Verizon 5G TF;
Network and Signalling Working Group;
Verizon 5th Generation Radio Access;
5G Packet Data Convergence Protocol (5G-PDCP) Specification (Release 1)

June 29, 2016

Cisco, Ericsson, Intel Corp, LG Electronics, Nokia, Qualcomm Technologies Inc., Samsung & Verizon

Version 1.0

Document History

Version	Date	Change	Verizon POC
0.0.1	2016-03-20	Data skeleton created	
	2016-04-12		
	2016-04-25	Updated based on agreement of N&S WS conf. call	
0.1	2016-04-28	Updated based on agreement in April F2F meeting	
1.0	2016-06-29	Ver1.0 released	

Document Approvals

Name	Title	Company	Date of Approval

Table of Contents

List of Figures

List of Tables

1 Scope

The present document provides the description of the 5G Packet Data Convergence Protocol (5G-PDCP) of the Verizon 5G system for initial Fixed Wireless Use case.

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 V5G document, a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1]: TS V5G.300: "5G Radio Access (5G RA) and 5G Radio Access Network (5G-RAN); Overall description".

[2]: TS V5G.321: "5G Radio Access (5G RA); 5G Medium Access Control (5G-MAC) protocol specification".

[3]: TS V5G.322: "5G Radio Access (5G RA); 5G Radio Link Control (5G-RLC) protocol specification".

[4]: TS V5G.331: "5G Radio Access (5G RA); 5G Radio Resource Control (5G-RRC) protocol specification".

[5]: 3GPP TS 33.401: “3GPP System Architecture Evolution (SAE);Security architecture”.

3 Definitions and abbreviations

3.1 Definitions

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

3.2 Abbreviations

For the purpose of the present document, the following abbreviations apply.

- AM Acknowledged Mode
- DRB Data Radio Bearer carrying user plane data
- 5G RA 5G Radio Access
- 5G-RAN 5G Radio Access Network
- FMS First missing PDCP SN
- HFN Hyper Frame Number
- MAC Medium Access Control
- MAC-I Message Authentication Code for Integrity

- PDCP Packet Data Convergence Protocol
- PDU Protocol Data Unit
- R Reserved
- RB Radio Bearer
- RLC Radio Link Control
- RRC Radio Resource Control
- SAP Service Access Point
- SDU Service Data Unit
- SN Sequence Number
- UE User Equipment
- UM Unacknowledged Mode
- X-MAC Computed MAC-I
- xDCCH 5G Dedicated Control Channel
- xDTCH 5G Dedicated Traffic Channel

4 General

4.1 Introduction

The present document describes the functionality of the 5G-PDCP. The functionality specified for the UE applies to communication on Uu interface.

4.2 5G-PDCP architecture

4.2.1 5G-PDCP structure

Figure 4.2.1-1 represents one possible structure for the 5G-PDCP sublayer; it should not restrict implementation. The figure is based on the radio interface protocol architecture defined in [1].

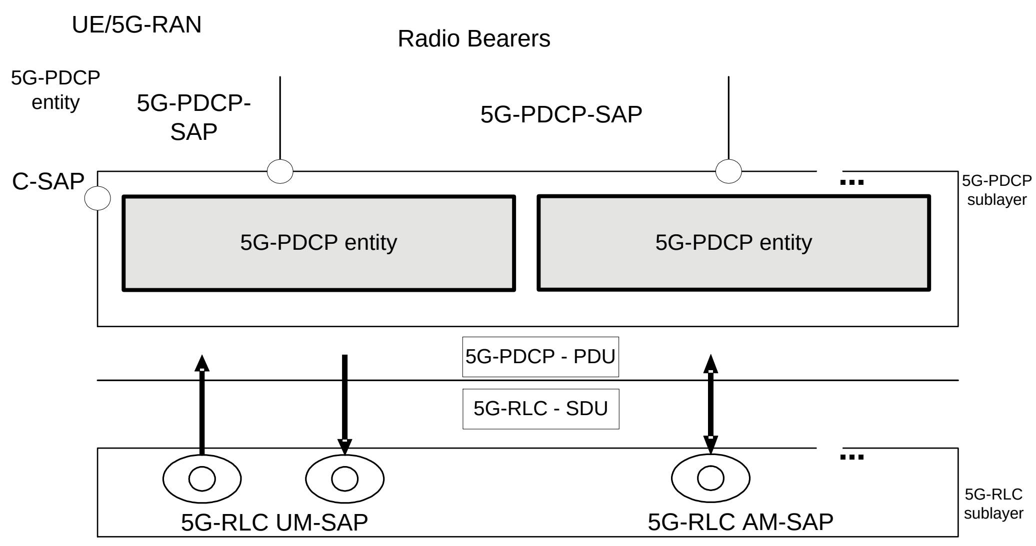

Figure 4.2.1-1: 5G-PDCP layer, structure view

Each RB (i.e. DRB and SRB, except for SRB0) is associated with one 5G-PDCP entity. Each 5G-PDCP entity is associated with one or two (one for each direction) 5G-RLC entities depending on the RB characteristic (i.e. uni-directional or bi-directional) and 5G-RLC mode. The 5G-PDCP entities are located in the 5G-PDCP sublayer.

The 5G-PDCP sublayer is configured by upper layers [4].

4.2.2 5G-PDCP entities

The 5G-PDCP entities are located in the 5G-PDCP sublayer. Several 5G-PDCP entities may be defined for a UE.

Each 5G-PDCP entity is carrying the data of one radio bearer.

A 5G-PDCP entity is associated to the user plane depending on which radio bearer it is carrying data for.

Figure 4.2.2-1 represents the functional view of the 5G-PDCP entity for the 5G-PDCP sublayer; it should not restrict implementation. The figure is based on the radio interface protocol architecture defined in [1].

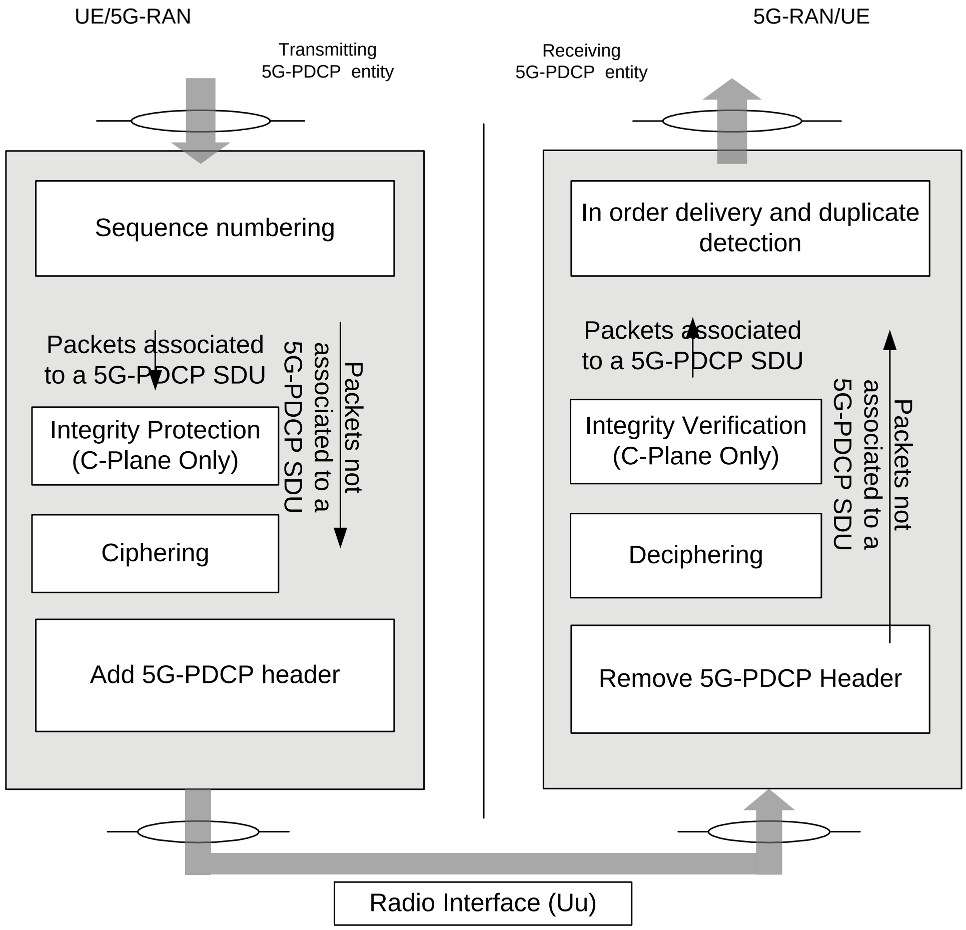

Figure 4.2.2-1: 5G-PDCP layer, functional view

4.3 Services

4.3.1 Services provided to upper layers

5G-PDCP provides its services to the 5G-RRC and user plane upper layers at the UE or at the 5GNB. The following services are provided by 5G-PDCP to upper layers:

- transfer of user plane data;
- transfer of control plane data;
- ciphering (only AES shall be mandatory);
- integrity protection (only AES shall be mandatory).

The maximum supported size of a 5G-PDCP SDU is 65528 octets.

4.3.2 Services expected from lower layers

For a detailed description of the following functions see [3].

- acknowledged data transfer service, including indication of successful delivery of 5G-PDCP PDUs;
- unacknowledged data transfer service;
- in-sequence delivery, except at re-establishment of lower layers;
- duplicate discarding, except at re-establishment of lower layers.

4.4 Functions

The 5G-PDCP supports the following functions:

- transfer of data (user plane or control plane);
- maintenance of 5G-PDCP SNs;
- in-sequence delivery of upper layer PDUs at re-establishment of lower layers;
- duplicate elimination of lower layer SDUs at re-establishment of lower layers for radio bearers mapped on 5G-RLC AM;
- ciphering and deciphering of user plane data and control plane data (only AES algorithm shall be mandatory);
- integrity protection and integrity verification of control plane data (only AES algorithm shall be mandatory);
- timer based discard;
- duplicate discarding.

5G-PDCP uses the services provided by the 5G-RLC sublayer.

5G-PDCP is used for SRBs, DRBs mapped on xDCCH, xDTCH type of logical channels. 5G-PDCP is not used for any other type of logical channels.

4.5 Data available for transmission

The UE shall consider 5G-PDCP Control PDUs, as well as the following as data available for transmission in the 5G-PDCP layer:

For SDUs for which no PDU has been submitted to lower layers:

– the SDU itself, if the SDU has not yet been processed by 5G-PDCP, or
– the PDU if the SDU has been processed by 5G-PDCP.

In addition, for radio bearers that are mapped on 5G-RLC AM, if the 5G-PDCP entity has previously performed the re-establishment procedure, the UE shall also consider the following as data available for transmission in the 5G-PDCP layer:

For SDUs for which a corresponding PDU has only been submitted to lower layers prior to the 5G-PDCP re-establishment, starting from the first SDU for which the delivery of the corresponding PDUs has not been confirmed by the lower layer, except the SDUs which are indicated as successfully delivered by the 5G-PDCP status report, if received:

– the SDU, if it has not yet been processed by 5G-PDCP, or
– the PDU once it has been processed by 5G-PDCP.

5 5G-PDCP procedures

5.1 5G-PDCP Data Transfer procedures

5.1.1 UL Data Transfer procedures

At reception of a 5G-PDCP SDU from upper layers, the UE shall:

– start the *discardTimer* associated with this 5G-PDCP SDU (if configured);

For a 5G-PDCP SDU received from upper layers, the UE shall:

– associate the 5G-PDCP SN corresponding to Next_PDCP_TX_SN to this 5G-PDCP SDU;

NOTE: Associating more than half of the 5G-PDCP SN space of contiguous 5G-PDCP SDUs with 5G-PDCP SNs, when e.g., the 5G-PDCP SDUs are discarded or transmitted without acknowledgement, may cause HFN desynchronization problem. How to prevent HFN desynchronization problem is left up to UE implementation.

– perform integrity protection (if applicable), and ciphering (if applicable) using COUNT based on TX_HFN and the 5G-PDCP SN associated with this 5G-PDCP SDU as specified in the subclause 5.6 and 5.5, respectively;
– increment Next_PDCP_TX_SN by one;
– if Next_PDCP_TX_SN > Maximum_PDCP_SN:
  – set Next_PDCP_TX_SN to 0;
    – increment TX_HFN by one;
– submit the resulting 5G-PDCP Data PDU to lower layer.

5.1.2 DL Data Transfer procedures

5.1.2.1 Procedures for DRBs

5.1.2.1.1 Procedures for DRBs mapped on 5G-RLC AM

For DRBs mapped on 5G-RLC AM at reception of a 5G-PDCP Data PDU from lower layers, the UE shall:

– if received 5G-PDCP SN – Last_Submitted_PDCP_RX_SN > Reordering_Window or 0 <= Last_Submitted_PDCP_RX_SN – received 5G-PDCP SN < Reordering_Window:
  – if received 5G-PDCP SN > Next_PDCP_RX_SN:
    – decipher the 5G-PDCP PDU as specified in the subclause 5.5, using COUNT based on RX_HFN - 1 and the received 5G-PDCP SN;
  – else:
    – decipher the 5G-PDCP PDU as specified in the subclause 5.5, using COUNT based on RX_HFN and the received 5G-PDCP SN;
  – discard this 5G-PDCP SDU;
– else if Next_PDCP_RX_SN – received 5G-PDCP SN > Reordering_Window:
  – increment RX_HFN by one;
  – use COUNT based on RX_HFN and the received 5G-PDCP SN for deciphering the 5G-PDCP PDU;
  – set Next_PDCP_RX_SN to the received 5G-PDCP SN + 1;

- else if received 5G-PDCP SN – Next_PDCP_RX_SN >= Reordering_Window:
  - use COUNT based on RX_HFN – 1 and the received 5G-PDCP SN for deciphering the 5G-PDCP PDU;
- else if received 5G-PDCP SN >= Next_PDCP_RX_SN:
  - use COUNT based on RX_HFN and the received 5G-PDCP SN for deciphering the 5G-PDCP PDU;
  - set Next_PDCP_RX_SN to the received 5G-PDCP SN + 1;
  - if Next_PDCP_RX_SN is larger than Maximum_PDCP_SN:
    - set Next_PDCP_RX_SN to 0;
    - increment RX_HFN by one;
- else if received 5G-PDCP SN < Next_PDCP_RX_SN:
  - use COUNT based on RX_HFN and the received 5G-PDCP SN for deciphering the 5G-PDCP PDU;
- if the 5G-PDCP PDU has not been discarded in the above:
  - perform deciphering for the 5G-PDCP PDU as specified in the subclauses 5.5;
  - if a 5G-PDCP SDU with the same 5G-PDCP SN is stored:
    - discard this 5G-PDCP SDU;
  - else:
    - store the 5G-PDCP SDU;
  - if the 5G-PDCP PDU received by 5G-PDCP is not due to the re-establishment of lower layers:
    - deliver to upper layers in ascending order of the associated COUNT value:
      - all stored 5G-PDCP SDU(s) with an associated COUNT value less than the COUNT value associated with the received 5G-PDCP SDU;
      - all stored 5G-PDCP SDU(s) with consecutively associated COUNT value(s) starting from the COUNT value associated with the received 5G-PDCP SDU;
    - set Last_Submitted_PDCP_RX_SN to the 5G-PDCP SN of the last 5G-PDCP SDU delivered to upper layers;.
  - else if received 5G-PDCP SN = Last_Submitted_PDCP_RX_SN + 1 or received 5G-PDCP SN = Last_Submitted_PDCP_RX_SN – Maximum_PDCP_SN:
    - deliver to upper layers in ascending order of the associated COUNT value:
      - all stored 5G-PDCP SDU(s) with consecutively associated COUNT value(s) starting from the COUNT value associated with the received 5G-PDCP SDU;
    - set Last_Submitted_PDCP_RX_SN to the 5G-PDCP SN of the last 5G-PDCP SDU delivered to upper layers.

5.1.2.1.2 Procedures for DRBs mapped on 5G-RLC UM

For DRBs mapped on 5G-RLC UM, at reception of a 5G-PDCP Data PDU from lower layers, the UE shall:

- if received 5G-PDCP SN < Next_PDCP_RX_SN:
  - increment RX_HFN by one;
- decipher the 5G-PDCP Data PDU using COUNT based on RX_HFN and the received 5G-PDCP SN as specified in the subclause 5.6;
- set Next_PDCP_RX_SN to the received 5G-PDCP SN + 1;
- if Next_PDCP_RX_SN > Maximum_PDCP_SN:
  - set Next_PDCP_RX_SN to 0;
  - increment RX_HFN by one;
- deliver the resulting 5G-PDCP SDU to upper layer.

5.1.2.2 Procedures for SRBs

For SRBs, at reception of a 5G-PDCP Data PDU from lower layers, the UE shall:

- if received PDCP SN < Next_PDCP_RX_SN:
  - decipher and verify the integrity of the PDU (if applicable) using COUNT based on RX_HFN + 1 and the received 5G-PDCP SN as specified in the subclauses 5.5 and 5.6, respectively;
- else:
  - decipher and verify the integrity of the PDU (if applicable) using COUNT based on RX_HFN and the received 5G-PDCP SN as specified in the subclauses 5.5 and 5.6, respectively;
- if integrity verification is applicable and the integrity verification is passed successfully; or
- if integrity verification is not applicable:
  - if received 5G-PDCP SN < Next_PDCP_RX_SN:
    - increment RX_HFN by one;
  - set Next_PDCP_RX_SN to the received 5G-PDCP SN + 1;
  - if Next_PDCP_RX_SN > Maximum_PDCP_SN:
    - set Next_PDCP_RX_SN to 0;
    - increment RX_HFN by one;
  - deliver the resulting 5G-PDCP SDU to upper layer;
- else, if integrity verification is applicable and the integrity verification fails:
  - discard the received 5G-PDCP Data PDU;
  - indicate the integrity verification failure to upper layer.

5.2 5G-PDCP Data Transfer procedures

When upper layers request a 5G-PDCP re-establishment, the UE shall additionally perform once the procedures described in this section for the corresponding 5G-RLC mode. After performing the procedures in this section, the UE shall follow the procedures in subclause 5.1.

5.2.1 UL Data Transfer procedures

5.2.1.1 Procedures for DRBs mapped on 5G-RLC AM

When upper layers request a 5G-PDCP re-establishment, the UE shall:

- apply the ciphering algorithm and key provided by upper layers during the re-establishment procedure;
- from the first 5G-PDCP SDU for which the successful delivery of the corresponding 5G-PDCP PDU has not been confirmed by lower layers, perform retransmission or transmission of all the 5G-PDCP SDUs already associated with 5G-PDCP SNs in ascending order of the COUNT values associated to the 5G-PDCP SDU prior to the 5G-PDCP re-establishment as specified below:
  - perform ciphering of the 5G-PDCP SDU using the COUNT value associated with this 5G-PDCP SDU as specified in the subclause 5.5;
  - submit the resulting 5G-PDCP Data PDU to lower layer.

5.2.1.2 Procedures for DRBs mapped on 5G-RLC UM

When upper layers request a 5G-PDCP re-establishment, the UE shall:

- set Next_PDCP_TX_SN, and TX_HFN to 0;
- apply the ciphering algorithm and key provided by upper layers during the re-establishment procedure;
- for each 5G-PDCP SDU already associated with a 5G-PDCP SN but for which a corresponding 5G-PDCP PDU has not previously been submitted to lower layers:
  - consider the 5G-PDCP SDUs as received from upper layer;
  - perform transmission of the 5G-PDCP SDUs in ascending order of the COUNT value associated to the 5G-PDCP SDU prior to the 5G-PDCP re-establishment, as specified in the subclause 5.1.1 without restarting the *discardTimer*.

5.2.1.3 Procedures for SRBs

When upper layers request a 5G-PDCP re-establishment, the UE shall:

- set Next_PDCP_TX_SN, and TX_HFN to 0;
- discard all stored 5G-PDCP SDUs and 5G-PDCP PDUs;
- apply the ciphering and integrity protection algorithms and keys provided by upper layers during the re-establishment procedure.

5.2.2 DL Data Transfer procedures

5.2.2.1 Procedures for DRBs mapped on 5G-RLC AM

When upper layers request a 5G-PDCP re-establishment, the UE shall:

- process the 5G-PDCP Data PDUs that are received from lower layers due to the re-establishment of the lower layers, as specified in the subclause 5.1.2.1.1;
- apply the ciphering algorithm and key provided by upper layers during the re-establishment procedure.

5.2.2.2 Procedures for DRBs mapped on 5G-RLC UM

When upper layers request a 5G-PDCP re-establishment, the UE shall:

- process the 5G-PDCP Data PDUs that are received from lower layers due to the re-establishment of the lower layers, as specified in the subclause 5.1.2.1.2;
- set Next_PDCP_RX_SN, and RX_HFN to 0;
- apply the ciphering algorithm and key provided by upper layers during the re-establishment procedure.

5.2.2.3 Procedures for SRBs

When upper layers request a 5G-PDCP re-establishment, the UE shall:

- discard the 5G-PDCP Data PDUs that are received from lower layers due to the re-establishment of the lower layers;
- set Next_PDCP_RX_SN, and RX_HFN to 0;
- discard all stored 5G-PDCP SDUs and 5G-PDCP PDUs;
- apply the ciphering and integrity protection algorithms and keys provided by upper layers during the re-establishment procedure.

5.3 5G-PDCP Status Report

5.3.1 Transmit operation

When upper layers request a 5G-PDCP re-establishment, for radio bearers that are mapped on 5G-RLC AM, the UE shall:

- if the radio bearer is configured by upper layers to send a 5G-PDCP status report in the uplink (*statusReportRequired* [4]), compile a status report as indicated below after processing the 5G-PDCP Data PDUs that are received from lower layers due to the re-establishment of the lower layers as specified in the subclause 5.2.2.1, and submit it to lower layers as the first 5G-PDCP PDU for the transmission, by:
  - setting the FMS field to the 5G-PDCP SN of the first missing 5G-PDCP SDU;
  - if there is at least one out-of-sequence 5G-PDCP SDU stored, allocating a Bitmap field of length in bits equal to the number of 5G-PDCP SNs from and not including the first missing 5G-PDCP SDU up to and including the last out-of-sequence 5G-PDCP SDUs, rounded up to the next multiple of 8, or up to and including a 5G-PDCP SDU for which the resulting 5G-PDCP Control PDU size is equal to 65528 bytes, whichever comes first;
  - setting as ‘0’ in the corresponding position in the bitmap field for all 5G-PDCP SDUs that have not been received as indicated by lower layers;
  - indicating in the bitmap field as ‘1’ for all other 5G-PDCP SDUs.

5.3.2 Receive operation

When a 5G-PDCP status report is received in the downlink, for radio bearers that are mapped on 5G-RLC AM:

- for each 5G-PDCP SDU, if any, with the bit in the bitmap set to '1', or with the associated COUNT value less than the COUNT value of the 5G-PDCP SDU identified by the FMS field, the successful delivery of the corresponding 5G-PDCP SDU is confirmed, and the UE shall process the 5G-PDCP SDU as specified in the subclause 5.4.

5.4 5G-PDCP discard

When the *discardTimer* expires for a 5G-PDCP SDU, or the successful delivery of a 5G-PDCP SDU is confirmed by 5G-PDCP status report, the UE shall discard the 5G-PDCP SDU along with the corresponding 5G-PDCP PDU. If the corresponding 5G-PDCP PDU has already been submitted to lower layers the discard is indicated to lower layers.

5.5 Ciphering and Deciphering

The ciphering function includes both ciphering and deciphering and is performed in 5G-PDCP. For the control plane, the data unit that is ciphered is the data part of the 5G-PDCP PDU (see subclause 6.3.3) and the MAC-I (see subclause 6.3.4). For the user plane, the data unit that is ciphered is the data part of the 5G-PDCP PDU (see subclause 6.3.3); ciphering is not applicable to 5G-PDCP Control PDUs.

The ciphering algorithm and key to be used by the 5G-PDCP entity are configured by upper layers [4] and the ciphering method shall be applied as specified in [5].

The ciphering function is activated by upper layers [4]. After security activation, the ciphering function shall be applied to all 5G-PDCP PDUs indicated by upper layers [4] for the downlink and the uplink, respectively.

The parameters that are required by 5G-PDCP for ciphering are defined in [5] and are input to the ciphering algorithm. The required inputs to the ciphering function include the COUNT value, and DIRECTION (direction of the transmission: set as specified in [5]).The parameters required by 5G-PDCP which are provided by upper layers [4] are listed below:

- BEARER (defined as the radio bearer identifier in [5]. It will use the value RB identity –1 as in [4]);
- KEY (the ciphering keys for the control plane and for the user plane are K_{RRCenc} and K_{UPenc}, respectively).

5.6 Integrity Protection and Verification

The integrity protection function includes both integrity protection and integrity verification and is performed in 5G-PDCP for 5G-PDCP entities associated with SRBs. The data unit that is integrity protected is the PDU header and the data part of the PDU before ciphering.

The integrity protection algorithm and key to be used by the 5G-PDCP entity are configured by upper layers [4] and the integrity protection method shall be applied as specified in [5].

The integrity protection function is activated by upper layers [4]. After security activation, the integrity protection function shall be applied to all PDUs including and subsequent to the PDU indicated by upper layers [4] for the downlink and the uplink, respectively.

NOTE: As the 5G-RRC message which activates the integrity protection function is itself integrity protected with the configuration included in this 5G-RRC message, this message needs first be decoded by 5G-RRC before the integrity protection verification could be performed for the PDU in which the message was received.

The parameters that are required by 5G-PDCP for integrity protection are defined in [5] and are input to the integrity protection algorithm. The required inputs to the integrity protection function include the COUNT value, and DIRECTION (direction of the transmission: set as specified in [5]). The parameters required by 5G-PDCP which are provided by upper layers [4] are listed below:

- BEARER (defined as the radio bearer identifier in [5]. It will use the value RB identity –1 as in [4]);
- KEY (K_{RRCint}).

At transmission, the UE computes the value of the MAC-I field and at reception it verifies the integrity of the 5G-PDCP PDU by calculating the X-MAC based on the input parameters as specified above. If the calculated X-MAC corresponds to the received MAC-I, integrity protection is verified successfully.

5.7 Handling of unknown, unforeseen and erroneous protocol data

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

- discard the received PDU.

6 Protocol data units, formats and parameters

6.1 Protocol data units

6.1.1 5G-PDCP Data PDU

The 5G-PDCP Data PDU is used to convey:

- a 5G-PDCP SDU SN; and
- user plane data;
- control plane data; and
- a MAC-I field for SRBs.

6.1.2 5G-PDCP Control PDU

The 5G-PDCP Control PDU is used to convey:

- a 5G-PDCP status report indicating which 5G-PDCP SDUs are missing and which are not following a 5G-PDCP re-establishment.

6.2 Formats

6.2.1 General

A 5G-PDCP PDU is a bit string that is byte aligned (i.e. multiple of 8 bits) in length. In the figures in sub clause 6.2, bit strings are represented by tables in which the most significant bit is the leftmost bit of the first line of the table, the least significant bit is the rightmost bit on 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. The bit order of each parameter field within a 5G-PDCP PDU is represented with the first and most significant bit in the leftmost bit and the last and least significant bit in the rightmost bit.

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

6.2.2 Control plane 5G-PDCP Data PDU

Figure 6.2.2-1 shows the format of the 5G-PDCP Data PDU carrying data for control plane SRBs.

R	R	R	R	R	R	5G-PDCP SN	Oct 1
5G-PDCP SN							Oct 2
5G-PDCP SN							Oct 3
Data							Oct 4
...							
MAC-I							Oct N-3
MAC-I (cont.)							Oct N-2
MAC-I (cont.)							Oct N-1
MAC-I (cont.)							Oct N

Figure 6.2.2-1: 5G-PDCP Data PDU format for SRBs

6.2.3 User plane 5G-PDCP Data PDU

Figure 6.2.3-1 shows the format of the 5G-PDCP Data PDU. This format is applicable for 5G-PDCP Data PDUs carrying data from DRBs mapped on 5G-RLC AM or 5G-RLC UM.

D/C	R	R	R	R	R	5G PDCP SN	Oct 1
5G PDCP SN (cont.)							Oct 2
5G PDCP SN (cont.)							Oct 3
Data							Oct 4
...							

Figure 6.2.3-1: 5G-PDCP Data PDU format for DRBs

6.2.4 5G-PDCP Control PDU for 5G-PDCP status report

Figure 6.2.4-1 shows the format of the 5G-PDCP Control PDU carrying one 5G-PDCP status report. This format is applicable for DRBs mapped on 5G-RLC AM.

D/C	PDU Type	R	R	FMS	Oct 1
FMS (cont.)					Oct 2
FMS (cont.)					Oct 3
Bitmap1 (optional)					Oct 4
...					
BitmapN (optional)					Oct 3+N

Figure 6.2.4-1: 5G-PDCP Control PDU format for 5G-PDCP status report

6.3 Parameters

6.3.1 General

If not otherwise mentioned in the definition of each field then the bits in the parameters shall be interpreted as follows: the left most bit string is the first and most significant and the right most bit is the last and least significant bit.

Unless otherwise mentioned, integers are encoded in standard binary encoding for unsigned integers. In all cases the bits appear ordered from MSB to LSB when read in the PDU.

6.3.2 5G-PDCP SN

Length: 18 bits for user plane data as indicated in table 6.3.2-1.

Table 6.3.2-1: 5G-PDCP SN length

Length	Description
18	SRBs
18	DRBs

6.3.3 Data

Length: Variable

The Data field may include either one of the following:

- 5G-PDCP SDU

6.3.4 MAC-I

Length: 32 bits

The MAC-I field carries a message authentication code calculated as specified in subclause 5.6.

For control plane data that are not integrity protected, the MAC-I field is still present and should be padded with padding bits set to 0.

6.3.5 COUNT

Length: 32 bits

For ciphering and integrity a COUNT value is maintained. The COUNT value is composed of a HFN and the 5G-PDCP SN.

HFN	5G-PDCP SN

Figure 6.3.5-1: Format of COUNT

The size of the HFN part in bits is equal to 32 minus the length of the 5G-PDCP SN.

NOTE: When performing comparison of values related to COUNT, the UE takes into account that COUNT is a 32-bit value, which may wrap around (e.g., COUNT value of 2^{32} - 1 is less than COUNT value of 0).

6.3.6 R

Length: 1 bit

Reserved. Reserved bits shall be set to 0. Reserved bits shall be ignored by the receiver.

6.3.7 D/C

Length: 1 bit

Table 6.3.7-1: D/C field

Bit	Description
0	Control PDU
1	Data PDU

6.3.8 PDU type

Length: 3 bits

Table 6.3.8-1: PDU type

Bit	Description
000	5G-PDCP status report
001-111	Reserved

6.3.9 FMS

Length: 18 bits

5G-PDCP SN of the first missing 5G-PDCP SDU.

6.3.10 Bitmap

Length: Variable

The length of the bitmap field can be 0.

The MSB of the first octet of the type "Bitmap" indicates whether or not the 5G-PDCP SDU with the SN (FMS + 1) modulo (Maximum_PDCP_SN + 1) has been received. The LSB of the first octet of the type "Bitmap" indicates whether or not the 5G-PDCP SDU with the SN (FMS + 8) modulo (Maximum_PDCP_SN + 1) has been received.

Table 6.3.10-1: Bitmap

Bit	Description
0	5G-PDCP SDU with 5G-PDCP SN = (FMS + bit position) modulo (Maximum_PDCP_SN + 1) is missing in the receiver. The bit position of N^{th} bit in the Bitmap is N, i.e., the bit position of the first bit in the Bitmap is 1.
1	5G-PDCP SDU with 5G-PDCP SN = (FMS + bit position) modulo (Maximum_PDCP_SN + 1) does not need to be retransmitted. The bit position of N^{th} bit in the Bitmap is N, i.e., the bit position of the first bit in the Bitmap is 1.

The UE fills the bitmap indicating which SDUs are missing (unset bit - ’0’), i.e. whether an SDU has not been received or, and which SDUs do not need retransmission (set bit - ’1’), i.e. whether an SDU has been received correct.

7 Variables, constants and timers

7.1 State variables

This sub clause describes the state variables used in 5G-PDCP entities in order to specify the 5G-PDCP protocol.

All state variables are non-negative integers.

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

a) Next_PDCP_TX_SN

The variable Next_PDCP_TX_SN indicates the 5G-PDCP SN of the next 5G-PDCP SDU for a given 5G-PDCP entity. At establishment of the 5G-PDCP entity, the UE shall set Next_PDCP_TX_SN to 0.

b) TX_HFN

The variable TX_HFN indicates the HFN value for the generation of the COUNT value used for 5G-PDCP PDUs for a given 5G-PDCP entity. At establishment of the 5G-PDCP entity, the UE shall set TX_HFN to 0.

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

c) Next_PDCP_RX_SN

The variable Next_PDCP_RX_SN indicates the next expected 5G-PDCP SN by the receiver for a given 5G-PDCP entity. At establishment of the 5G-PDCP entity, the UE shall set Next_PDCP_RX_SN to 0.

d) RX_HFN

The variable RX_HFN indicates the HFN value for the generation of the COUNT value used for the received 5G-PDCP PDUs for a given 5G-PDCP entity. At establishment of the 5G-PDCP entity, the UE shall set RX_HFN to 0.

e) Last_Submitted_PDCP_RX_SN

For 5G-PDCP entities for DRBs mapped on 5G-RLC AM the variable Last_Submitted_PDCP_RX_SN indicates the SN of the last 5G-PDCP SDU delivered to the upper layers. At establishment of the 5G-PDCP entity, the UE shall set Last_Submitted_PDCP_RX_SN to Maximum_PDCP_SN.

7.2 Timers

The transmitting side of each 5G-PDCP entity for DRBs shall maintain the following timers:

a) *discardTimer*

The duration of the timer is configured by upper layers [4]. In the transmitter, a new timer is started upon reception of an SDU from upper layer.

7.3 Constants

a) Reordering_Window

Indicates the size of the reordering window. The size equals to 131072 when a 18-bit SN length is used, i.e. half of the 5G-PDCP SN space, for radio bearers that are mapped on 5G-RLC AM.

b) Maximum_PDCP_SN is:

- 262143 if the 5G-PDCP entity is configured for the use of 18 bits SNs