Scheme Of Evaluation

Internal Assessment Test 3 – May.2019

Sub:	Wireless Cellular and LTE 4G Broadband							**Code:**	15EC81
Date:	13/05/2019	Duration:	90mins	Max Marks:	50	**Sem:**	VIII	**Branch:**	ECE

Note: Answer Any Five Questions

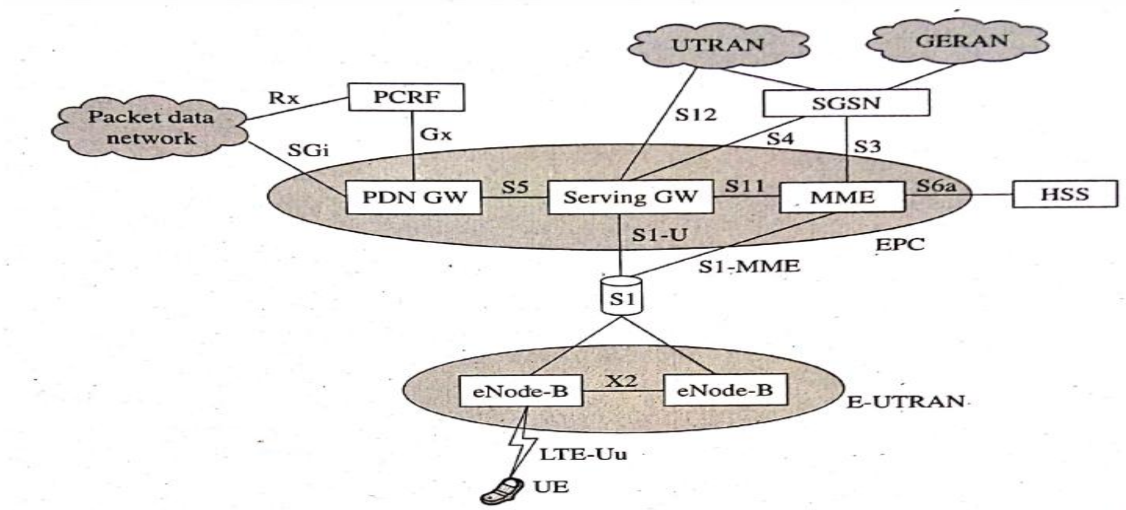
Question #	Description	Marks Distribution	Max Marks
1	**List and explain briefly about the components of LTE Network Architecture.** Diagram Explanation of the Components	4 M 6 M	10 M
2	**Analyze and explain the frame structure of LTE downlink and Uplink.** Explanation of Type 1 Frame Structure Explanation of Type 2 Frame Structure	5 M 5 M	10 M
3	**Illustrate the various resource units of OFDMA with a neat sketch of resource grid.** Diagram-Structure of downlink resource grid Explanation of resource units	4 M 6 M	10 M
4	**Discuss briefly about the EPS bearer service architecture with a neat sketch.** Diagram Explanation	5 M 5 M	10 M
5	**Describe the functions of RLC Layer along with PDU Formats.** Functions and three modes PDU Formats and explanation	4 M 6 M	10 M

6	**Demonstrate the process of mobility management over S1 interface with a neat flow diagram.** Flow Diagram Explanation	 6 M 4 M	10 M
7	**Explain briefly about the role of H-ARQ in Uplink.** Explanation and need of H-ARQ FDD Mode and TDD Mode	 6 M 4 M	10 M
8	**Explain briefly about the Random access procedures.** Diagram Explanation	 2 M 8 M	10 M

1. **List and explain briefly about the components of LTE Network Architecture. 10M**

Network Architecture

LTE end-to-end Network Architecture



Network Architecture

- **Packet Data Network Gateway (PDN GW) –** Routes data b/w EPC & external PDN, policy enforcement, charging data collection, mobility point with non-3GPP access.
- **S1 Interface –** interface separating E-UTRAN & EPC.
  - **S1-U** – carries **traffic data** b/w eNode-B & Serving GW
  - **S1-MME** – **signaling interface** b/w eNode-B & MME.
- **X2 Interface –** interface b/w the eNode-B.
  - **X2-C** – **control plane** interface b/w eNode-B
  - **X2-U** – **user plane** interface b/w eNode-B.
- **Policy & Charging Rules Function PCRF**
- **Home Subscriber Server HSS-** user authorization & authentication
- **Serving GPRS Support Node SGSN** – controlling packet sessions & mobility management for GPRS network.

Network Architecture

- LTE consists of radio access network E-UTRAN and core network EPC.
- **UE –** mobile terminal
- **eNode-B –** base station. It contains **RNC** with functions – *uplink & downlink dynamic radio resource management, data packet scheduling, mobility management.*
- **Mobility Management Entity (MME) –** manages mobility aspects in 3GPP – *gateway selection, tracking area list management.*
- **Serving Gateway (Serving GW)** – routes data packets between E-UTRAN and EPC, ***mobility anchor point*** for inter-eNode-B handovers and *inter-3GPP mobility, lawful intercept, charging, policy enforcement.*

2. Analyze and explain the frame structure of LTE downlink and Uplink. 10M

Frame Structure

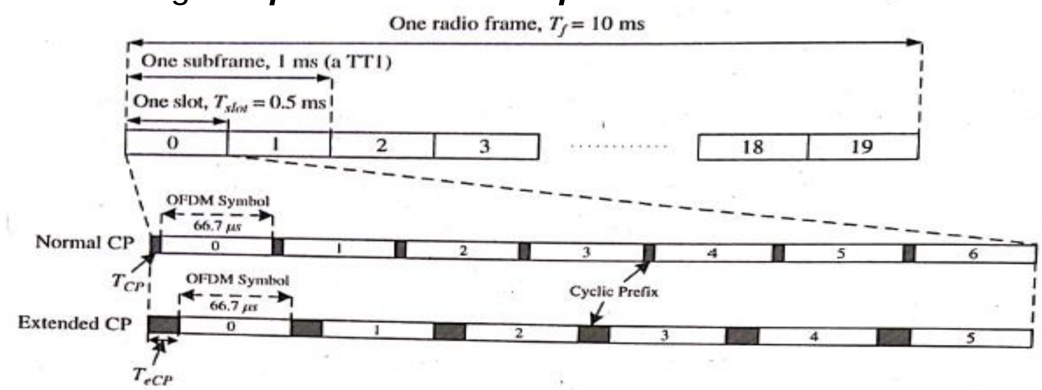
- Frame structure in the time domain which is shared by both uplink and downlink.
- In LTE ***size of elements*** in the time domain is expressed as a ***no. of time units Ts = 1/ (15000x2048)*** seconds.
- Subcarrier spacing is 15kHz, Ts is considered as the sampling time and FFT size $N_{FFT}=2048$.
- FFT size increases 128-2048 with increase in transmission BW 1.4-20MHz.
- Radio frames duration ***Tf = 307200 x Ts = 10ms.***
- LTE supports both FDD and TDD modes.
- LTE supports 2 types of frame structures :
  - Frame structure type 1 for the FDD and
  - Frame structure type 2 for the TDD mode.

Frame Structure Type 1

- Applicable to both full duplex and half duplex **FDD mode.**
- 3 different kinds of **units** specified for this frame structure :
  - ***Slot*** – smallest one – length ***Tslot = 15360 x Ts = 0.5ms.***
  - ***Subframe*** – 2 consecutive slots – length ***1ms.***
  - ***Radio frame*** – 20 slots, from 0-19 of length ***10ms.***
- Channel dependent scheduling and link adaptation operates on a subframe level, subframe duration corresponds to minimum downlink ***TTI=1ms.***
- Each slot consists of no. of OFDM symbols including CP.
- With subcarrier spacing of $\Delta f = 15kHz$, OFDM ***symbol time*** $1/\Delta f = 66.7 \mu s$.
- LTE has 2 CP: ***normal CP*** – 7 OFDM symbol and ***extended CP*** – 6 OFDM symbol

Frame Structure type-1

- ***Extended CP –*** used in multicast/broadcast services with length T_{eCP} ***= 512 x Ts =16.7µs.***
- ***Normal CP –*** urban environment and high data rate application with length ***Tcp = 160 x Ts = 5.2µs***



Frame Structure Type 2

- Applicable to **TDD mode.**
- Each radio frame is of length ***Tf = 30720 x Ts =10ms,*** consisting of **2 half frames** of length 5ms each.
- Each half frame is divided into **5 subframes** of ***1ms duration***.
- **Special subframes** of length **1ms** consisting of 3 fields :
- **Downlink Pilot TimeSlot DwPTS –** downlink part of the special subframe for downlink data transmission – length= 3-12 OFDM symbols.
- **Uplink Pilot TimeSlot UpPTS –** uplink part of the special subframe for uplink data transmission – length = 1-2 OFDM symbols.
- **Guard Period GP –** 2-10 OFDM symbols – provides guard period for switching b/w downlink to plink and vice versa.

Frame Structure type-2

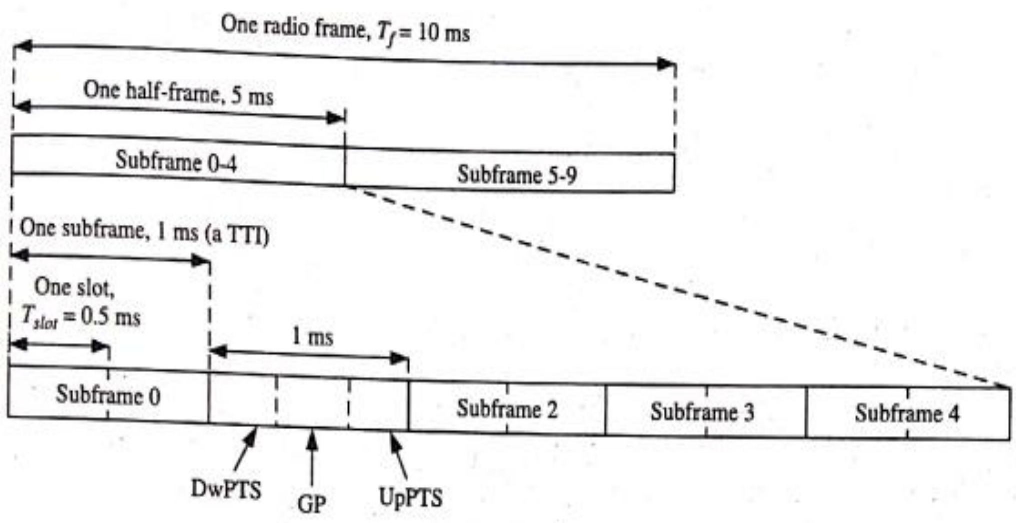


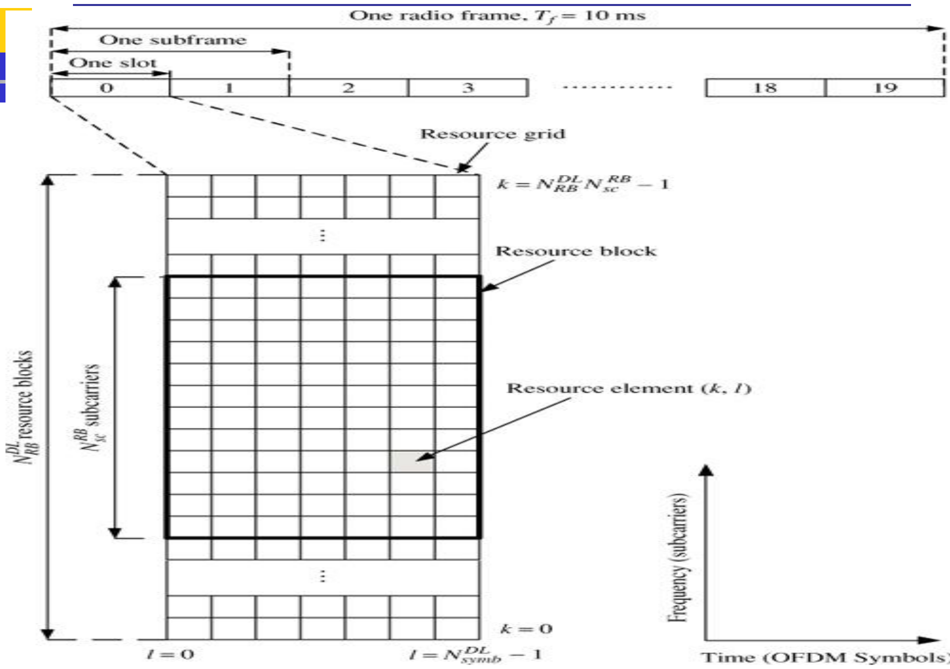
Figure 6.9 Frame structure type 2.

3. Illustrate the various resource units of OFDMA with a neat sketch of resource grid. 10M

Physical Resource Blocks for OFDMA

- **Physical resource** in the downlink in each slot is described by a time-frequency grid – ***resource grid.***
- Each column and row corresponds to 1 OFDM symbol and OFDM subcarrier.
- Smallest time –frequency unit in a resource grid **–** ***resource element.***
- Each resource grid consists of a no. of resource blocks – describing the ***mapping of physical channels to resource elements.***

Structure of Downlink Resource Grid



Physical Resource Blocks for OFDMA

- **Resource Grid** – each resource grid structure is characterize by 3 parameters:
  - **No. of downlink resource block** N_{RB}^{DL} - depends on transmission BW $N_{RB}^{min,DL} \leq N_{RB}^{DL} \leq N_{RB}^{max,DL}$ min – 6 and max -110.
  - **No. of subcarriers in each resource block** N_{sc}^{RB} - depends on subcarrier spacing ***Δf =180kHz,*** each resource block is 180kHz wide in frequency domain. Total of N_{RB}^{DL} x N_{sc}^{RB} no. of **subcarriers in each resource grid**.
  - **No. of OFDM symbols in each block** N_{symb}^{DL} **-** depends on CP length and subcarrier spacing.
- Each downlink resource grid has $N_{RB}^{DL} \times N_{RB}^{sc} \times N_{symb}^{DL}$ no. of **resource elements**.

Physical Resource Blocks for OFDMA

- For 10MHz BW, Δf = 15kHz, normal CP,

  $N_{RB}^{DL} = 50 \quad N_{RB}^{sc} = 12$ and $N_{symb}^{DL} = 7$ from

- There are ***50x12x7 = 4200 resource elements*** in the downlink resource grid.

Table 6.4 Physical Resource Block Parameters for the Downlink

Configuration		N_{sc}^{RB}	N_{symb}^{DL}
Normal CP	$\Delta f = 15\text{kHz}$	12	7
Extended CP	$\Delta f = 15\text{kHz}$	12	6
	$\Delta f = 7.5\text{kHz}$	24	3

Physical Resource Blocks for OFDMA

- **Resource Element** – each resource element in the resource grid is **uniquely identified by the index pair (k,l)** in a slot, where k and l are indices in the frequency and time domain.

  $k = 0, 1, \ldots, N_{RB}^{DL} N_{sc}^{RB} - 1$ and $l = 0, 1, \ldots, N_{symb}^{DL} - 1$

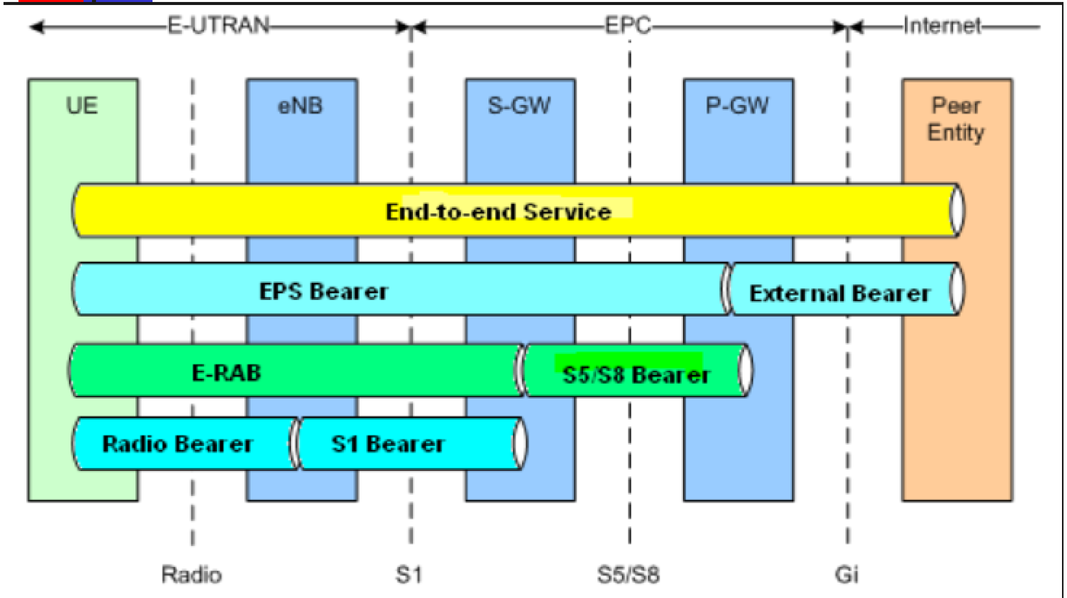
- Size of each recourse element depends on th CP length and subcarrier spacing Δf.
- **Resource Block** – basic element for radio resource allocation.
- The minimum size of radio resource that can be allocated is the minimum TTI in the time domain, i.e. 1 subframe of 1ms corresponds to 2 resource blocks.
- Size of each resource block is same for all BW -180kHz.
- 2 types of resource block in LTE : *physical* and *virtual* resource block.

4. Discuss briefly about the EPS bearer service architecture with a neat sketch. 10M

EPC bearer Service Architecture

- **Bearer -** IP packet flow with a defined quality of **service** (QoS) between the gateway and the UE.
- To support different QoS requirements of different IP applications, LTE uses concept of **bearer** as the **central element of QoS control.**
- Each EPS – Evolved Packet System bearer defined b/w PDN-GW & UE – has QoS as *latency, data rate, packet error rate.*
- End-to-end connectivity through the network is made through bearer service.
- **EPS bearer** has to cross multiple interfaces – across each interfaces it is **mapped to transport layer bearer**.
- ***S5/S8*** bearer transport the packets of an EPC bearer b/w S-GW & PDN-GW; ***S1*** bearer transports packets b/w eNode-B & S-GW.

EPC bearer Service Architecture



EPC bearer Service Architecture

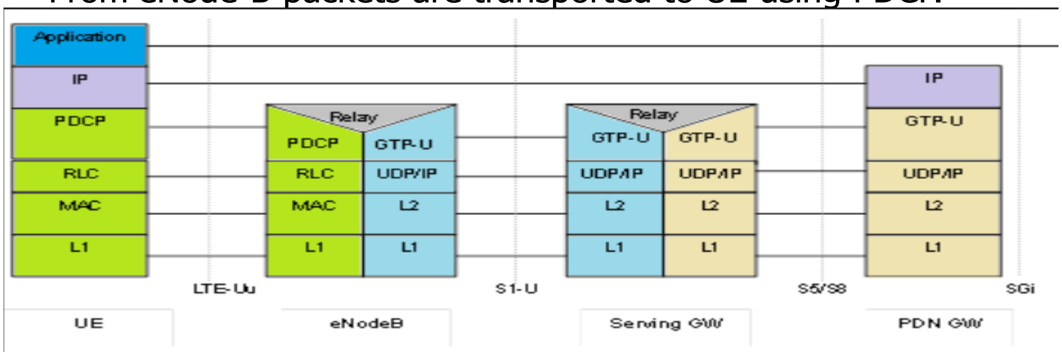
- **Radio bearer-** transports packets b/w UE & E-UTRAN.
- **Signalling Radio bearer SRB-** carry RRC signalling messages, Data Radio bearer DRB – carry user plane data.
- 2 classes of bearers:
  - **Guaranteed Bit Rate GBR bearers-** define & guarantee min BR to the UE- use for voice, streaming video, real-time streaming.
  - **Non-GBR bearers –** do no define/guarantee a min BR to UE. BR depend on system load, min UE served, scheduling algorithm – used for web browsing, email, FTP, P2P file sharing.
- Each bearer is associated with a **QoS class identifier QCI** – indicating *priority, packet delay bucket, acceptable packet error loss rate, GBR/Non-GBR classification.*

EPC bearer Service Architecture

- One EPS bearer is established when the UE connects to the PDN and that remains established throughout the lifetime of the PDN – UE has always ON connectivity to that PDN – default bearer.
- Additional EPS established to the same PDN – dedicated bearer.
- **LTE protocol architecture b/w UE and core network EPC – Evolved Packet Core** is divided into:
  - User Plane Protocol Stack
  - Control Plane Protocol Stack

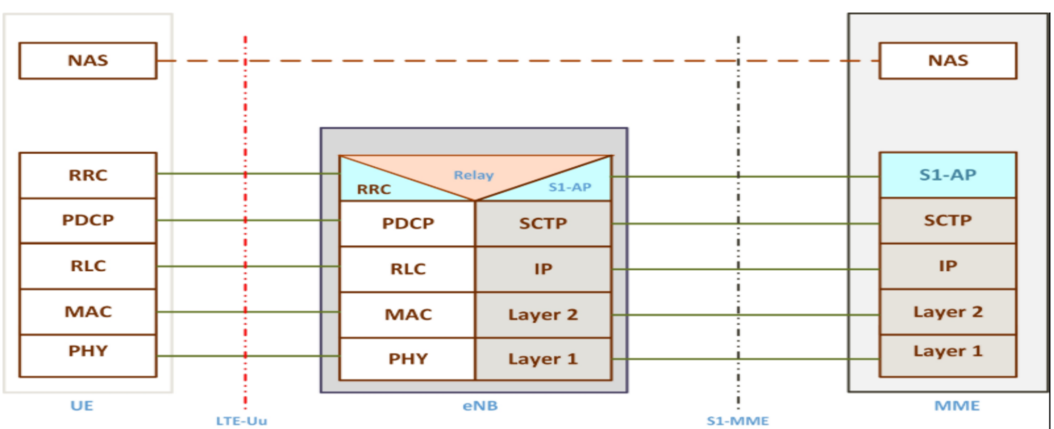
User Plane Protocol Stack

- Transporting **IP packets** carrying application specific data from the **PDN-GW to UE.**
- This is done by **encapsulating IP packets in an EPC specific protocol** and tunnelling them from PDN-GW to the eNode-B using GPRS tunnelling protocol GTP.
- From eNode-B packets are transported to UE using PDCP.



Control Plane Protocol Stack

- **Transporting signalling b/w MME and UE.**
- Signals are – bearer management, QoS management, mobility management with handover and paging.



5. Describe the functions of RLC Layer along with PDU Formats. 10M

10.2 – MAC/RLC Overview

- **RLC layer** performs **segmentation / concatenation** on PDCP PDU based on the size indicated by MAC.
  - Reorder RLC PDU.
  - Support ARQ mechanism.
- **MAC layer** supports **MUX & DEMUX** of various logical channels on to the transport channels.
  - At eNode-B this involves multiplexing and prioritizing the various UE and radio bearers.
- **Data Transfer Modes –** RLC layer functioning is done by RLC entities with the following modes:
  - TM - Transparent Mode TM
  - UM - Unacknowledged Mode UM
  - AM - Acknowledged Mode AM

Data Transfer Modes

- **Transparent Mode TM-** not used in user plane, *no RLC header* is added to PDU, *no data segmentation/concatenation, no retransmission.*
  - Broadcast system information messages & paging uses TM. PDU called **TM Data PDU.**
- **Unacknowledged Mode UM-** *in-sequence delivery of data, segmentation/concatenation of RLC SDU size indicated by MAC, duplicate detection*, but *no retransmission.*
  - Used by **delay sensitive and error tolerant real-time application** – VoIP. **PDU called UM Data PDU.**
- **Acknowledged Mode AM-** *retransmission of missing PDU, rest UM mode functionalities.* **PDU called AMD PDU.**
  - Used by error sensitive and delay tolerant application.

Purpose of MAC and RLC Layers

- **Services and functions of RLC sublayer**:
  - **Transferring/receiving PDU from upper layer** – from RRC for CCCH, from PDCP.
  - **Error correction through ARQ** – in AM
  - **Segmentation, concatenation, reassembly** of RLC SDU – in UM & AM
  - **Re-segmentation of RLC data PDU** – in AM
  - **In sequence delivery** of upper layer PDUs – in UM & AM
  - **Duplicate detection** – in UM & AM
  - **Protocol error detection** and recovery
  - **RLC SDU discard** – in UM & AM
  - **RLC re-establishment.**

PDU Headers and Formats

RLC Data PDU

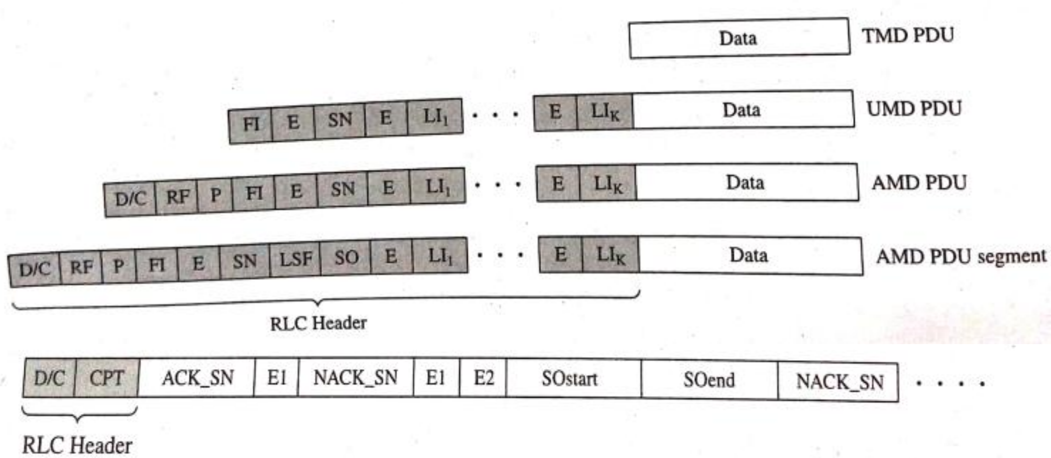


Figure 10.9 The format of STATUS PDU.

RLC PDU Headers and Formats

- **RLC data PDU –** used by TM, UM, AM RLC to transfer upper layer PDU.
- **RLC control PDU –** used in P2P signalling b/w AM RLC.
- **TMD PDU –** has only data field, no RLC header. RLC header are different for UMD and AMD PDU, with some common fields:
- **Framing Info FI –** if RLC SDU is *segmented at the beginning* or at the end of Data field.
- **Length Indicator LI –** *length of Data field* in UMD & AMD in Bytes.
- **Extension Bit E –** if a Data field follows or a set of E field and LI field follows.
- **SN field-** sequence no. of UMD/AMD. 10 bits for AMD and 5/10bits for UMD.

RLC PDU Headers and Formats

- Additional fields present for AMD PDU & AMU PDU segments.
  - **D/C field –** if RLC data PDU or RLC control PDU.
  - **Re-segmentation Flag RF field –** if RLC PDU is AMD PDU or AMD PDU segment.
  - **Polling Bit P field –** whether the transmitting side of an AM RLC entity **requests STATUS report** from its peer AM RLC entity.
- RLC header of an AMD PDU contains special fields:
  - **Segment Offset SO field – position of AMD PDU segment** in bytes within the original AMD PDU.
  - **Last Segment Flag LSF field –** whether the last byte of AMD PDU segment corresponds to the last byte of an AMD PDU.

RLC PDU Headers and Formats

- **STATUS PDU** is used to indicate the *missing portions of AMD PDU*. Contains fields:
- **Control PDU Type CPT field –** type of RLC control PDU.
- **Acknowledgement SN ACK_SN field –** SN of the *next not received* RLC data PDU, which is not reported as missing in the STATUS PDU.
- **Extension bit 1 E1 field –** whether a set of NACk_SN, E1 & E2 follows.
- **Extension bit 2 E2 field –** whether a set of SOstart & SOend follows.
- **Negative Acknowledgement SN NACK_SN field –** SN of the AMD PDU that is detected as lost at the Rx.
- **Sostart and Soend field –** together indicate *portion of AMD PDU with SN=NACK_SN* that was detected as lost at the Rx.

6. Demonstrate the process of mobility management over S1 interface with a neat flow diagram. 10M

10.4 - Mobility Management

- LTE mobility management function is categorized as : mobility within the LTE system and mobility to other 3GPP and non-3GPP systems.
- **X2 interface -** Mobility b/w multiple eNode-B within same RAN.
- **S1 interface -** Mobility b/w multiple eNode-B part of different network.
- **S1 Mobility –** steps :
  - **Preparation phase –** once **handover decision** is made and target MME and eNode-B is **identified.**
  - **MME sends handover request** to target eNode-B **requesting to allocate resource to the UE.**

10.4 - Mobility Management

- Once resource is allocated it sends a **handover request ACK** to the MME and MME sends **handover command** to UE.
- **Execution phase –** once UE receives **handover command**, it performs RAN related procedures.
- Source eNode-B initiates **status transfer** of PDCP to target eNode-B.
- Once UE establish a **radio access bearer** to the target eNode-B it **sends handover confirm message** to the target eNode-B.
- **Completion phase –** once target eNode-B receives handover confirm message it sends **handover notify message to MME**, MME informs the UE and **releases the resource originally given to the UE.**

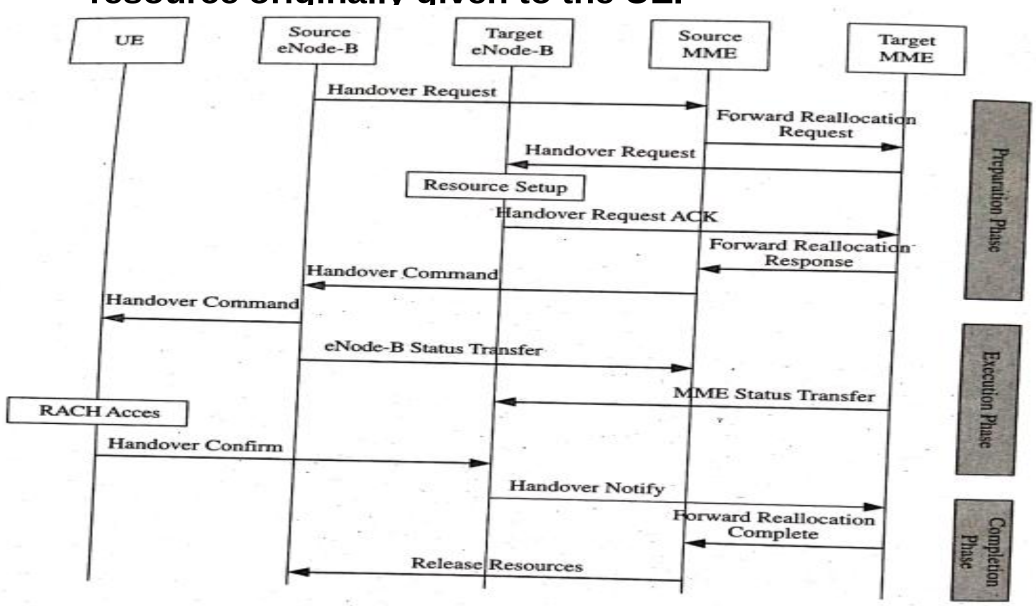


Figure 10.14 Mobility management over the S1 interface.

7. Explain briefly about the role of H-ARQ in Uplink. 10M

8.6 H-ARQ in Uplink

- **H-ARQ retransmission protocol is also used in LTE UL** – eNode-B request retransmission of corrupted data.
- For UL H-ARQ process, corresponding **ACK/NAK data is carried on PHICH.**
- LTE UL uses **synchronous H-ARQ protocol-retransmissions are scheduled on periodic intervals -** due to less protocol overhead. DL scheduler decides retransmission
- Synchronous H-ARQ is preferred in UL
- No. of H-ARQ process and time interval b/w transmission and retransmission depends on duplexing mode and H-ARQ operation type.
- 2 types or H-ARQ operations in UL : **non-subframe bundling** (normal) and **subframe bundling** (4 H-ARQ retransmissions back to back, without waiting for ACK/NAK feedback)

FDD Mode and TDD Mode

- **FDD mode -** has 8 parallel-ARQ process in UL for non-subframe bundling operations.
  - Upon detection of a NAK in subframe n UE retransmits the corresponding PUSCH in subframe n+4.
  - 4 H-ARQ process for subframe bundling operation.
  - Upon detection of a NAK in subframe n-5, UE retransmits the corresponding PUSCH in subframe n+4.
- **TDD Mode –** no. of H-ARQ process is determined by the DL/UL configuration listed in table.
  - *Conf 1-6 and normal H-ARQ operation–* upon detection of a NAK in subframe n, UE retransmits in subframe n+k.
  - *Conf 0 and normal H-ARQ -* NAK in subframe n, UE retransmits in subframe n+7 or n+k.

FDD Mode and TDD Mode

- *Conf 1-6 with subframe bundling –* NAK in subframe n-l, UE retransmit s in bundle in subframe n+k.
- *Conf 0 with subframe bundling –* NAK in subframe n-l, UE retransmits n+7 or n+k.

Table 8.12 Number of Synchronous UL H-ARQ Processes for TDD

TDD UL/DL Configuration	Number of H-ARQ Processes for Normal H-ARQ Operation	Number of H-ARQ Processes for Subframe Bundling Operation
0	7	3
1	4	2
2	2	N/A
3	3	N/A
4	2	N/A
5	1	N/A
6	6	3

8. Explain briefly about the Random access procedures. 10M

8.5 Random Access Channels

- UL random access procedure is used during initial access or to re-establish UL synchronization – PRACH channels.
- random access channels carries random access preambles – consisting of CP of length ***Tcp*** and a sequence part of length ***Tseq.***
- ***Guard time GT –*** round trip propagation delay b/w UE & eNode-B.
- 5 different preamble formats defined in LTE.

Table 8.11 Parameters for Random Access Preamble

Preamble Format	Δf_{RA}	N_{ZC}	φ
0–3	1.25 kHz	839	7
4	7.5 kHz	139	2

8.5 Random Access Channels

- Format 0- normal cell.
- Format 1 – extended format, used for large cells.
- Format 2 & 3 – repeated preamble sequences to compensate for increased path loss, used for small and large cells.
- Format 4 – for frame structure type 2 only.

Table 8.10 Random Access Preamble Parameters

Preamble Format	T_{CP}	T_{SEQ}
0	$3168 \cdot T_s$	$24576 \cdot T_s$
1	$21024 \cdot T_s$	$24576 \cdot T_s$
2	$6240 \cdot T_s$	$2 \cdot 24576 \cdot T_s$
3	$21024 \cdot T_s$	$2 \cdot 24576 \cdot T_s$
4	$448 \cdot T_s$	$4096 \cdot T_s$

8.5 Random Access Channels

- Random access preambles are generated from **Zadoff-Chu sequences**, similar to reference signals.
- Network configures the set of preambles that the UE is allowed to use.
- In each cell there are 64 available preambles, which are generated from one or more root Zadoff-Chu sequences.
- Transmission of random access preamble is restricted to time and frequency resources.
- Frame structure type 1 with preamble format 0-3 – 1 random access resource per subframe.
- Frame structure type 2 with preamble format 0-4 – multiple random access resources.

8.5 Random Access Channels

- Signal for PRACH – **DFT of Zadoff-Chu sequence** is also a Zadoff-Chu sequence.

$$s(t) = \beta \sum_{k=0}^{N_{ZC}-1} \sum_{n=0}^{N_{ZC}-1} x_{u,v}(n) \cdot e^{-j\frac{2\pi nk}{N_{ZC}}} \cdot e^{j2\pi(k+\varphi+K(k_0+1/2))\Delta f_{RA}(t-T_{CP})}$$

where $0 \leq t \leq (T_{SEQ} + T_{CP})$ and:

- β is an amplitude scaling factor for power control;
- $x_{u,v}(n)$ is the uth root Zadoff-Chu sequence with cyclic shift v;
- φ is a fixed offset determining the frequency-domain location of the random preamble within the physical resource blocks, given in Table 8.11;
- $K = \Delta f / \Delta f_{RA}$ accounts for the difference in subcarrier spacing between the random access preamble and uplink data transmission;
- $k_0 = n_{PRB}^{RA} N_{sc}^{RB} - N_{RB}^{UL} N_{sc}^{RB}/2$ controls the random access preamble location in the frequency domain, with $0 \leq n_{PRB}^{RA} \leq (N_{RB}^{UL} - 6)$ as the physical resource block number configured by higher layers.