04830241 – Computer Network Practicum

Cross layer analysis over LTE and WLAN networks

LTE Tutorial for Lab 1

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What is LTE

- LTE stands for “Long Term Evolution”
- Fourth-generation (4G) cellular technology from 3GPP
- Deployed worldwide

- 4G LTE
  - Increased speed
  - High peak data rate
  - Low end-user latency
  - Mobility: 350 km/h
  - New air interface:
    - OFDMA (Orthogonal Frequency-Division Multiple Access),
    - MIMO (multiple antennas)
  - …


In-building


Driving


Outdoor

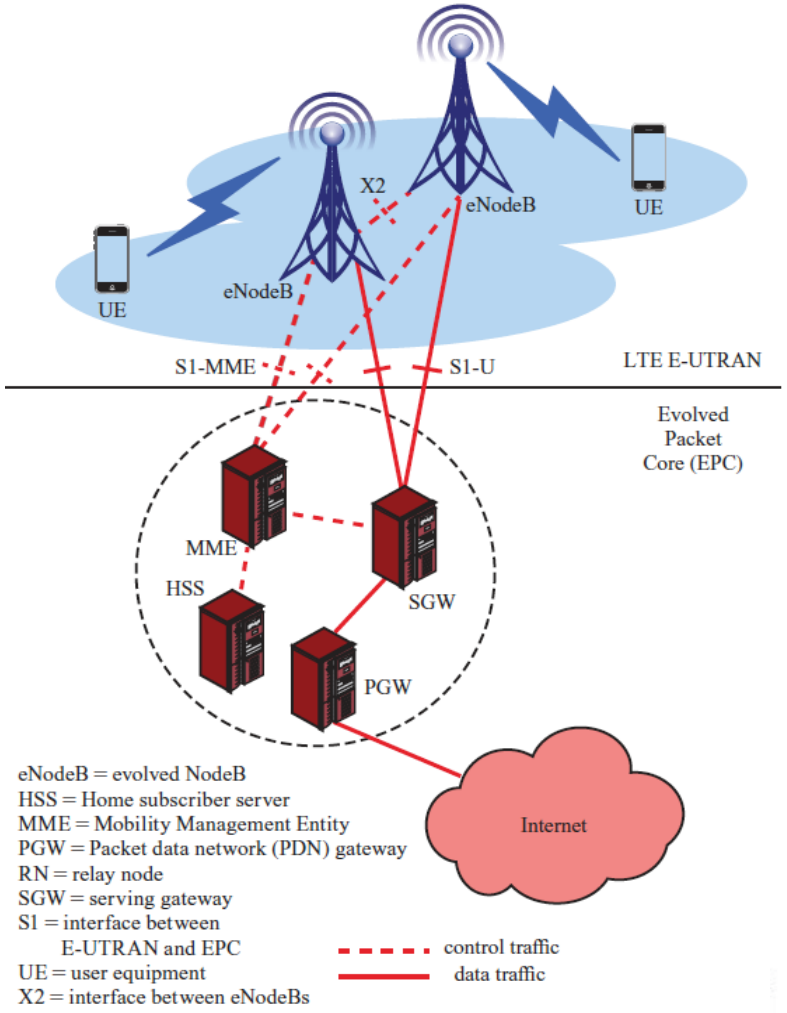

Subway


Walking


High-speed train

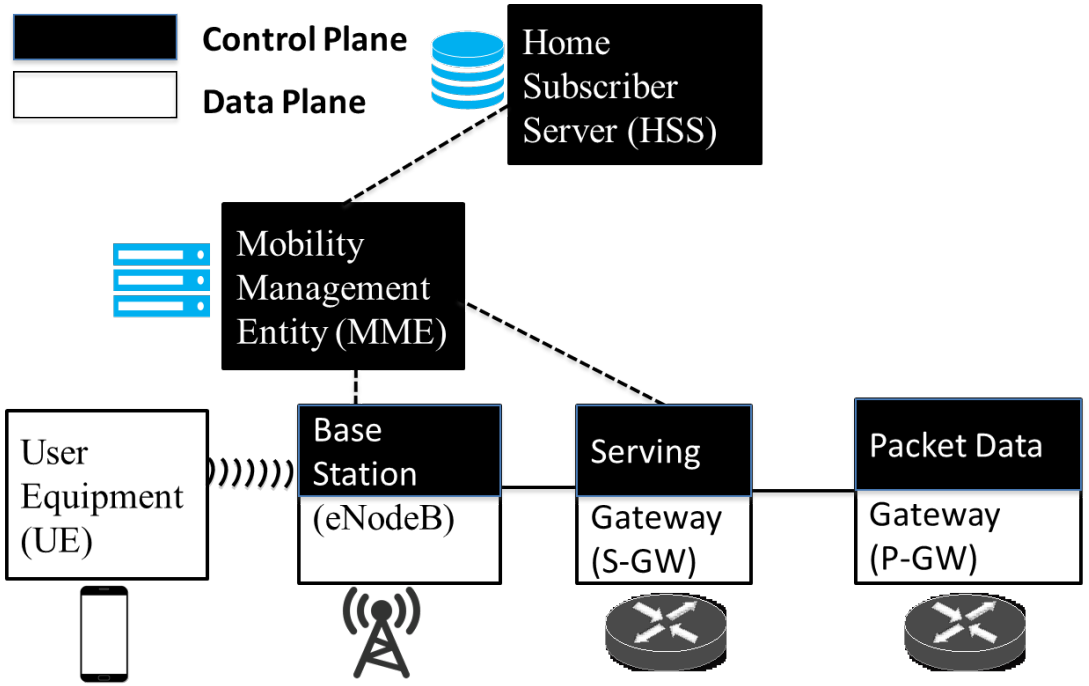
LTE Infrastructure

- User Equipment (UE)
  - Mobile device holding information including
    - phone number, home network identity and security keys etc.
- Evolved UMTS Terrestrial Radio Access Network (E-UTRAN)
  - Relays data between UE and core network
  - Embedded its own control functionalities
    - radio resource control
    - admission control
    - mobility management
- Evolved Packet Core (EPC)
  - Operator/Carrier core network that interconnects all of the eNodeBs



Evolved Packet Core

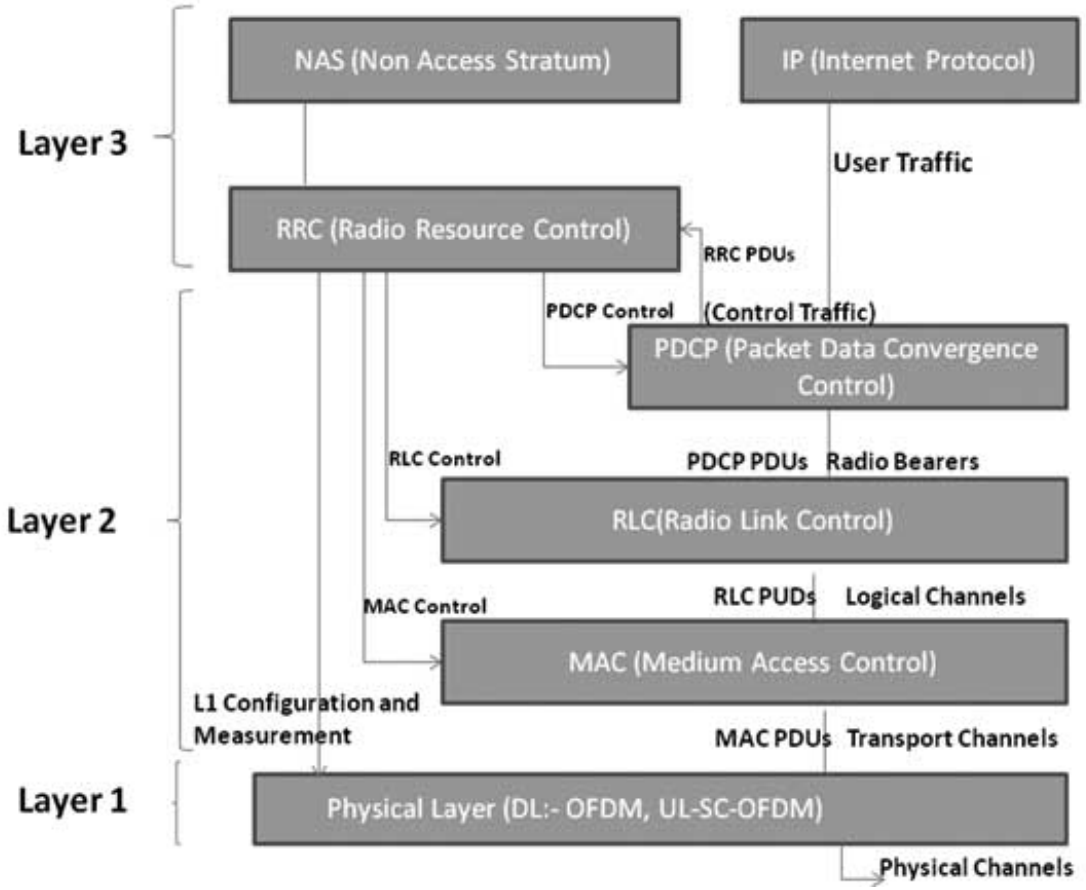
- Mobility Management Entity (MME)
  - Manages control signaling related to UE mobility and security
  - Interacts with home subscriber servers for authentication, and negotiation of security algorithms
- Serving Gateway (SGW)
  - Receives and sends packets between the eNodeB and the core network
  - Serves as mobility anchor when UE moves
- Packet Data Network (PDN) Gateway (PGW)
  - Connects the EPC with external networks
  - IP services, address allocation
  - Deep packet inspection, policy enforcement
- Home Subscriber Server (HSS)
  - Database of user-related and subscriber-related information



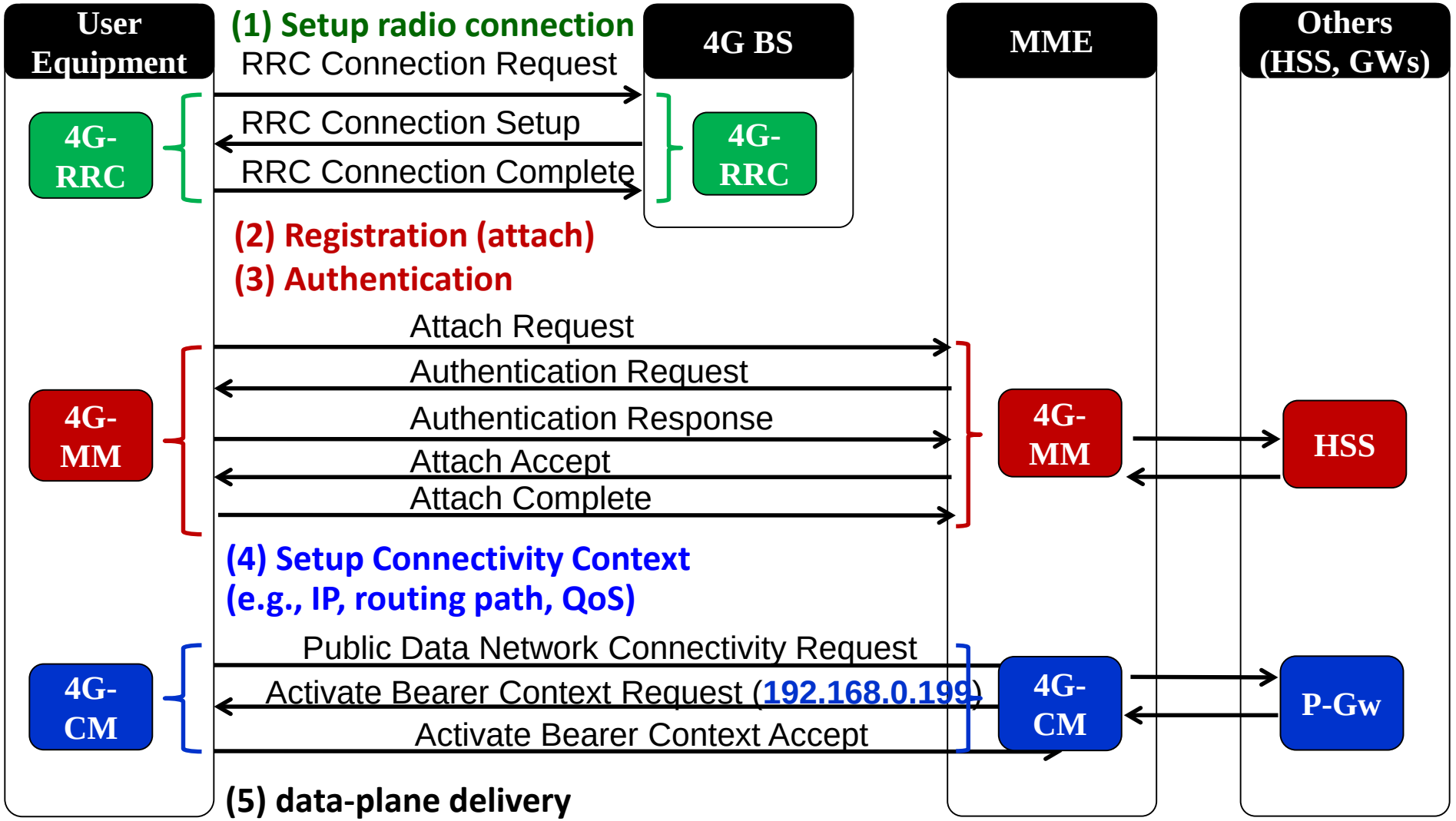
LTE Protocols Stack Layers

- Radio Resource Control (RRC)
  - Broadcast system information
  - RRC connection management
    - establishment, maintenance and release
  - Security functions
  - Release of point to point Radio Bearers
  - Paging

- Non Access Stratum (NAS) Protocols
  - Support the mobility of the UE
  - Session management procedures
    - establish and maintain IP connectivity between the UE and a PDN GW

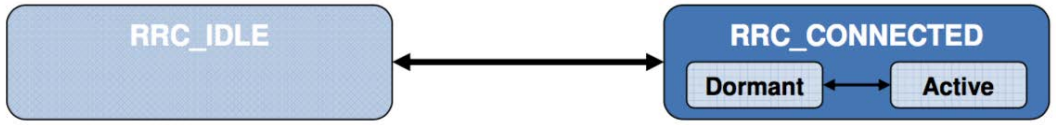


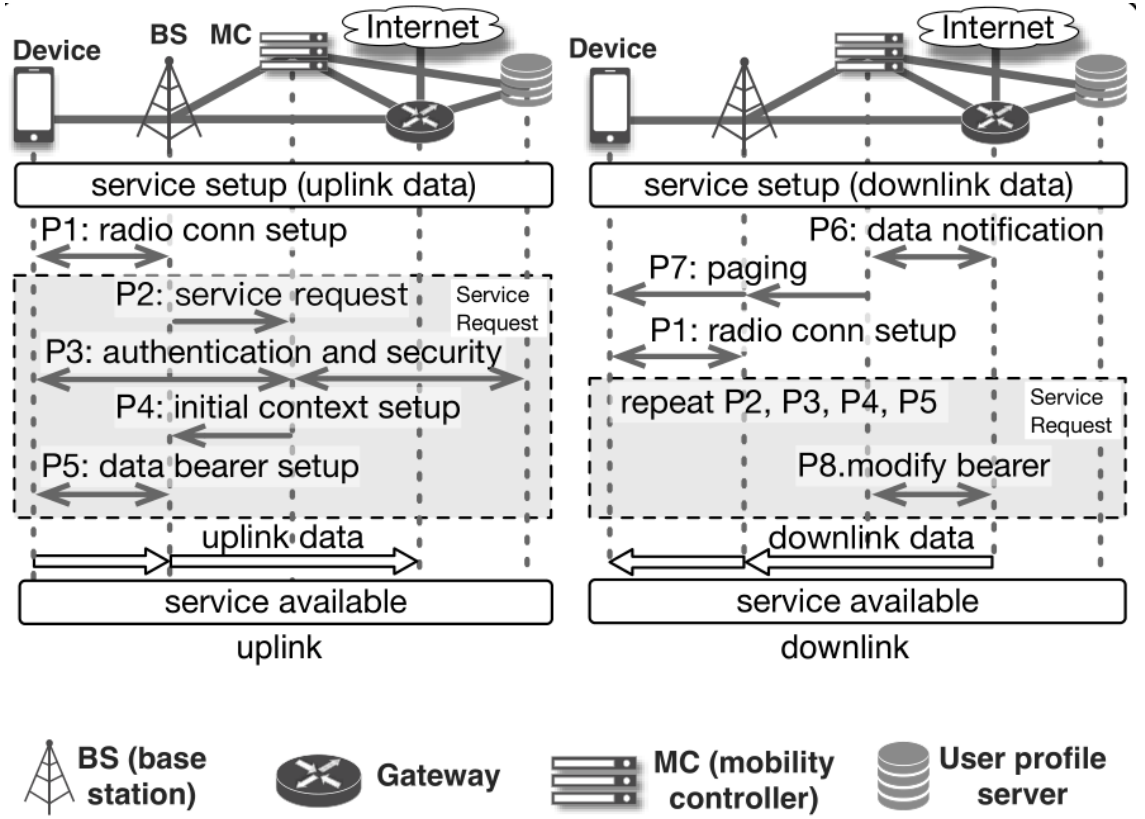
Setting Up Data Service in 4G



Service Establishment

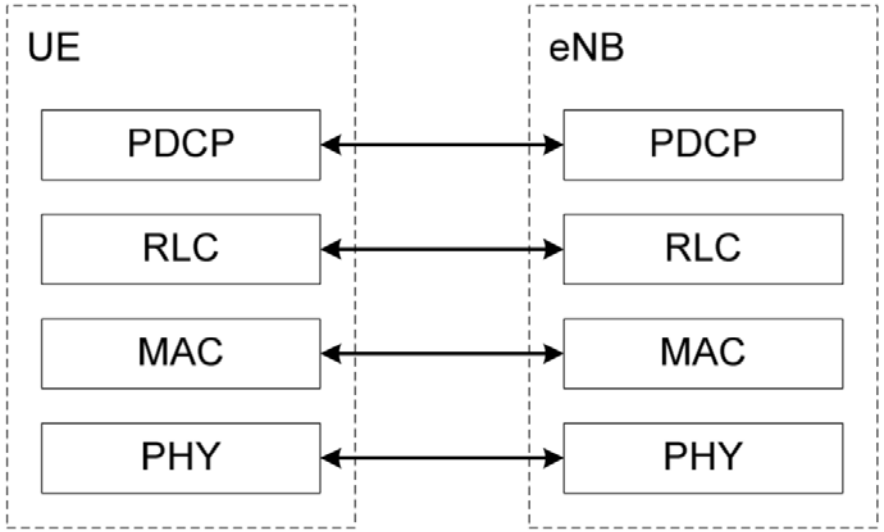
- **RRC_CONNECTED**
  - UE known in EPC and E-UTRAN/eNB;
  - Mobility is UE-assisted, network-controlled
  - Unicast data transfer possible
- **RRC_IDLE**
  - The Idle mode minimized battery consumption
  - UE known in EPC and has IP address;
  - UE not known in E-UTRAN/eNB;
  - Unicast data transfer not possible;





User plane protocol stack

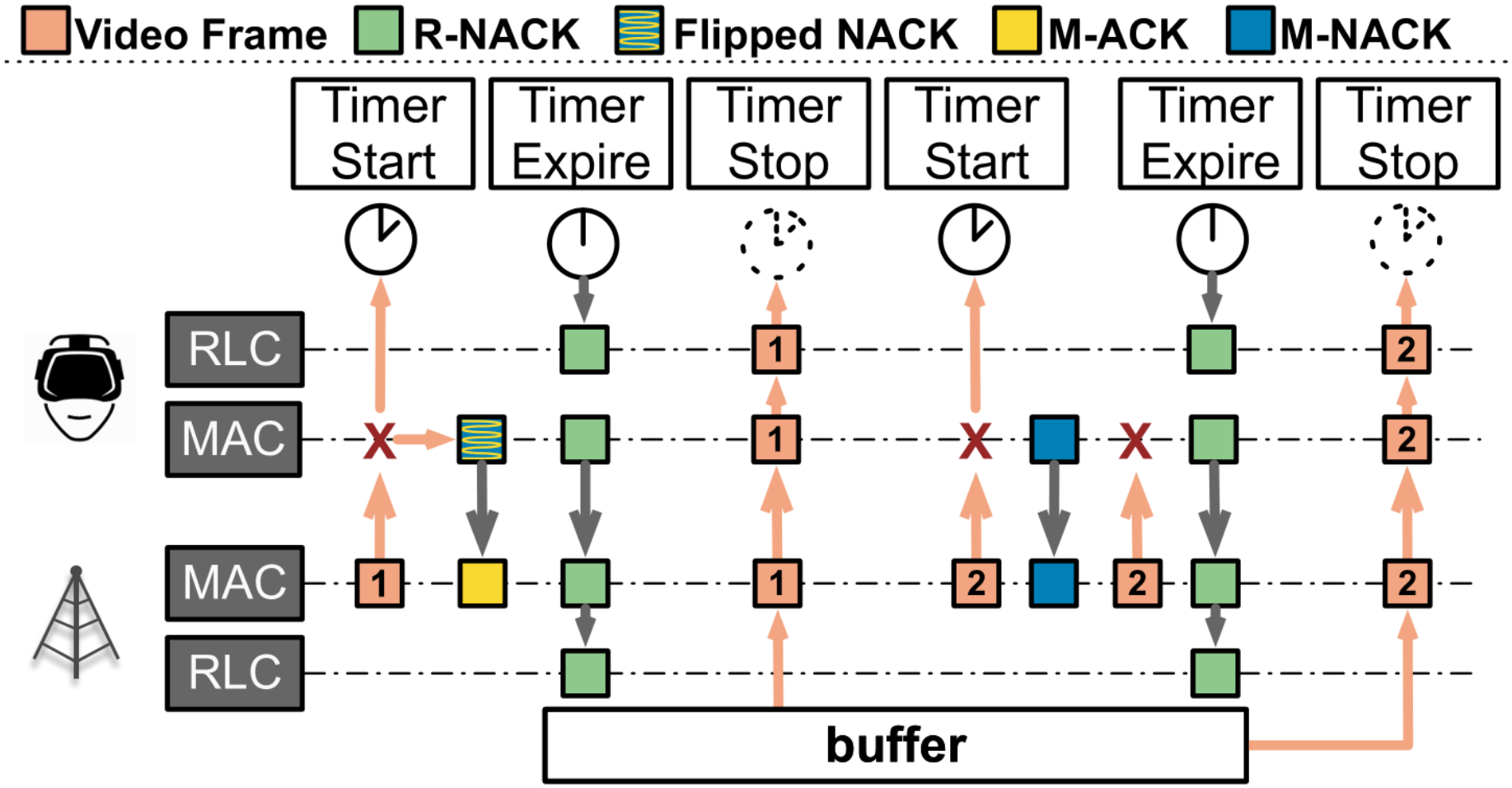
- PDCP (Packet Data Convergence Protocol) – TS 36.323
  - Ciphering and Integrity protection
  - In-sequence delivery and retransmission of PDCP SDUs for AM Radio Bearers at handover
  - Duplicate detection
  - Header compression using
- RLC (Radio Link Control) – TS 36.322
  - Error Correction through ARQ
  - (re)-Segmentation according to the size of the TB
  - Concatenation of SDUs for the same radio bearer
  - In-sequence delivery
- MAC (Media Access Control) – TS 36.321
  - Multiplexing/demultiplexing of RLC PDUs
  - Scheduling Information reporting
  - Error correction through HARQ
  - Logical Channel Prioritization



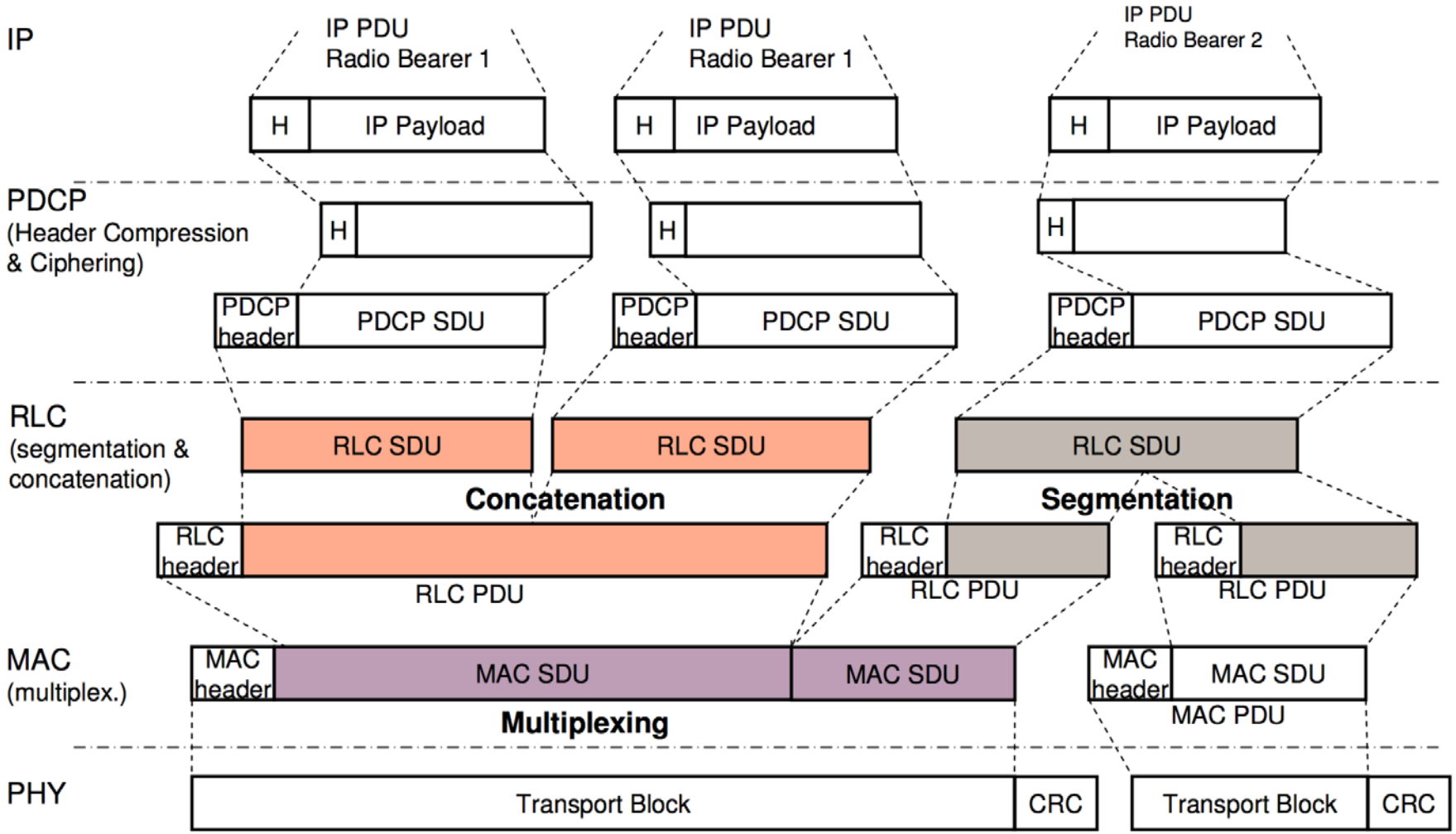
Reliable Transport – Retransmission Protocols

- L1 applies 24 bit CRC protection to transport blocks (MAC PDUs)
  - Erroneous transport blocks are discarded on L1
- Hybrid ARQ (HARQ) in MAC complemented by ARQ in RLC
  - High reliability and radio efficiency
  - HARQ feedback sent on L1/L2 control channel
    - Single, un-coded bit (low overhead)
    - Sent for each scheduled subframe (fast)
    - Retransmissions are soft-combined with previous attempt (efficient)
  - ARQ status report sent as MAC data
    - RLC Status is sent on demand (poll, timer, gap detection)
    - Protected by CRC and HARQ retransmissions
- Both HARQ and ARQ protocols operate between the eNB and UE
  - Fast handling of residual HARQ errors
- Ensures low latency and high reliability

LTE's Two-Tier Retransmissions

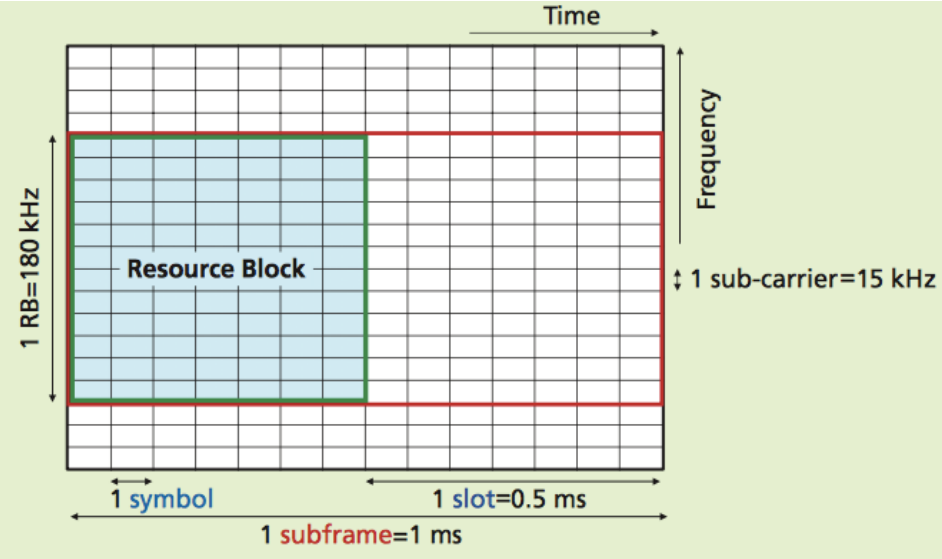


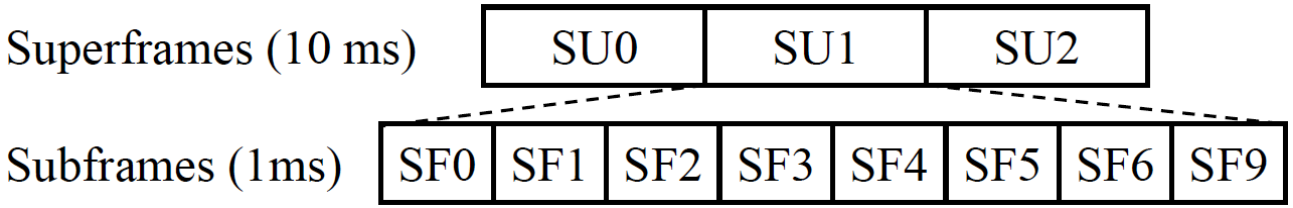
User Plane Data Flow (transmitter)



LTE Resource Allocation

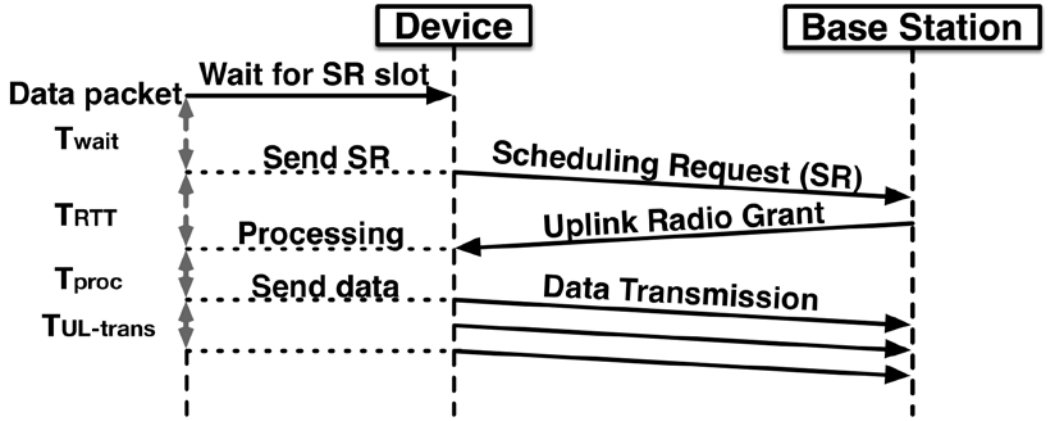
- Time slot: 0.5 ms – 6 or 7 OFDM symbols
- Subcarriers: 15 kHz
- Physical Resource Block: 12 sub carriers (180 kHz) over 1 time slot
- Minimum allocation: 2 PRB per subframe
- Subframe = 2 slots of 0.5 ms each

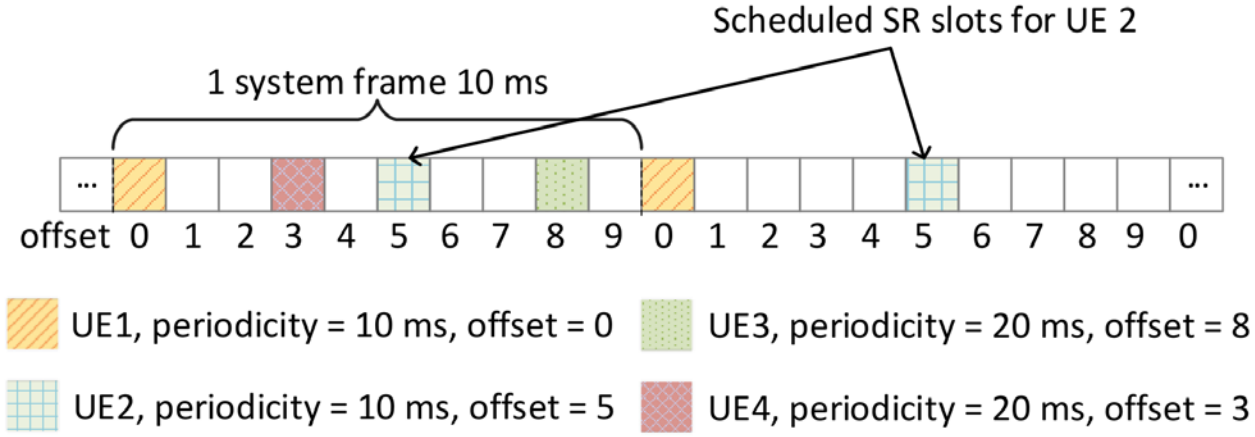




Uplink Latency

- Device first requests radio grants
  - sends a scheduling request (SR)
- LTE scheduling and periodic SR prefer channel utilization over latency
- Uplink control channel shares the underlying physical resource with the data channel
- Base station pre-allocates periodic physical-layer slots for each device to send SR



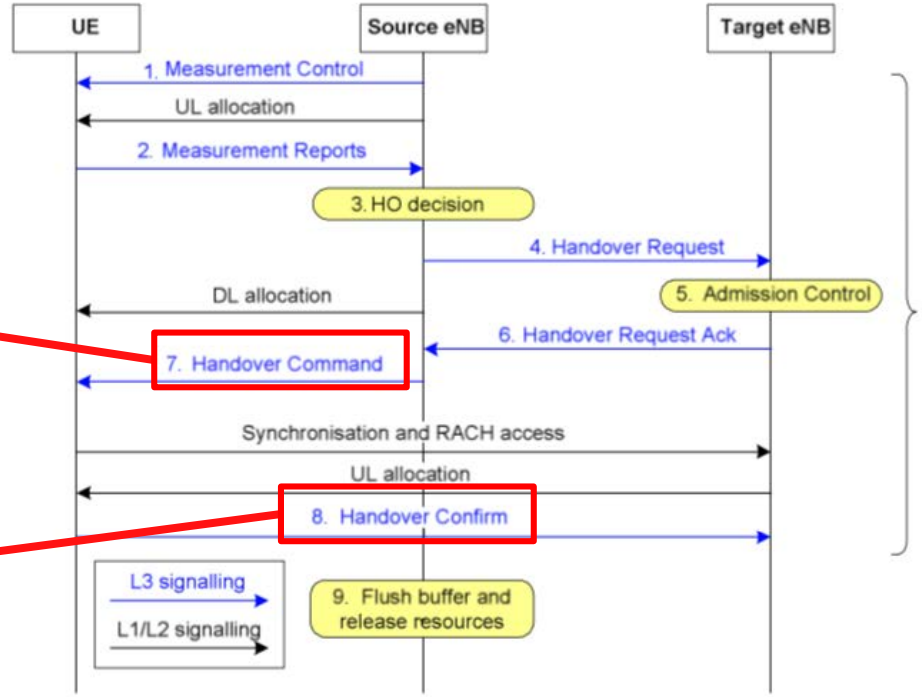


Handoff/handover

- Network-controlled/UE-assisted mobility.
- Handover related information is exchanged via the old radio path.
- Data forwarding and in-order delivery.
  - Ensures that none of the data buffered in the source eNB is lost.

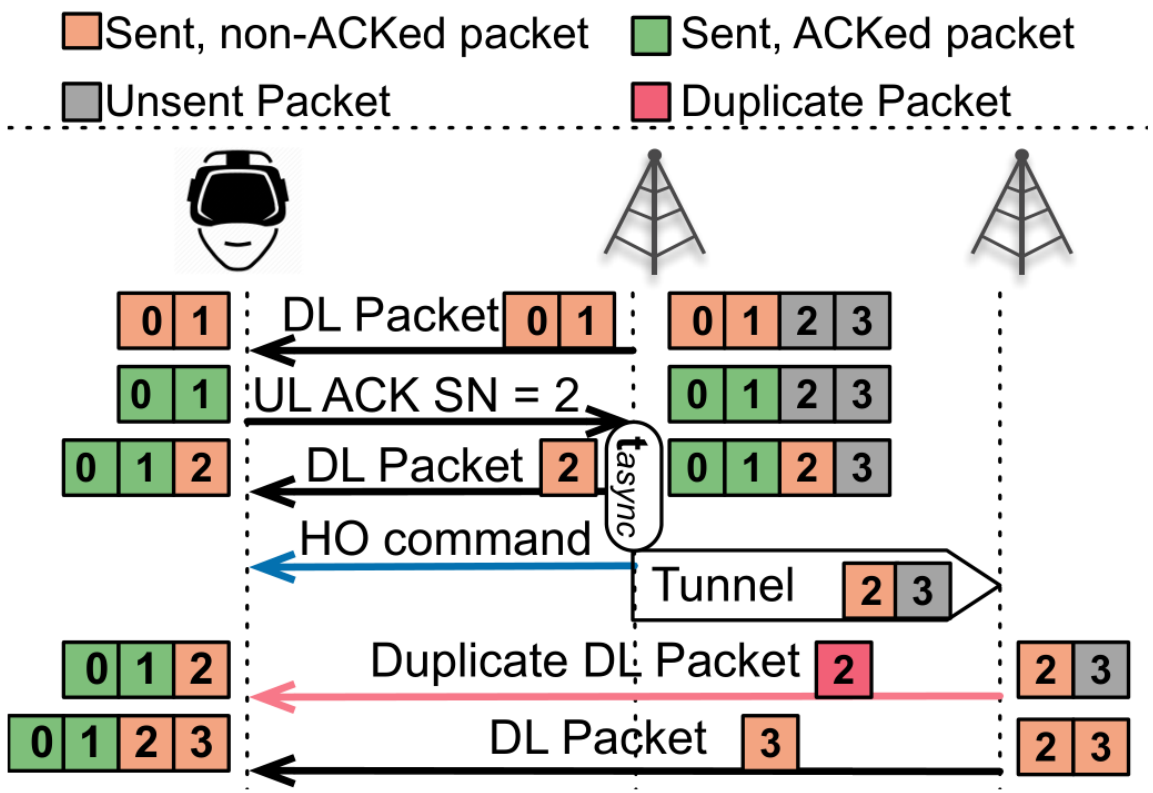
RRC Connection Reconfiguration message including the mobilityControlInfo

RRC Connection Reconfiguration Complete message



Head-of-Line (HOL) Blocking

- RLC incurs duplicate packets
- Before the handover
  - received some DL packets from the old BS
  - does not immediately respond with R-ACKs
- BS tunnels these packets to the new BS
- After the handover
  - the new BS retransmits the duplicates



Reference

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