.2.14 Extension bit 2 (E2) field

Length: 1 bit.

The E2 field indicates whether or not a set of SOstart and SOend follows. The interpretation of the E2 field is provided in Table 6.2.2.14-1.

Table 6.2.2.14-1: E2 field interpretation

Value	Description
0	A set of SOstart and SOend does not follow for this NACK_SN.
1	A set of SOstart and SOend follows for this NACK_SN.

6.2.2.15 SO start (SOstart) field

Length: 16 bits.

When the value of E3 for the NACK_SN is 0, the SOstart field (together with the SOend field) indicates the portion of the AMD PDU with SN = NACK_SN (the NACK_SN for which the SOstart is related to) that has been detected as lost at the receiving side of the AM RLC entity. Otherwise, the SOstart field indicates the portion of the AMD PDU with SN=[(NACK_SN)-(NACK_Length)] modulo 262144 that has been detected as lost at the receiving side of the AM 5G-RLC entity. Specifically, the SOstart field indicates the position of the first byte of the portion of the AMD PDU in bytes within the Data field of the AMD PDU. The first byte in the Data field of the original AMD PDU is referred by the SOstart field value "0000000000000000", i.e., numbering starts at zero.

6.2.2.16 SO end (SOend) field

Length: 16 bits.

The SOend field indicates the portion of the AMD PDU with SN = NACK_SN (the NACK_SN for which the SOend is related to) that has been detected as lost at the receiving side of the AM RLC entity. Specifically, the SOend field indicates the position of the last byte of the portion of the AMD PDU in bytes within the Data field of the AMD PDU. The first byte in the Data field of the original AMD PDU is referred by the SOend field value " "0000000000000000", i.e., numbering starts at zero. The special SOend value ""1111111111111111" is used to indicate that the missing portion of the AMD PDU includes all bytes to the last byte of the AMD PDU.

6.2.2.17 Extension bit 3 (E3) field

Length: 1 bit.

The E3 field indicates whether or not a NACK_Length follows. The interpretation of the E3 field is provided in Table 6.2.2.17-1.

Table 6.2.2.17-1: E3 field interpretation

Value	Description
0	A NACK_Length does not follow for this NACK_SN
1	A NACK_Length follows for this NACK_SN

6.2.2.18 NACK_Length field

Length: 8 bits.

The NACK_Length field indicates the number of consecutive lost AMD PDUs but not including the AMD PDU with SN = NACK_SN

7 Variables, constants and timers

7.1 State variables

This sub clause describes the state variables used in AM and UM entities in order to specify the 5G-RLC protocol. The state variables defined in this subclause are normative.

All state variables and all counters are non-negative integers.

All state variables related to AM data transfer can take values from 0 to 262143 for 18 bit SN. All arithmetic operations contained in the present document on state variables related to AM data transfer are affected by the AM modulus (i.e. final value = [value from arithmetic operation] modulo 262144 for 18 bit SN).

All state variables related to UM data transfer can take values from 0 to 262143 for 18 bit SN. All arithmetic operations contained in the present document on state variables related to UM data transfer are affected by the UM modulus (i.e. final value = [value from arithmetic operation] modulo 262144 for 10 bit SN).

AMD PDUs and UMD PDUs are numbered integer sequence numbers (SN) cycling through the field: 0 to 262143 for 18 bit SN

When performing arithmetic comparisons of state variables or SN values, a modulus base shall be used.

VT(A) and VR(R) shall be assumed as the modulus base at the transmitting side and receiving side of an AM 5G-RLC entity, respectively. This modulus base is subtracted from all the values involved, and then an absolute comparison is performed (e.g. VR(R) <= SN < VR(MR) is evaluated as [VR(R) – VR(R)] modulo 262144 <= [SN – VR(R)] modulo 262144 < [VR(MR) – VR(R)] modulo 262144).

VR(UH) – UM_Window_Size shall be assumed as the modulus base at the receiving side of an UM RLC entity. This modulus base is subtracted from all the values involved, and then an absolute comparison is performed (e.g. (VR(UH) – UM_Window_Size) <= SN < VR(UH) is evaluated as [(VR(UH) – UM_Window_Size) – (VR(UH) – UM_Window_Size)] modulo 262144 <= [SN – (VR(UH) – UM_Window_Size)] modulo 262144 < [VR(UH) – (VR(UH) – UM_Window_Size)] modulo 262144).

The transmitting side of each AM 5G-RLC entity shall maintain the following state variables:

a) VT(A) – Acknowledgement state variable

This state variable holds the value of the SN of the next AMD PDU for which a positive acknowledgment is to be received in-sequence, and it serves as the lower edge of the transmitting window. It is initially set to 0, and is updated whenever the AM 5G-RLC entity receives a positive acknowledgment for an AMD PDU with SN = VT(A).

b) VT(MS) – Maximum send state variable

This state variable equals VT(A) + AM_Window_Size, and it serves as the higher edge of the transmitting window.

c) VT(S) – Send state variable

This state variable holds the value of the SN to be assigned for the next newly generated AMD PDU. It is initially set to 0, and is updated whenever the AM 5G-RLC entity delivers an AMD PDU with SN = VT(S).

d) POLL_SN – Poll send state variable

This state variable holds the value of VT(S)-1 upon the most recent transmission of a 5G-RLC data PDU with the poll bit set to “1”. It is initially set to 0.

The transmitting side of each AM 5G-RLC entity shall maintain the following counters:

a) PDU_WITHOUT_POLL – Counter

This counter is initially set to 0. It counts the number of AMD PDUs sent since the most recent poll bit was transmitted.

b) BYTE_WITHOUT_POLL – Counter

This counter is initially set to 0. It counts the number of data bytes sent since the most recent poll bit was transmitted.

c) RETX_COUNT – Counter

This counter counts the number of retransmissions of an AMD PDU (see subclause 5.2.1). There is one RETX_COUNT counter per PDU that needs to be retransmitted.

The receiving side of each AM 5G-RLC entity shall maintain the following state variables:

a) VR(R) – Receive state variable

This state variable holds the value of the SN following the last in-sequence completely received AMD PDU, and it serves as the lower edge of the receiving window. It is initially set to 0, and is updated whenever the AM 5G-RLC entity receives an AMD PDU with SN = VR(R).

b) VR(MR) – Maximum acceptable receive state variable

This state variable equals VR(R) + AM_Window_Size, and it holds the value of the SN of the first AMD PDU that is beyond the receiving window and serves as the higher edge of the receiving window.

c) VR(X) – *t-Reordering* state variable

This state variable holds the value of the SN following the SN of the 5G-RLC data PDU which triggered *t-Reordering*.

d) VR(MS) – Maximum STATUS transmit state variable

This state variable holds the highest possible value of the SN which can be indicated by "ACK_SN" when a STATUS PDU needs to be constructed. It is initially set to 0.

e) VR(H) – Highest received state variable

This state variable holds the value of the SN following the SN of the 5G-RLC data PDU with the highest SN among received 5G-RLC data PDUs. It is initially set to 0.

Each transmitting UM 5G-RLC entity shall maintain the following state variables:

a) VT(US)

This state variable holds the value of the SN to be assigned for the next newly generated UMD PDU. It is initially set to 0, and is updated whenever the UM 5G-RLC entity delivers an UMD PDU with SN = VT(US).

Each receiving UM 5G-RLC entity shall maintain the following state variables:

a) VR(UR) – UM receive state variable

This state variable holds the value of the SN of the earliest UMD PDU that is still considered for reordering. It is initially set to 0.

b) VR(UX) – UM *t-Reordering* state variable

This state variable holds the value of the SN following the SN of the UMD PDU which triggered *t-Reordering*.

c) VR(UH) – UM highest received state variable

This state variable holds the value of the SN following the SN of the UMD PDU with the highest SN among received UMD PDUs, and it serves as the higher edge of the reordering window. It is initially set to 0.

7.2 Constants

a) AM_Window_Size

This constant is used by both the transmitting side and the receiving side of each AM 5G-RLC entity to calculate VT(MS) from VT(A), and VR(MR) from VR(R). AM_Window_Size = 131072 when a 18 bit SN is used.

b) UM_Window_Size

This constant is used by the receiving UM 5G-RLC entity to define SNs of those UMD PDUs that can be received without causing an advancement of the receiving window., UM_Window_Size = 131072 when a 18 bit SN is used.

7.3 Timers

The following timers are configured by 5G-RRC [2]:

a) *t-PollRetransmit*

This timer is used by the transmitting side of an AM 5G-RLC entity in order to retransmit a poll (see sub clause 5.2.2).

b) *t-Reordering*

This timer is used by the receiving side of an AM RLC entity and receiving UM 5G-RLC entity in order to detect loss of 5G-RLC PDUs at lower layer (see sub clauses 5.1.2.2 and 5.1.3.2). If *t-Reordering* is running, *t-Reordering* shall not be started additionally, i.e. only one *t-Reordering* per 5G-RLC entity is running at a given time.

c) *t-StatusProhibit*

This timer is used by the receiving side of an AM 5G-RLC entity in order to prohibit transmission of a STATUS PDU (see sub clause 5.2.3).

7.4 Configurable parameters

The following parameters are configured by 5G-RRC [2]:

a) *maxRetxThreshold*

This parameter is used by the transmitting side of each AM 5G-RLC entity to limit the number of retransmissions of an AMD PDU (see subclause 5.2.1).

b) *pollPDU*

This parameter is used by the transmitting side of each AM 5G-RLC entity to trigger a poll for every *pollPDU* PDUs (see subclause 5.2.2).

c) *pollByte*

This parameter is used by the transmitting side of each AM 5G-RLC entity to trigger a poll for every *pollByte* bytes (see subclause 5.2.2).