An Overview of RLC Layer In 4G LTE

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***Abstract* - The 3rd Generation Partnership Project(3GPP) has been working on the new mobile communication technology called Long Term Evolution(LTE), from the previous years and has developed it. Universal Mobile Telecommunications System (UMTS) and High-Speed Packet Access (HSPA) systems are presently prevalently-deployed systems and LTE provides a prodigious improvement in these standards . The Radio Link Control (RLC) is a part of the protocol stack in both the UE and the eNodeB which is defined on top of the Medium Access Control (MAC) layer. In this paper, we give an overview of the RLC architecture, three modes Transparent Mode(TM), Unacknowledged Mode (UM) and Acknowledged Mode (AM) and the comparison of LTE and HSPA. We also concentrate on the data structures, variables, constants and timers used in the RLC layer.**

***Keywords* - Radio Link Control (RLC), Transparent**

I. INTRODUCTION

The 4G is the latest and emerging technology in the wireless mobile communication system. It provides the improvements in performance compared to the previous mobile technologies.4G-LTE represents an emerging technology for ubiquitous broadband internet access where release 10 which is a member of IMT-Advanced is proposed for evaluation to International Telecommunications Union-Radio communications (ITU-R).
Some of the performance requirements of LTE are:

- High data rate: Uplink(UL) - 500 Mbps and Downlink(DL)- 1000 Mbps.
- Mobility: Supports high speed in the mobility range of 0-15 kmph.
- Lower Latency and power consumption: User plane-less than 5ms and control plane-less than 50 ms.
- Cell capacity: It supports up to 200 active users.
- Improved broadcasting and co-existence with the existing systems.

The RLC layer is present on top of the medium access control (MAC) layer and beneath other higher layers such as RRC (radio resource control) and PDCP (packet data convergence protocol) in the LTE protocol stack. PDCP, RLC, MAC-layers together make up LTE Layer 2. RLC acts as an interface between PDCP and MAC layers and provides services to both. At times, the services of the RRC are directly utilized by RLC.

The radio link control (RLC) layer has three functional modes: the TM (transparent mode), UM (unacknowledged mode) and AM (acknowledged mode).
The main functions of RLC are:

- Segmentation and concatenation of upper layer SDUs into RLC PDUs which offers reliable data transmission and allows the packets to adjust to the size acceptable by radio interface. Each RLC is given a sequence number (SN) and the PDUs are reassembled on the receiver side and passed on to the upper layers. All PDUs and SDUs are byte aligned, which means sometimes unused padding bits are used in addition to acquire processing speed.
- Reordering takes place in order to assemble the out-of-order packets from the HARQ MAC in downlink and provides in-sequence delivery of PDUs. This allows the RLC layer to deliver the SDUs in the actual order.
- Error correction takes place through ARQ where ,the ARQ is realized by the mechanisms of polling, PDU sequence SN and status report.
- Protocol error detection and recovery and duplicate detection are also the functions of RLC layer which assures that the SDUs are delivered only once to the upper layers .
- Retransmission may be accomplished to regain packet losses for radio bearers which need error-free transmission. There is one RLC entity per radio bearer. Ciphering function ensures privacy protection.
- Flow control is guaranteed by presenting a mechanism to the receiver to adjust the data rate of the sender.[1]

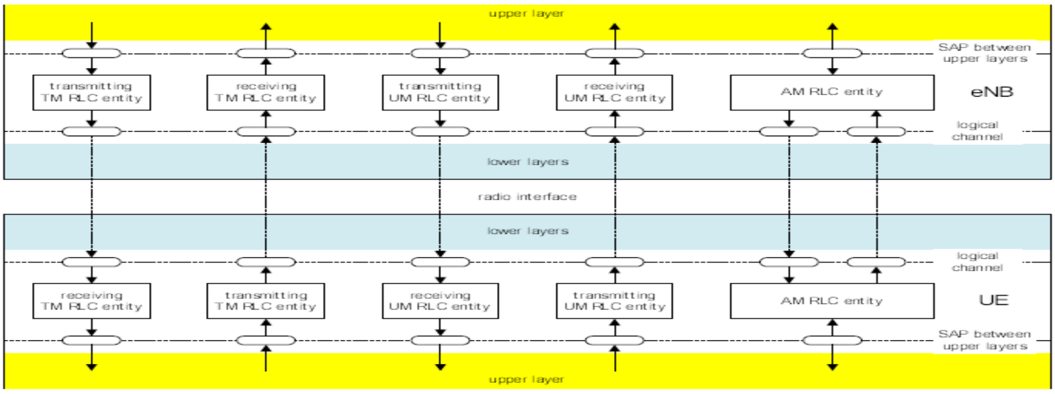

Figure 4.2.1-1: Overview model of the RLC sub layer

Figure 1 RLC architecture

II. RLC ARCHITECTURE

The control of RRC is normally in the hands of the RLC configuration. RLC entities perform the functions of RLC layer. For a RLC entity configured at the UE, a peer RLC entity configured at the eNodeB is present and vice versa. [2]

Figure 1 shows the RLC architecture. An RLC entity transmits SDUs from upper layer to its peer entity through lower layers. An RLC PDU can be a control PDU (signaling information) or a data PDU (user data information. A single SAP between RLC and upper layer is used to receive SDUs from upper layer and after creating RLC data PDUs from the SDUs, The PDUs are delivered to the lower layer through logical channels and the vice versa process takes place on the receiver end [2]. The same logical channels used for transmission/reception of data PDUs are used for control PDUs.

An RLC entity is classified as a TM RLC entity, an UM RLC entity or an AM RLC entity depending on the mode of data transfer . In all the three modes, the transmitter and receiver entities operate with their respective peer entities.

III. RLC MODES

There are three different modes in which RLC PDUs can operate: Transparent mode (TM), Unacknowledged mode (UM), or Acknowledged Mode (AM)[3]. The mode of operation controls the functionality and applicability of the RLC. TM is only applicable for control plane signaling related RLC data packets. AM or UM can be used for control or user plane RLC data packets.

A. Transparent Mode (TM)

TM stands for 'Transparent Mode'. Buffering is the only operation done in TM mode which is very simple. It just retains the data for a certain period of time or until the next input data arrives, and discards it after that time frame, if the data do not get transmitted.

RLC is totally transparent and is in essence bypassed. In this context, transparent implies that the contents pass through this layer without any alteration. Alteration means that, firstly, the header is not added to or removed from the input data. Secondly, Segmentation- the input data is not split into multiple segments (SDUs). Thirdly, Reassembly-multiple data segments (SDUs) are not combined into big units of data.

Retransmission and in-sequence delivery do not take place in TM. As there is no uplink, terminal to feedback status reports are impossible and hence retransmissions are not possible. The message sizes are selected such that all calculated terminals are reached with a high probability. Therefore, there is no need for retransmission to offer error-free data transmission or segmentation to manage changing channel conditions. The TM configuration is used for BCCH, CCCH, and PCCH, which are broadcast channels meant for extending the data to the multiple users. There is no delivery guarantee in this mode and it is suitable to carrying voice data.[4]

Figure 2 shows that BCCH, PCCH, CCCH channels through this type of RLC process. This mode was used by voice call traffic (DTCH) in WCDMA as well.

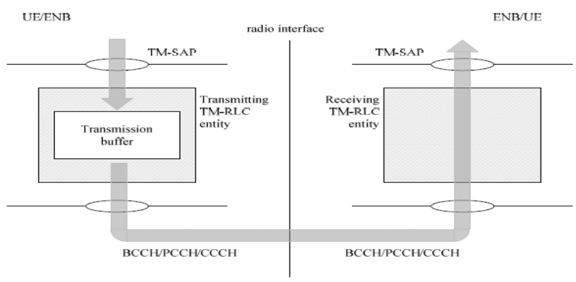

Figure 4.2.1.1.1-1: Model of two transparent mode peer entities

Figure 2. Transparent Mode(TM)

B. Unacknowledged mode (UM)

UM means 'Unacknowledged Mode', which implies that it does not require any acknowledgement (ACK/NACK) from the receiver. It supports segmentation or reassembly, and in-sequence delivery in sequence delivery of data packets (PDUs). This mode is preferred for VoIP and when error free delivery is not required, for example for MCCH and MTCH using MBSFN. UM does not guarantee the delivery of packets but, is appropriate for streaming traffic. In analogy, UM mode is alike TM in that no ACK/NACK is required from the other end, but is unlike TM in that it has its own header and adds it to the PDUs. RLC UM is more like UDP in IP world.

The operations of the *Transmitter* side are follows according to the figure 3 :

i) Buffering- retains the received SDUs from the upper layer in the transmission buffer until the opportunity for transmission is obtained.

ii) Segmentation -Segment a big chunk of data into multiple small chunks of data to fit the right size (PDUs).

iii) Concatenation -Combine multiple small chunks of data into a single large chunk of data (PDU) of proper size for transmitting which also depends on SDU size.

iv) Add RLC header which includes information such as SN and LI(Length Indicator).These information are included because the receiver has to re-split or re-combine the data to retrieve the original data. These PDUs are then passed on to MAC layer for transmission [5].

The operations of the *Receiver* side are as follows according to the figure 3:

i) Buffering- The receiving entity holds the received packets(PDUs) in the reception buffer.

ii) Reordering - Due to late arrival of the PDUs in the lower layer retransmissions, packets may become out of order. Hence, based on the SN the PDUs are reordered.

iii) Remove the RLC header - Before reassembling the data, the header appended to the PDUs while transmitting should be removed.

iv) Reassembly- Undoing any segmentation or concatenation of PDUs ,the data fields are assembled back into SDUs and passed to the upper layers of the protocol stack.[2]

As seen in figure, DTCH, MTCH, MCCH use this type of RLC process. We can use AM or TM mode for DTCH as it is an option.

C. Acknowledged Mode (AM)

AM is the most complicated mode of the RLC modes.AM stands for 'Acknowledged Mode' which means that it requires ACK/NACK from the receiver. Segmentation/reassembly and in-sequence delivery of PDUs are supported by AM. Retransmissions of erroneous data is also supported. AM is suitable for carrying TCP traffic and acts more like TCP packet in IP world. DL-SCH is used for main mode of operation for TCP/IP packets. Error correction in AM is based on ARQ which is based on special rules such as polling request, special timers etc. Flow control is done by varying window size.

The *Transmitter* side operations are:

It includes buffering, segmentation/concatenation, Addition of header, which are carried out in the same way as UM. But the difference lies in the retransmission buffer where, after adding the header ,two identical copies of the PDUs is formed where one is sent to MAC layer for buffer for the later amount of time, then the PDUs stored in the retransmission buffer is retransmitted. If an ACK is transmission and another to the retransmission received, the PDUS in the retransmission buffer is discarded [5].

The *Receiver* side operations:

It includes buffering, reordering, removal of the RLC header and reassembly of packets similar to UM.

Figure 4 shows the structure of the RLC AM. In AM, retransmission mechanism is based on ARQ and is used to get back any missing PDUs.

retransmission of data if needed. If the receiver sends a NACK , or the transmitter does not receive any reply for a certain

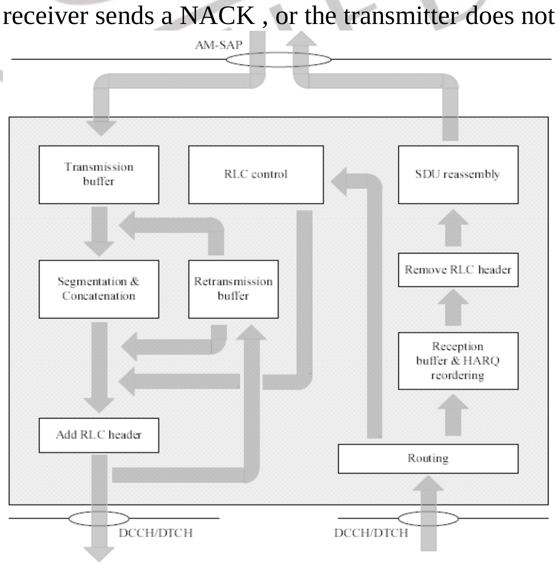

Figure 4.2.1.3.1-1: Model of an acknowledged mode enttiy

Figure 4. Acknowledged Mode(AM)

IV. STATE VARIABLES, CONSTANTS AND TIMERS

A. STATE VARIABLES

i. *TX AM RLC variables.*

a) VT(A) –ACK. Sequence Number of the next PDU for which ACK is to be received in sequence lower edge of Tx window.
b) VT(MS) -Maximum send. VT(MS)=VT(A) + AM_Window_Size, higher edge of Tx window.
c)VT(S) –Send. SN for next new PDU.
d) POLL_SN –Poll send. VT(S) -1 upon latest TX of PDU with poll bit set to "1".

ii. *TX AM RLC counters:*

a) PDU_WITHOUT_POLL - PDUs sent since the most recent poll bit transmitted.
b) BYTE_WITHOUT_POLL – Bytes sent since the most recent poll bit transmitted.
c) RETX_COUNT –no. of retransmissions of a PDU.

iii. *RX AM RLC variables:*

a) VR(R) –Receive. SN following the last in-sequence received PDU, lower edge of receiving window.
b) VR(MR) –Maximum receive Sequence Number. VR(MR)=(VR(R)+AM_Window_Size)=SN of first PDU beyond receiving window-higher edge of the receiving window.
c) VR(X) –t-Reordering variable = SN following SN of PDU which triggered t-Reordering.
d) VR(MS) –Maximum STATUS transmits highest "ACK_SN" when STATUS PDU is constructed.
e) VR(H) –Highest received. Highest SN among received PDUs plus 1.

iv. *TX UM RLC variables:*

a) VT(US) -SN of next new PDU.

E. RX UM RLC variables:

a) VR(UR) –UM received. Earliest PDU SN still considered for reordering.
b) VR(UX) –UM t-Reordering. SN of PDU which triggered t-Reordering plus 1.
c) VR(UH) –UM highest received. PDU with highest SN among received PDUs plus 1 -higher edge of reordering window.

B. CONSTANTS

a) AM_Window_Size(=512) - RLC uses to calculate VT(MS) from VT(A), and VR(MR) from VR(R).
b) UM_Window_Size – Defines SNs of receivable UM PDUs without causing advancement of receiving window.
c) UM_Window_Size = 16 when a 5 bit SN; 512 when a 10 bit SN; 0 for MCCH or MTCH.[6]

C. TIMERS:

a) t-PollRetransmit –Tx AM RLC uses to retransmit a poll.
b) t-Reordering –Rx AM/UM RLC uses to detect loss of RLC PDUs at MAC.
c) t-StatusProhibit –Rx AM RLC uses to prohibit transmission of a STATUS PDU.

D. CONFIGURABLE PARAMETERS

a) maxRetxThreshold – Tx AM RLC Max retransmissions.
b) pollPDU – Tx AM RLC triggers poll for every pollPDU PDUs.
c) pollByte – Tx AM RLC triggers poll for every pollByte bytes.
d) sn-FieldLength - UM SN field size in bits.[6]

V. LTE VERSUS HSPA

- RLC is located in eNodeB in LTE whereas in HSPA it is present in RNC.
- In LTE, no ciphering is present in RLC layer and it is carried out in PDCP layer whereas, HSPA supports ciphering in both UM and AM modes.
- Re-segmentation of PDUs is allowed during retransmission in LTE but it is not allowed in HSPA.
- In LTE, Transparent mode is used for signaling channels only .But in HSPA, both traffic channels and signaling channels should use TM.
- In LTE, flexible PDU sizes are used to match the PHY layer capacity . But in HSPA, PDUs are semi-statically configured.[5]

VI. CONCLUSION

In this paper, an insight of the several RLC layer functions of LTE is provided. Especially the architecture and the three modes(TM, UM and AM) have been explained. Various state variables, constants and timers of the three modes are elaborated. A comparison between the LTE and HSPA is covered, which gives the difference between the both. Some further work has to be performed related to the implementation of Acknowledged Mode(AM), flow control, ARQ/HARQ interaction and configurations of RLC layer in the near future.

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