INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

4TC-Architectures de Réseaux Mobiles
Mobile Network Architectures

Part 3 – Universal Mobile Telecommunications Systems

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Outline

- Evolution from GSM to UMTS
- UMTS architecture
- UTRAN access network
- UMTS core network
- Radio protocols
- Call and mobility management

Evolution

- 2G networks designed for voice only
- Circuit switched approach, inherited from landline telephony
- In parallel, the huge success of *www*
- A market for mobile Internet access

Evolution

- 2G+ solutions initially proposed: GPRS, EDGE
- Up to 171 kb/s for GPRS and 384 kb/s for EDGE
- More than enough for basic web browsing
- But not to cope with the success of multimedia applications

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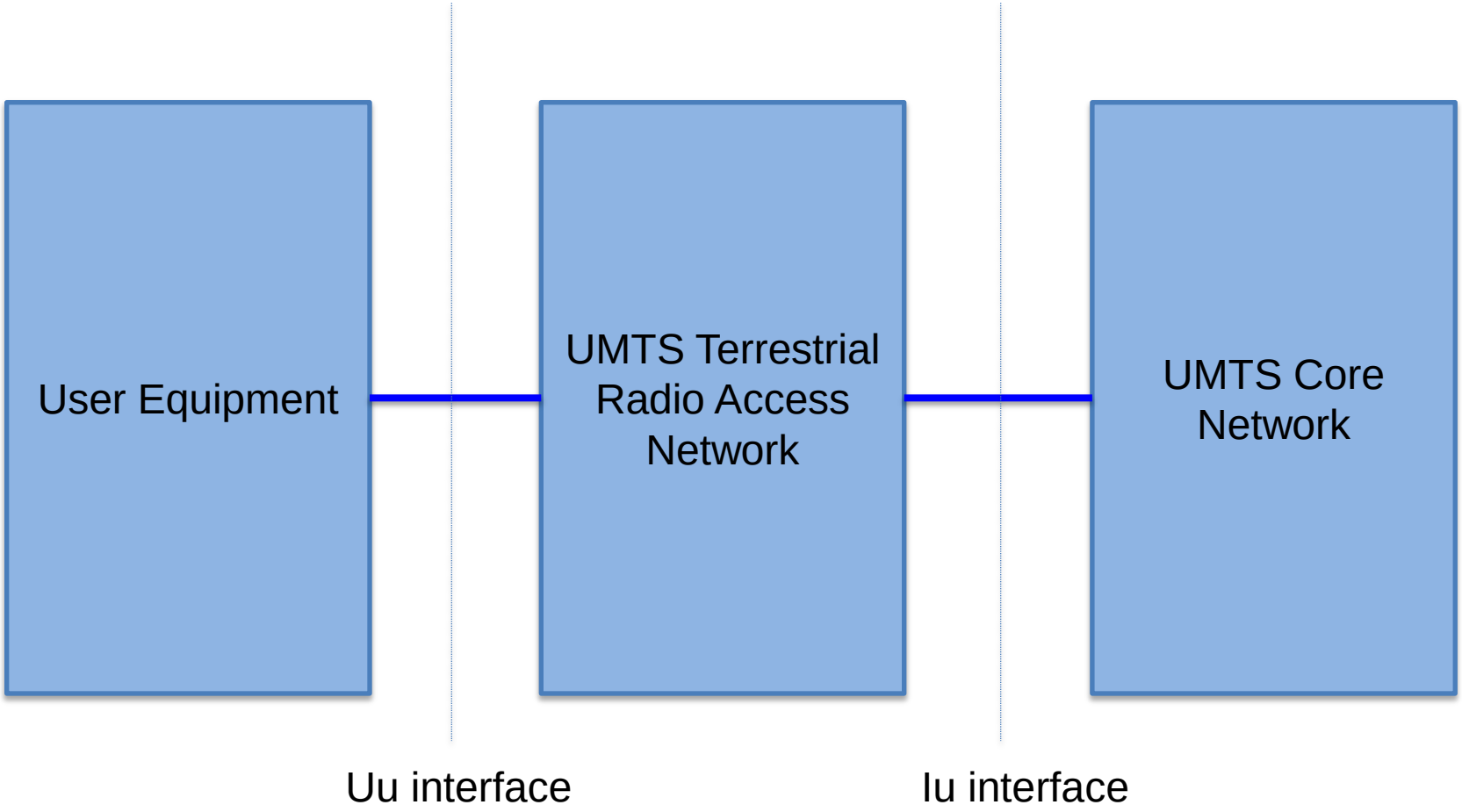
- UMTS: up to 2 Mb/s

UMTS

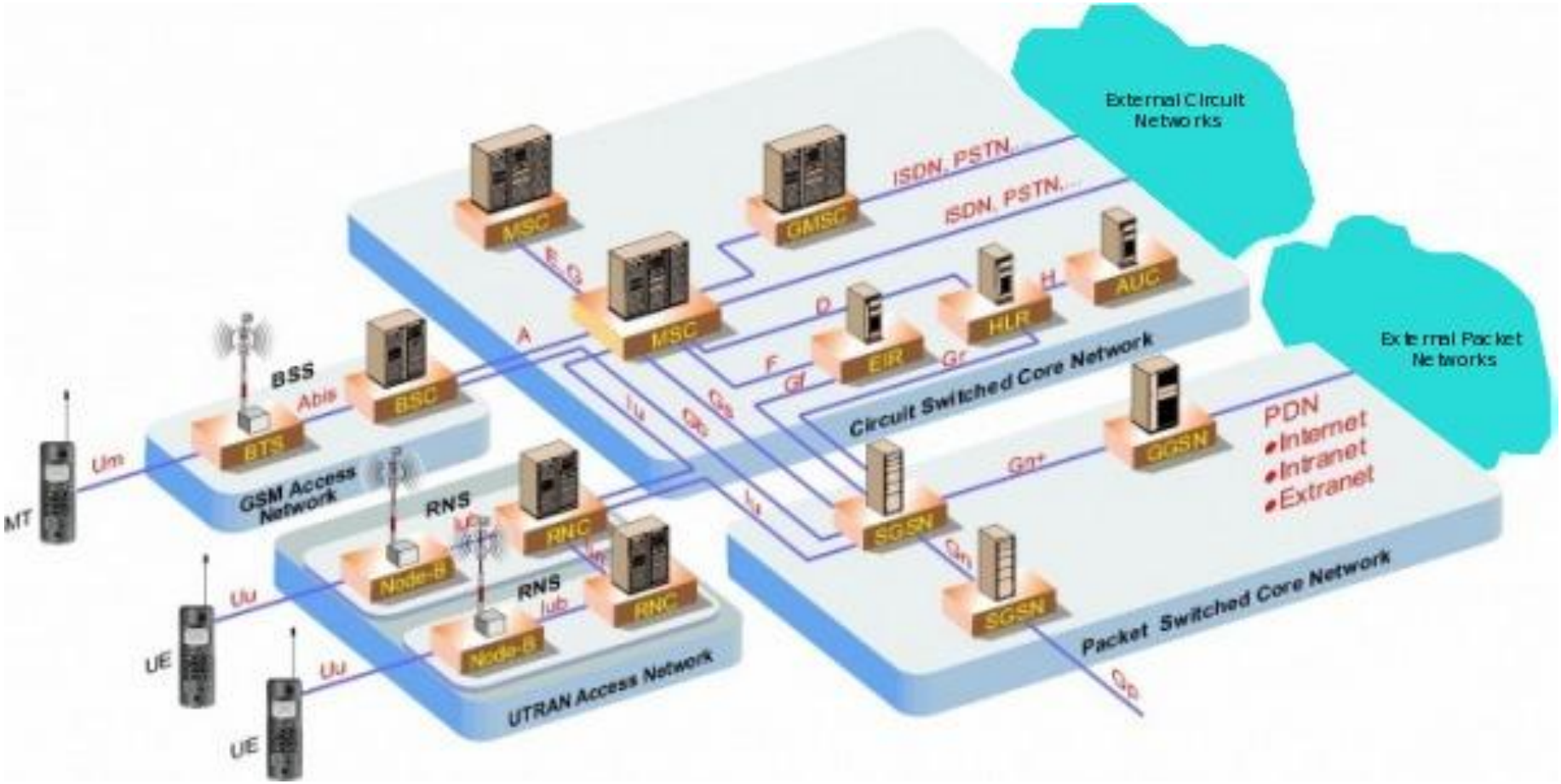
- Universal Mobile Telecommunications System
- One of the technologies submitted, and approved, to the ITU in the context of the IMT-2000 framework
- Worldwide deployment, especially in Europe, Asia and South America

UMTS architecture

- Basic architecture



UMTS architecture



UMTS architecture

- User Equipment (UE) domain
  - Terminal: phones, but also new types of hardware
  - Universal Subscriber Identity Module (USIM)

- USIM
  - Evolution of the SIM concept
  - Distinction between the hardware and the software part
  - USIM represents only the software part

UMTS architecture

- Information stored in the USIM
  - International Mobile Subscriber Identity – IMSI
  - Mobile Station International Subscriber Directory Number – MSISDN
  - Encryption keys
  - Available service list and corresponding providers
  - Operator applications
  - Personal settings

UMTS architecture

- The *bearer* concept
  - An abstraction of layer 2 services proposed to the UE
  - Each bearer has an associated number of parameters, defining a certain Quality of Service (QoS)
  - Example of parameters: bit rate, transfer delay, bit-error rate, etc.
  - The parameters are negotiated at the bearer set-up and can be used for access control

UMTS architecture

- The *stratum* concept
  - Clear separation between access and core network operations from the UE perspective
- The access stratum
  - A set of protocols and functions enabling the dialogue with the access network
- The non-access stratum
  - A set of protocols and functions enabling the dialogue between the UE and the core network

UMTS architecture

- Different stratum functions

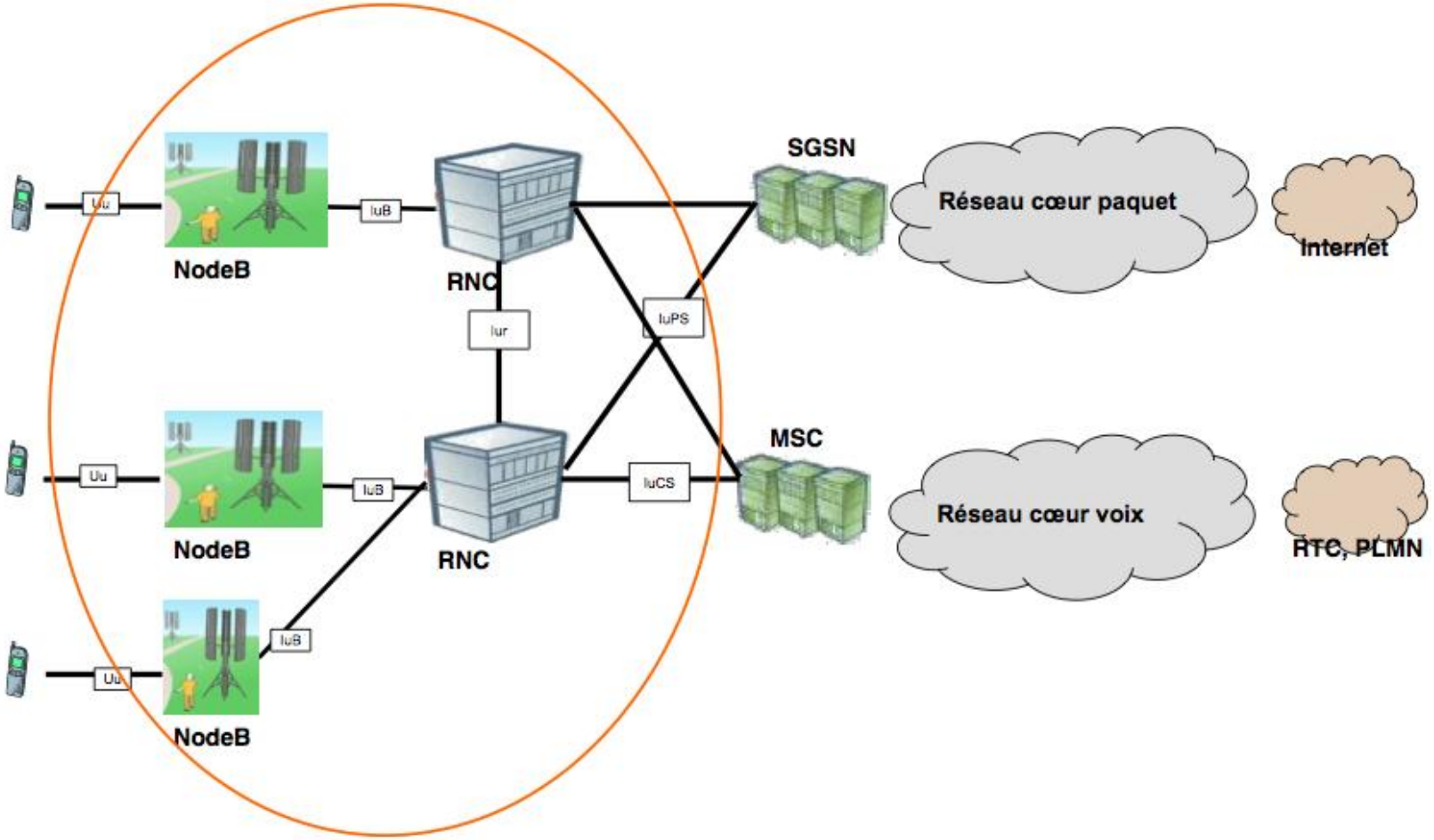
Function	Non-Access Stratum	Access Stratum
Call Control	Yes	No
Bearer Service	Yes (activation)	Yes (realization)
Supplementary Services	Yes	No
Mobility Management	Yes	Yes
Attachment/Detachment	Yes	No
Handover	Yes (bearer reallocation)	Yes
Ciphering	Yes (activation)	Yes (execution)
Authentication	Yes	No
Voice and video coding	Yes	No
Radio channel coding	No	Yes
Location based services	Yes (handling)	Yes (position estimation)
Charging	Yes	No

UTRAN

- Universal Terrestrial Radio Access Network – UTRAN
  - Responsible for the control and handling of radio resources
  - Allows data and signaling traffic exchange between the UE and the core network
  - Allocation and withdrawal of radio bearers
  - Functionalities related to mobility management and network access

UTRAN

- UTRAN architecture



UTRAN

- Node B
  - The evolution of the GSM BTS
  - Controls the physical layer parameters (coding, modulation)
  - Error control
  - Manages power control on the UE side
  - Receives feed-back from the UE for its own power control

UTRAN

- Radio Network Controller - RNC
  - Controls and handles radio resource through the Radio Resource Control (RRC) protocol
  - Connected to one or more Node B
  - Handles Node B load and congestion control
  - Access control
  - Handover control
  - Data transmission scheduling (in packet transfer mode)

UTRAN

- Definition of new interfaces
  - Uu – between UE and UTRAN, equivalent to Um in GSM
  - Iu – between UTRAN and CN, divided in Iu-CS for circuit networks (A in GSM) and Iu-PS for packet networks (Gb in GPRS)
  - Iub – between Node B and RNC, equivalent to Abis in GSM
  - Iur – between RNC and RNC, with no equivalent in GSM

UTRAN

- Differences with respect to the GSM access network
  - Use of Code Division Multiple Access – CDMA, based on spread spectrum and allowing multiple UEs to transmit simultaneously on the same band, using different codes
  - Use of Asynchronous Transfer Mode (ATM) on the Iu, Iub and Iur interfaces, particularly adapted to QoS in networks with variable bit rate
  - Handling of UE mobility in the UTRAN, with efficient radio management through the Iur interface

UTRAN

- Types of RNC from the UE perspective
  - Controlling RNC (CRNC) – the RNC handling the resources of the Node B that covers the UE
  - Serving RNC (SRNC) – the RNC handling the radio resources of a UE (generally, a CRNC also becomes a SRNC when the UE connects to the CN)
  - Drift RNC (DRNC) – an RNC connected to the SRNC through the Iur interface, and involved in the connection between the UE and the UTRAN (e.g. in a soft handover scenario)

UTRAN

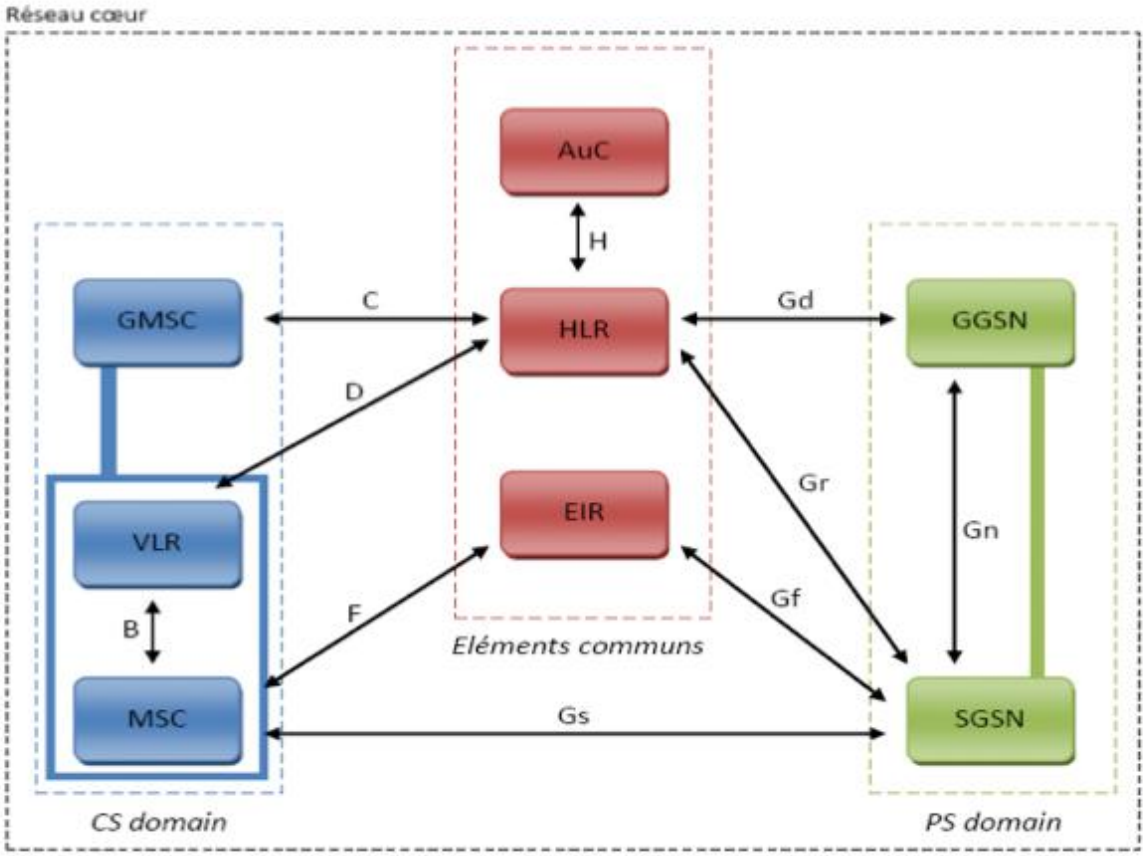
- UE temporary identifiers in the UTRAN
  - Should not be confused with the temporary identifiers allocated to the UE by the CN for security purposes (TMSI, P-TMSI)
  - Known as Radio Network Temporary Identifiers (RNTI)
  - S-RNTI (Serving RNC RNTI) – allocated by the SRNC during the connection procedure
  - D-RNTI (Drift RNC RNTI) – identifier used for the UE by the DRNC, never communicated to the UE
  - C-RNTI (Cell RNTI) – allocated by the CRNC to a UE entering a new cell under its control
  - U-RNTI (UTRAN RNTI) – used to identify the UE globally in the UTRAN, composed of the SRNC identifier and the S-RNTI

UMTS Core Network

- UMTS Core Network - CN
  - Enables communication between users within a mobile network
  - Provides inter-connection to other networks, fixed or mobile
  - Divided in a circuit-switched (CS) domain and a packet-switched (PS) domain
  - Practically, the combination of the GSM NSS and the GPRS backbone (pragmatic choice from the operators)

UMTS Core Network

- CN architecture



UMTS Core Network

- A reminder of the CN components – CS domain
  - Mobile-services Switching Center (MSC) – manages UE registration and mobility, validates call connection requests
  - Visitor Location Register (VLR) – database covering a Location Area (LA), and storing UE information when within the LA
  - Gateway MSC (GMSC) – a MSC routing a UE call to the MSC currently serving the UE

UMTS Core Network

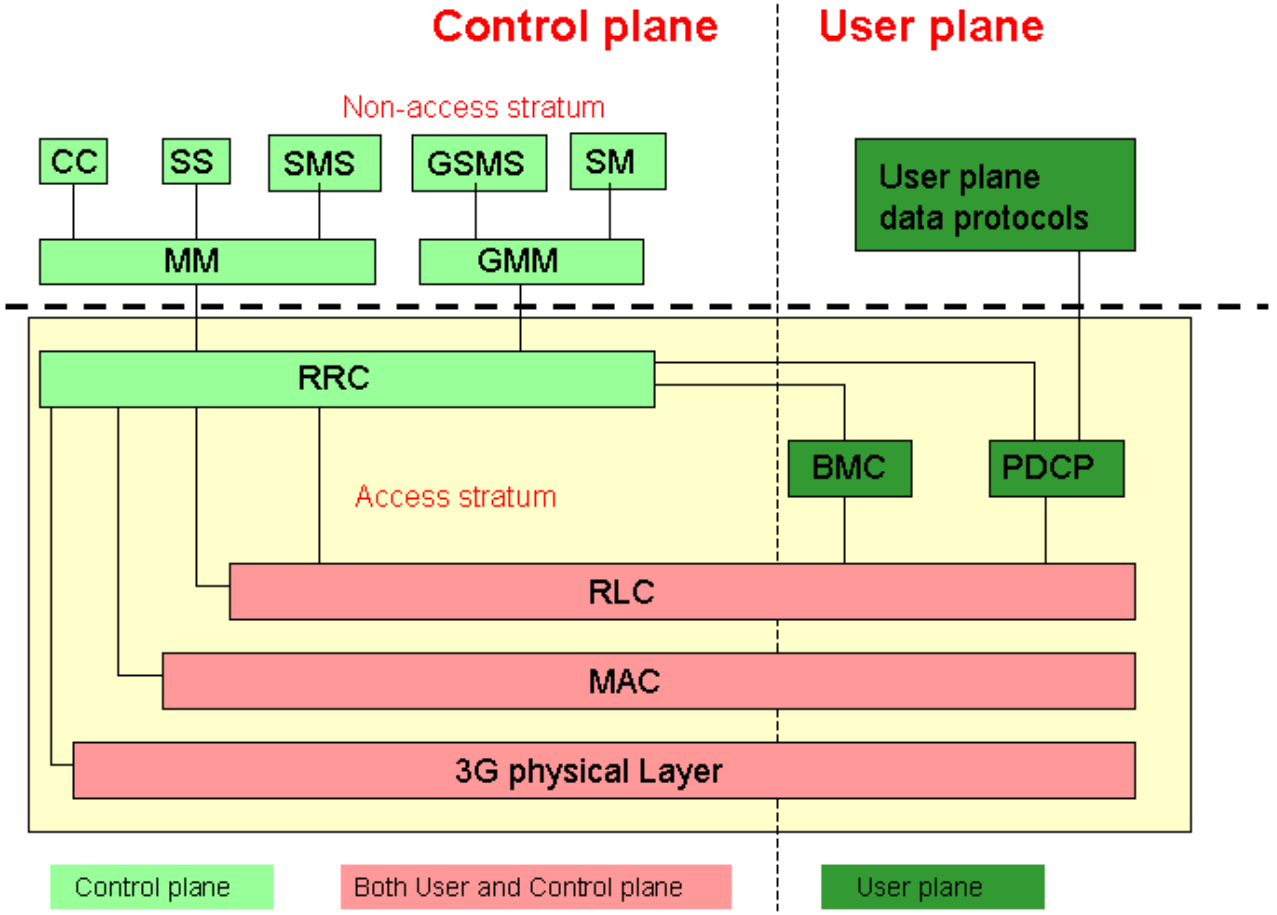
- A reminder of the CN components – shared elements
  - Home Location Register (HLR) – the database containing all the UE information for a given operator, for both CS and PS domains
  - Equipment Identity Register (EIR) – a database used to prevent call service from stolen, unauthorized or faulty terminals
  - Authentication Center (AuC) – protected database storing a copy of the secret keys stored in the USIMs

UMTS Core Network

- A reminder of the CN components – PS domain
  - Serving GPRS Support Node (SGSN) – handles the packet connection of all the UEs in a given Routing Area (RA), as well as security, charging and mobility management function
  - Gateway GPRS Support Node (GGSN) – the logical interface to a particular external packet data network, handling packet conversion from the SGSN format in the external network format

Access Stratum Protocols

- User plane and control plane protocols



Access Stratum Protocols

- Physical layer
  - Provides transport service to the MAC layer (through the transport channels)
  - Multiplexing of transport channels on one or several physical channels
  - Channel coding/decoding for error detection and correction
  - Modulation and spreading of physical channels
  - Frequency and time synchronization
  - Closed loop and power control

Access Stratum Protocols

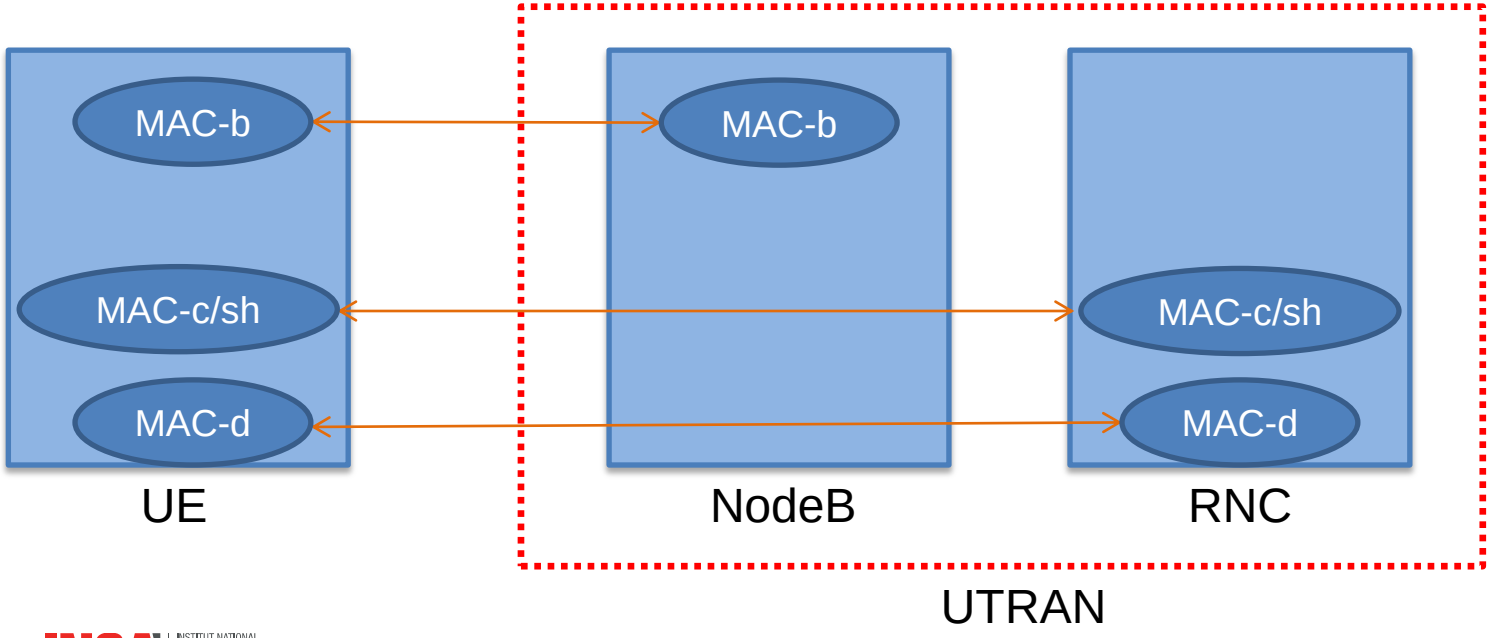
- MAC layer
  - Mapping of logical channels on transport channels
  - Priority handling between different data flows of one user
  - Scheduling of traffic from different users on common and shared channels
  - Ciphering and deciphering of data on the radio link
  - Identification of UEs on common transport channels

Access Stratum Protocols

- MAC layer – transport channel switching
  - MAC measures the state of transmission and retransmission buffers
  - Measurements transmitted to RRC, periodically or upon threshold detection
  - RRC can decide on radio resource reconfiguration
  - MAC, based on RRC request, can change the mapping of logical and transport channels
  - For example, a DTCH logical channel can be mapped ob the DCH at the beginning of an Internet connection, but switched to a RACH after a period of inactivity

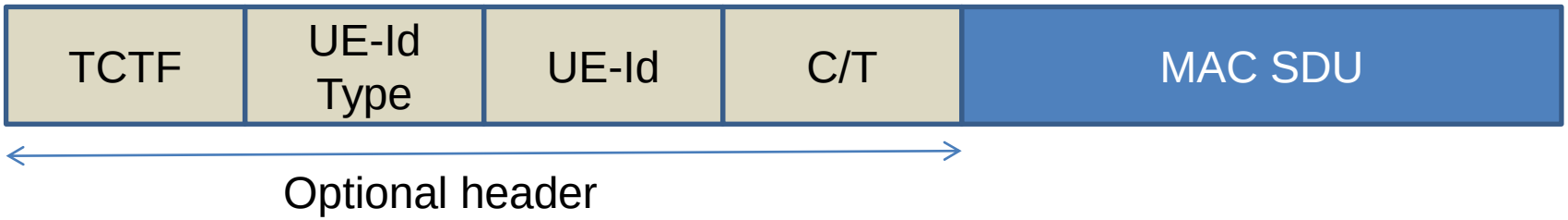
Access Stratum Protocols

- MAC layer entities
  - Based on the transport channels they can access
  - MAC-b – handles the functioning on the BCH
  - MAC-c/sh – handles the functioning on PCH, FACH, RACH, CPCH, DSCH
  - MAC–d – handles the functioning on the DCH



Access Stratum Protocols

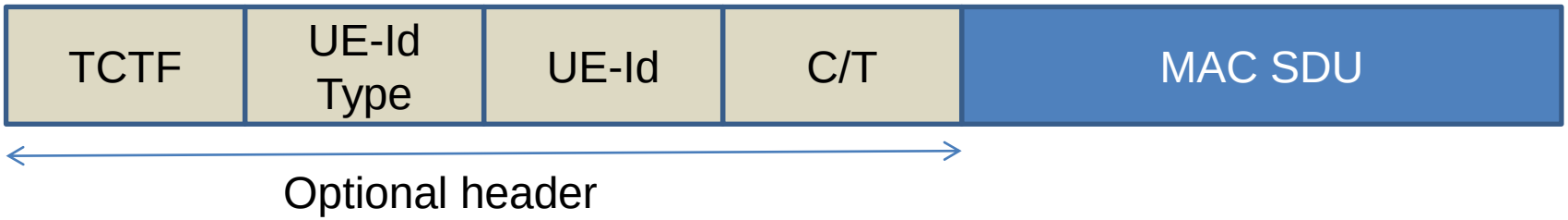
- MAC Protocol Data Unit
  - Optional fields, depending on the type of transport channel used for transmission



  - C/T – Control/Traffic
  - 4 bits
  - Indicates whether the message transports control or user traffic
  - In reality, it identifies the instance of the logical channel to which the MAC SDU is destined

Access Stratum Protocols

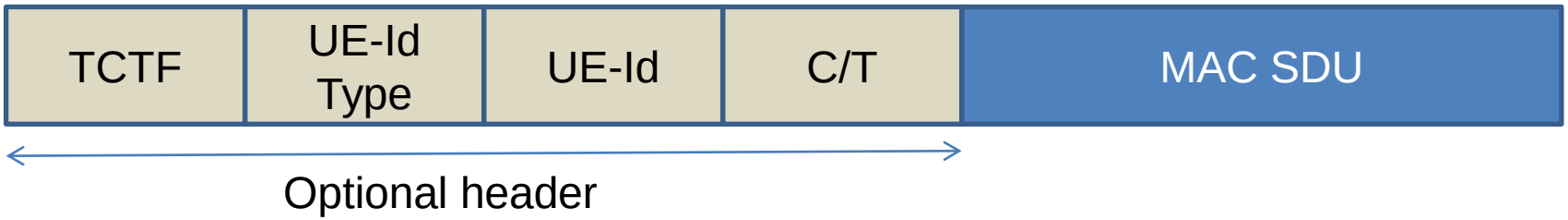
- MAC Protocol Data Unit
  - Optional fields, depending on the type of transport channel used for transmission



  - UE-Id – user identity on a common transport channel
  - Three possible identifiers
  - C-RNTI (16 bits)
  - U-RNTI (32 bits)
  - DSCH-RNTI (16 bits)

Access Stratum Protocols

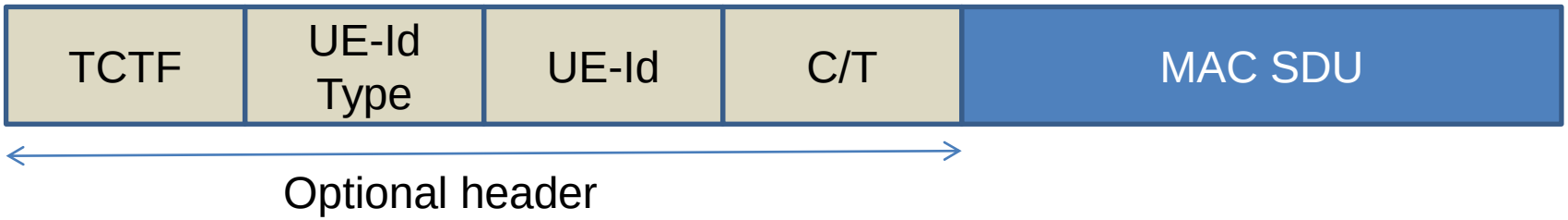
- MAC Protocol Data Unit
  - Optional fields, depending on the type of transport channel used for transmission



  - UE-Id Type – indicates the type of identifier
  - Makes the decoding of UE-Id possible

Access Stratum Protocols

- MAC Protocol Data Unit
  - Optional fields, depending on the type of transport channel used for transmission



  - TCTF – Target Channel Type Field
  - Used to identify the logical channel transported on RACH and FACH
  - One identifier for each common channel, a unique identifier for all dedicated traffic channels
  - C/T used in order to distinguish between multiplexed dedicated channels

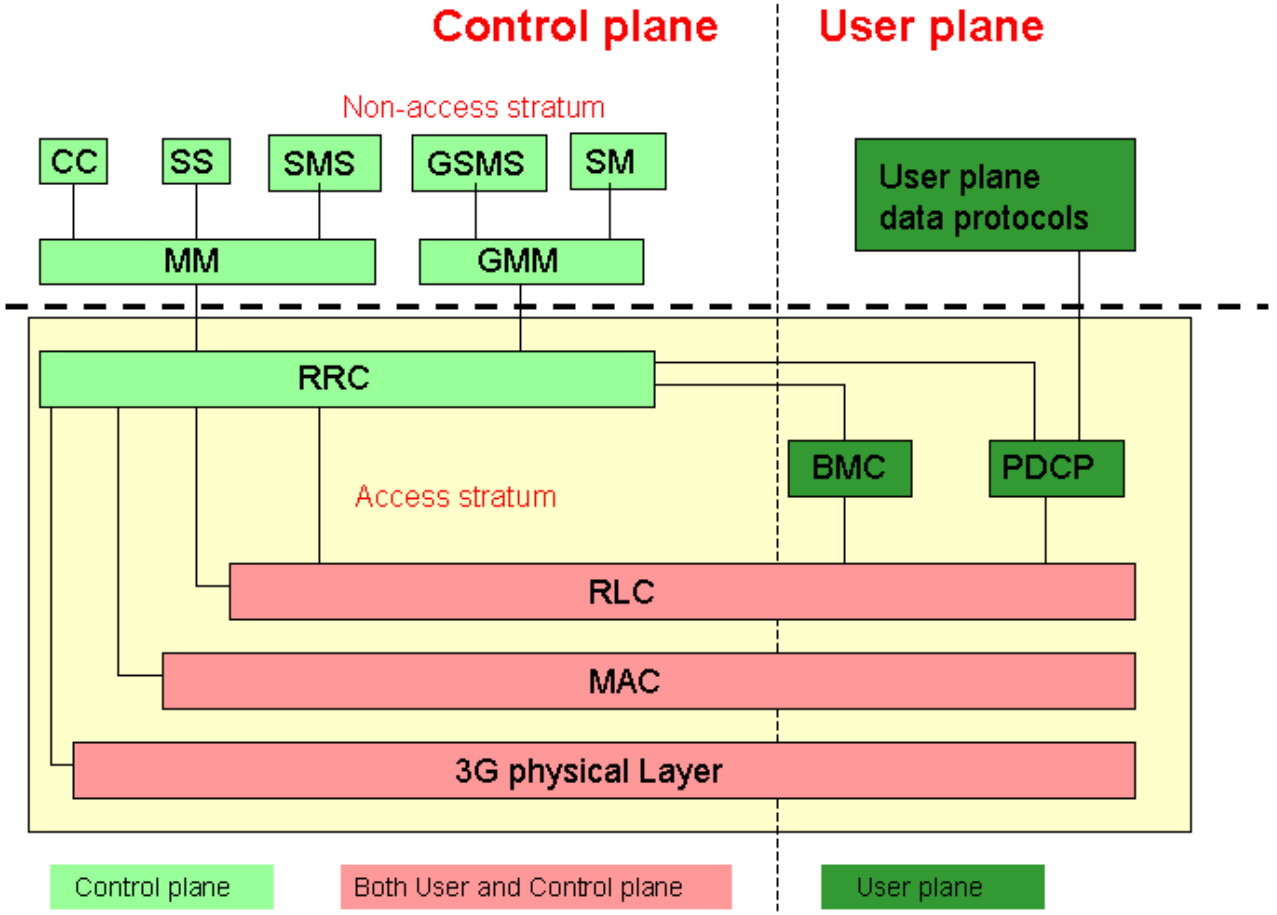
Access Stratum Protocols

- MAC Protocol Data Unit
  - Optional fields, depending on the type of transport channel used for transmission

Header Option	**Control Traffic**				**Data Traffic**	
	BCH	PCH	FACH	RACH	DCH	RACH/ FACH
TCTF	No	No	Yes	Yes	If multiplexing	Yes
UE-Id and UE-Id Type	No	No	No	No	No	Yes
C/T	No	No	Yes	Yes	No	Yes

Access Stratum Protocols

- User plane and control plane protocols



Access Stratum Protocols

- RLC layer – 3 different modes
  - Transparent mode (TM)
    - No additional control information
    - No error control
    - Used for services such as voice or video calls
  - Unacknowledged Mode (UM)
    - No delivery guarantee
    - Suitable for packet service such as streaming
  - Acknowledged Mode (AM)
    - Error control
    - Delivery guarantee
    - Used for packet traffic without real time constraints

Access Stratum Protocols

- RLC layer
  - Segmentation and reassembly of RLC SDUs
  - Ciphering and deciphering (UM and AM)
  - Error correction by retransmission (AM)
  - In-sequence delivery of upper layer PDUs (AM)
  - Duplicate detection (AM)
  - Flow control

Access Stratum Protocols

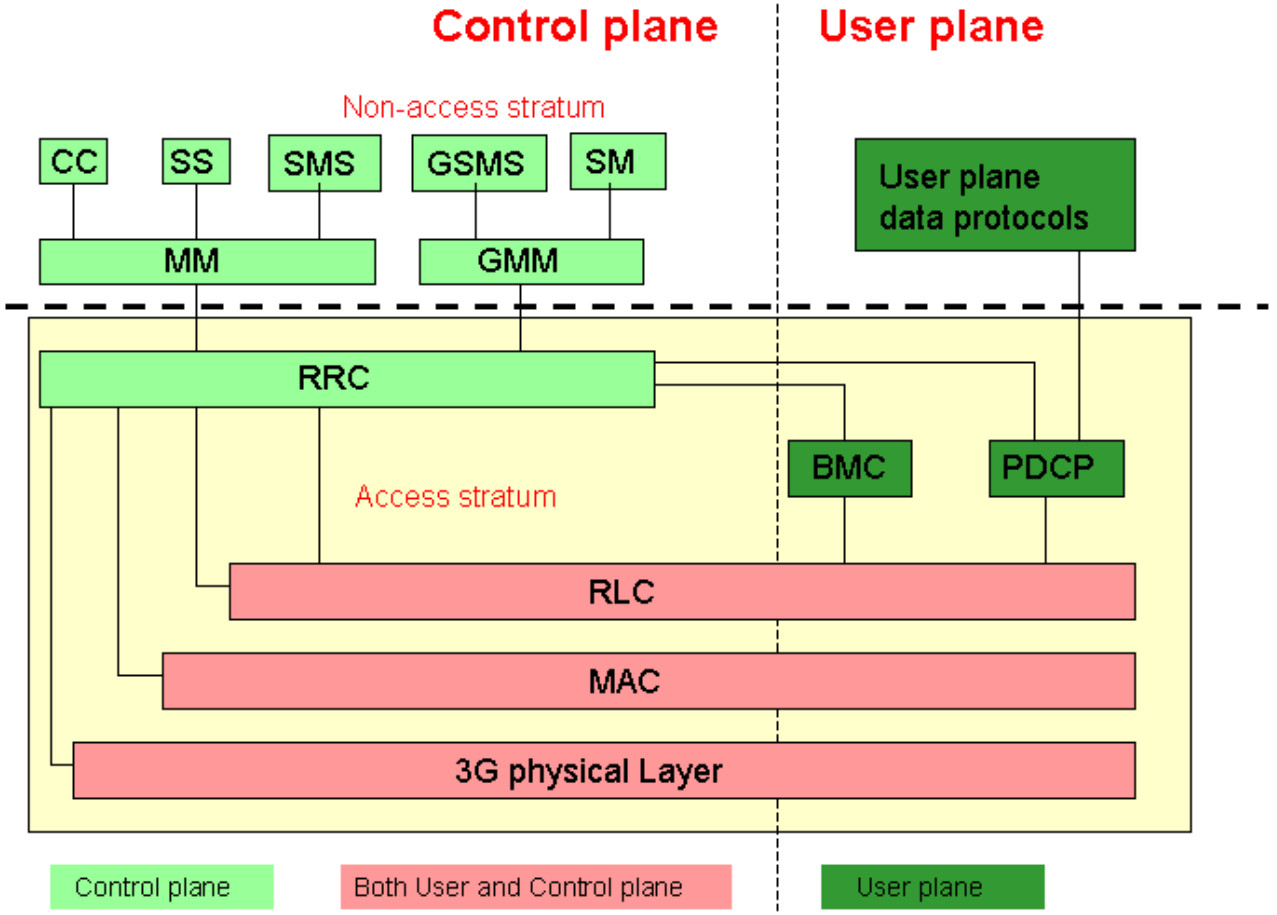
- RLC Protocol Data Unit
  - Transparent mode (TM)

  - Unacknowledged Mode (UM)

  - Acknowledged Mode (AM)

Access Stratum Protocols

- User plane and control plane protocols



Access Stratum Protocols

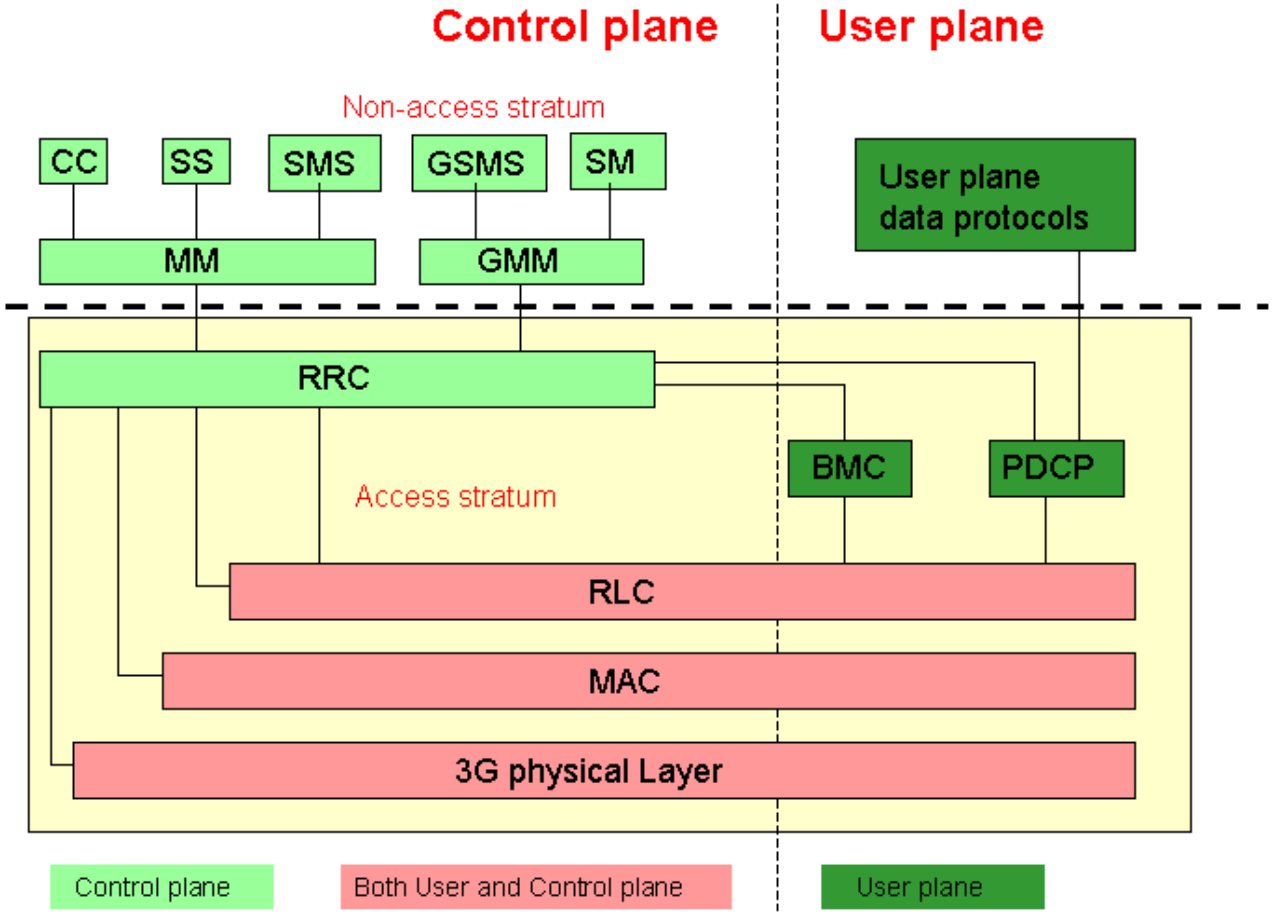
- PDCP – Packet Data Convergence Protocol
  - User plane and PS services only
  - Header compression and decompression – this can divide by 10 the size of a TCP/IP header
  - If combined with an AM RLC, it can provide lossless transfer between RNCs for radio bearers requiring this service

Access Stratum Protocols

- BMC – Broadcast/Multicast Control
  - User plane only
  - Transparent for all services except multicast/broadcast
  - Stores, schedules and transmits messages issued by the Cell Broadcast Center, connected to the RNC
  - Relies on UM RLC

Access Stratum Protocols

- User plane and control plane protocols



Access Stratum Protocols

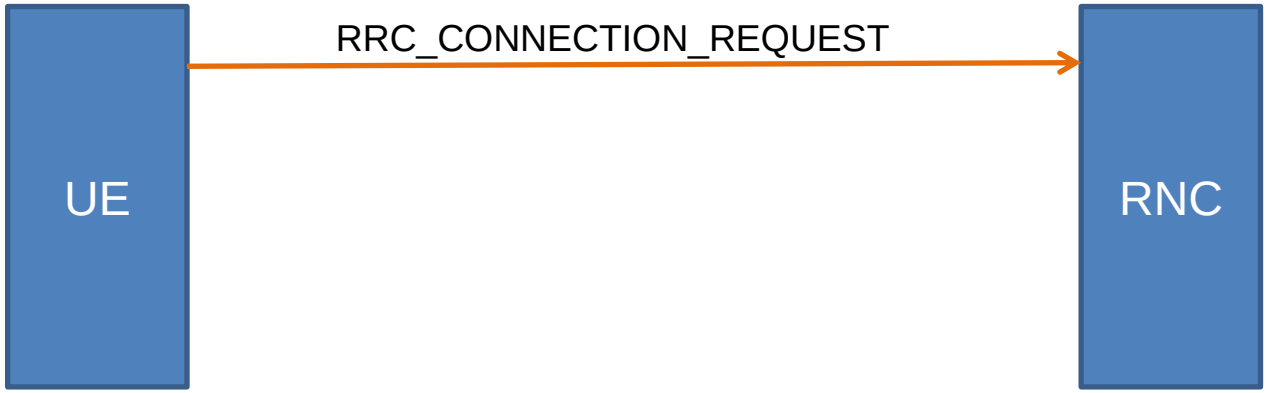
- RRC – Radio Resource Control
  - Responsible for generating signaling between UTRAN and UE
  - Transfer service of signaling messages generate by NAS
  - Handling of paging
  - Cell selection and reselection process
  - Handling of mobility within the UTRAN
  - Radio bearers management
  - Measurement control

Access Stratum Protocols

- RRC Connection
  - Signaling connection between the UE and UTRAN
  - Always initiated by the UE when the UE RRC entity receives a request from NAS protocols to send a message to the core network, and no ongoing RRC connection exists

Access Stratum Protocols

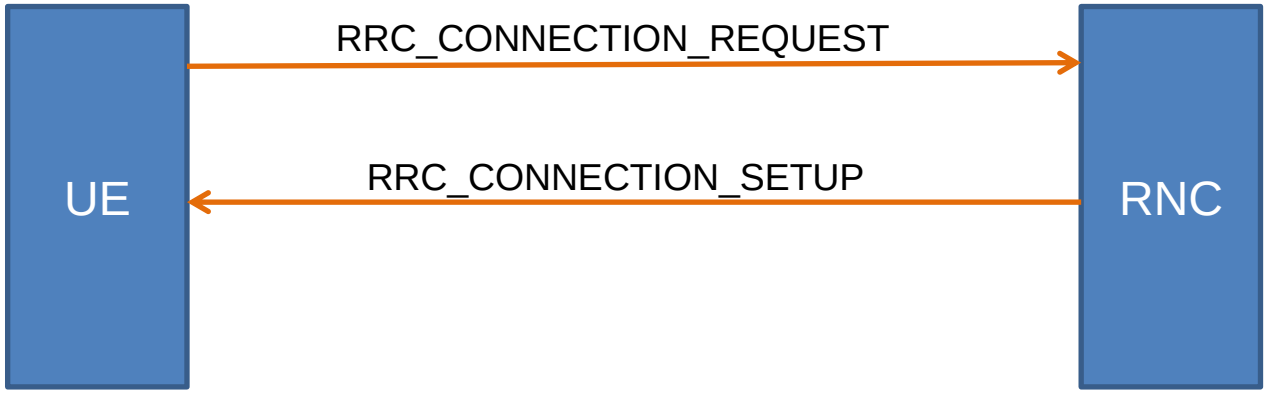
- RRC Connection



  - RRC_CONNECTION_REQUEST
    - Transmitted on the CCCH, but using the RACH procedure
    - Current UE identity (in this order: TMSI, P-TMSI, IMSI, IMEI)
    - Connection establishment cause (outgoing call, incoming call, signaling transmission)

Access Stratum Protocols

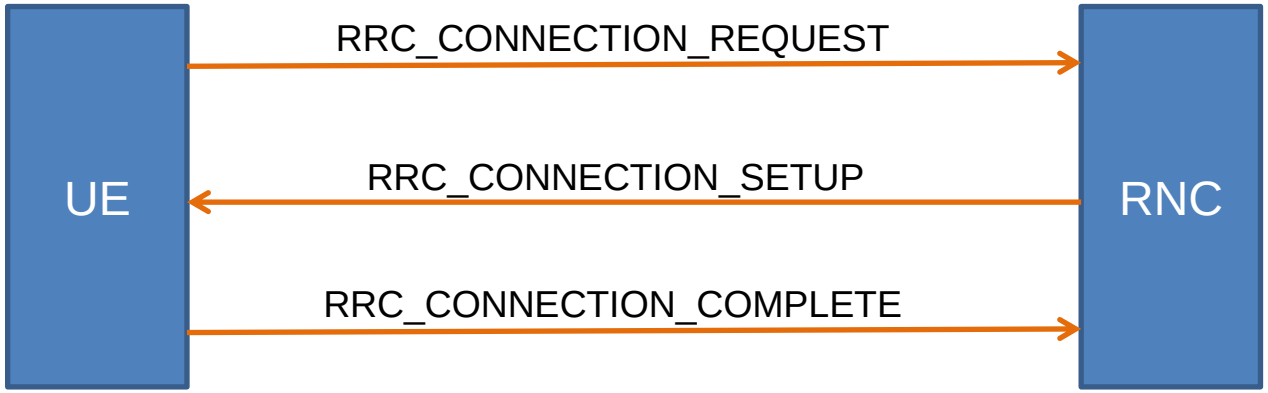
- RRC Connection



- RRC_CONNECTION_SETUP
  - Transmitted on CCCH, mapped on FACH
  - Signaling Radio Bearer (SRB) information and establishment
  - Announces the RRC state of the UE and an RNTI
  - Resource allocation (i.e. the uplink scrambling code to be used)

Access Stratum Protocols

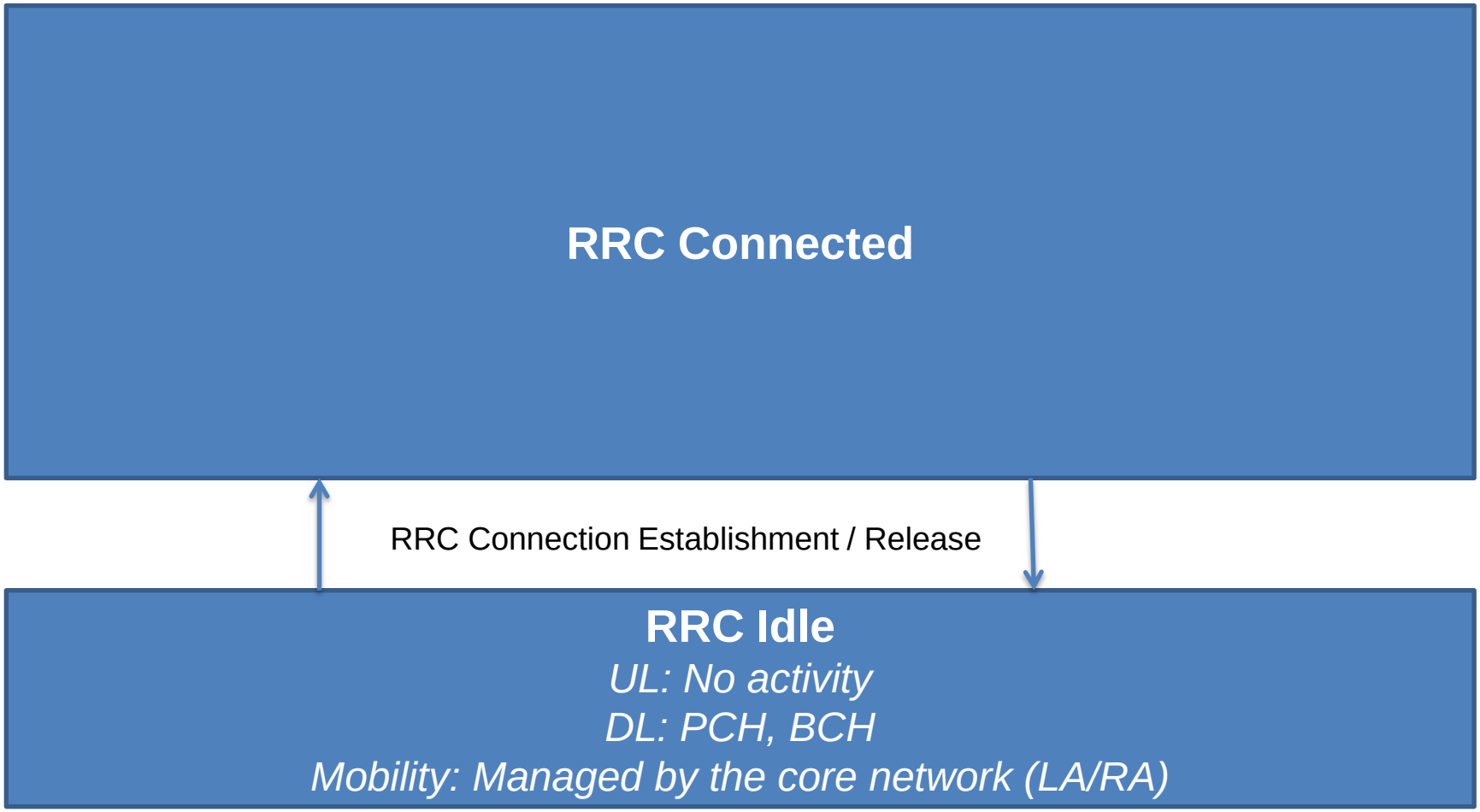
- RRC Connection



- RRC_CONNECTION_COMPLETE
  - Transmitted on DCCH, mapped either on DCH or FACH, depending on the RRC state previously announced
  - Indicates UE L1/L2 capabilities
  - Ciphering and integrity protection information

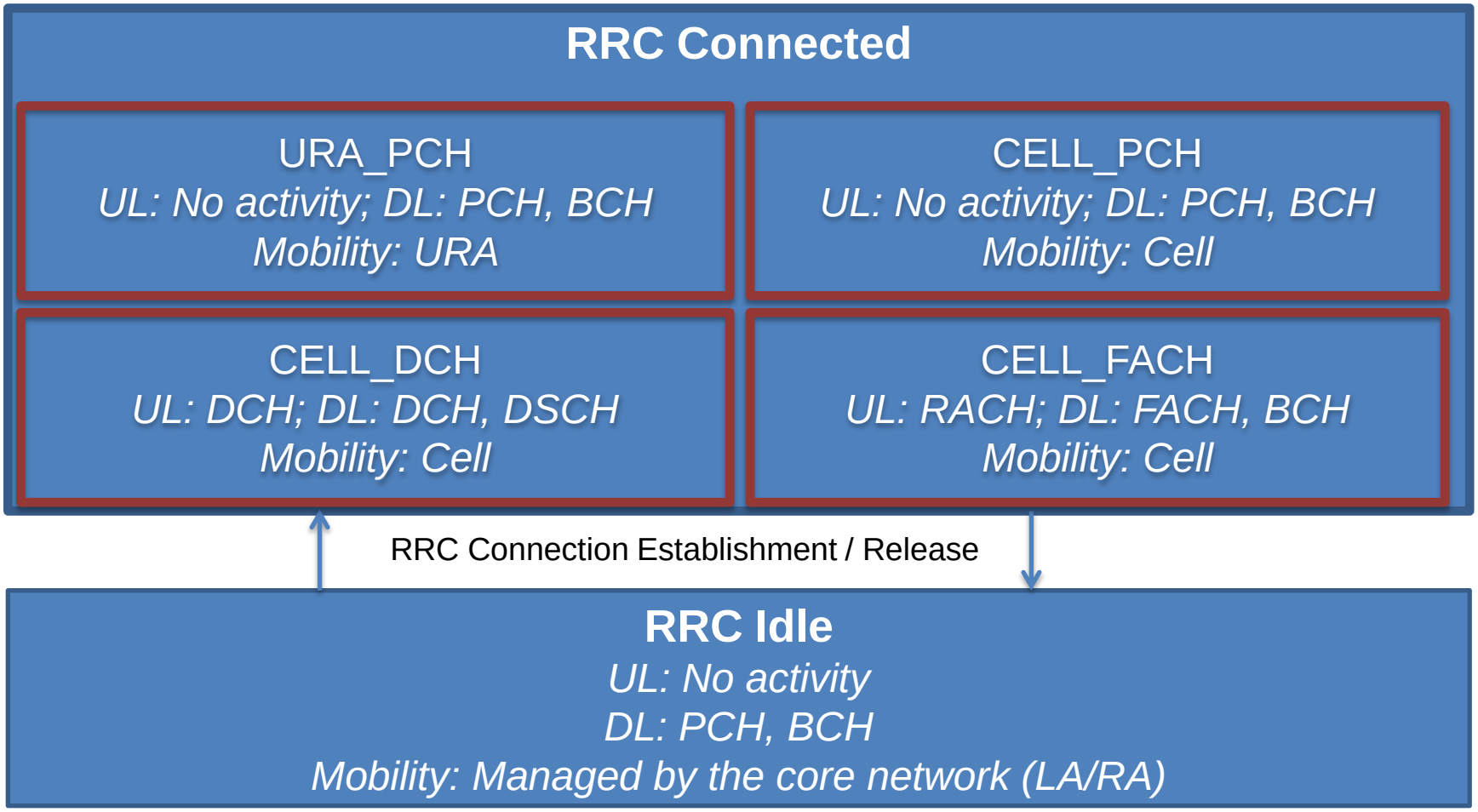
Access Stratum Protocols

- RRC States



Access Stratum Protocols

- RRC States



Access Stratum Protocols

- RRC System Information Broadcast
  - Core network or UTRAN originated control information
  - Enables UE to identify cells in their network coverage (and their parameters)
  - System Information Blocks (SIBs) periodically and continuously broadcast by UTRAN in RRC_SYSTEM_INFORMATION messages
  - UE reads SIBs only once, and then only in case parameters are changed
  - The changes are announced in a Master Information Block (MIB), transmitted every 80ms
  - MIBs are transmitted in paging messages (for UEs in idle mode, CELL_PCH and URA_PCH) and mapped on the FACH in RRC_SYSTEM_INFORMATION_CHANGE_INDICATION (for UEs in CELL_FACH)

Access Stratum Protocols

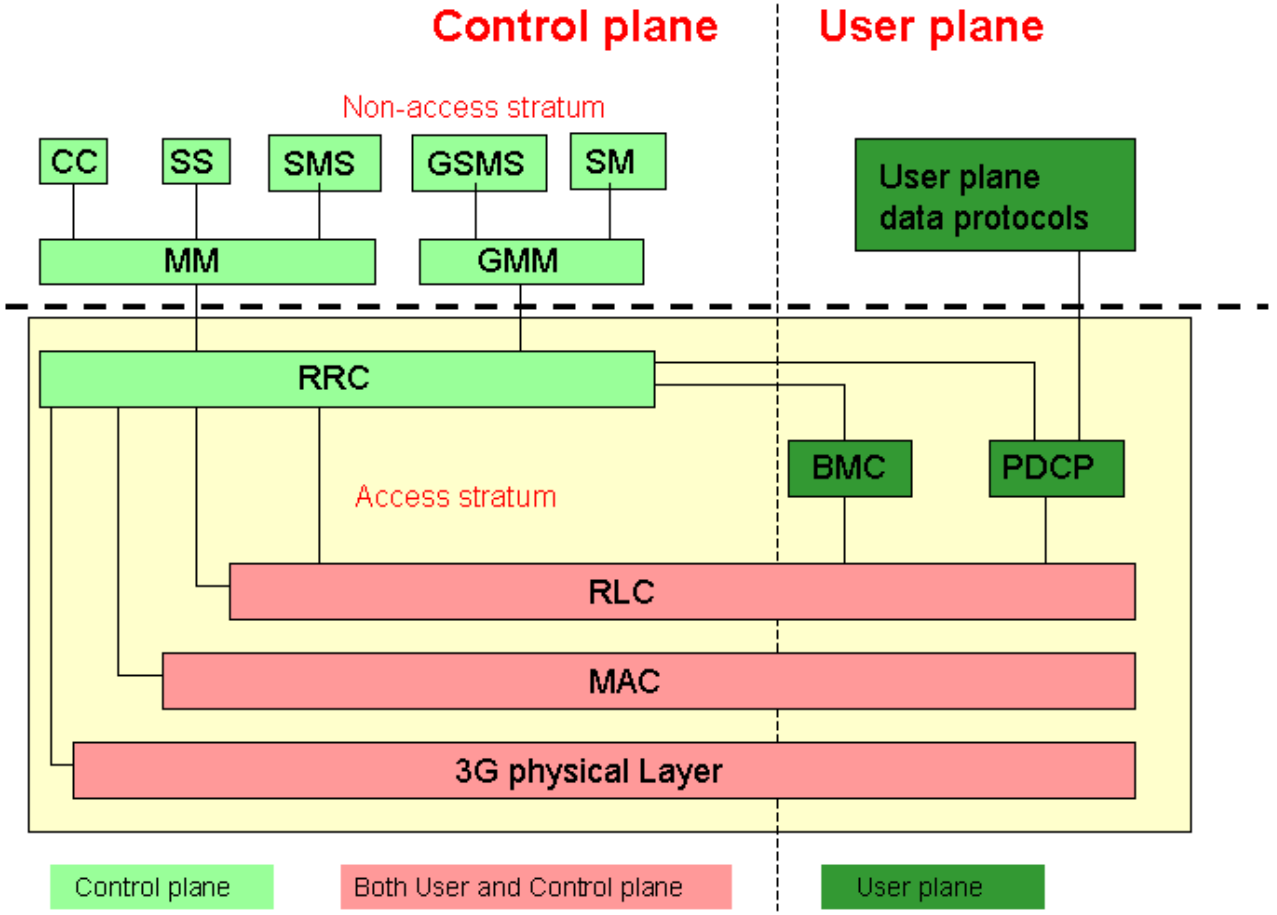
- RRC Paging
  - Paging message type 1 – transmitted on the PCH, to UEs in idle mode, CELL_PCH or URA_PCH
  - Paging message type 2 – transmitted on dedicated resources to UEs in CELL_FACH and CELL_DCH
  - If the paging is issued by the core network, the UE RRC informs upper layers about the paging cause
  - If the paging is issued by the UTRAN (SIB update), the UE will start monitoring the BCH

Access Stratum Protocols

- RRC Mobility Handling
  - In RRC idle mode – UE is ignored by the UTRAN, mobility handled by CN (using TMSI or P-TMSI temporary identifiers)
  - In URA_PCH, CELL_PCH or CELL_FACH – UE connected to the UTRAN, and associated with an U-RNTI or C-RNTI. Mobility management procedure initiated and performed by UE, based on SIB information
  - In CELL_DCH – UE position known at a cell level, and mobility handled by SRNC based on mobility measures provided by UE (handover process)

Non-Access Stratum Protocols

- User plane and control plane protocols



Non-Access Stratum Protocols

- NAS Mobility Handling
  - Functions such as PLMN selection, network attachment, location update, etc.
  - Mobility Management (MM) entity – in charge of all functions related to UE mobility in the CN, for the CS domain
  - GPRS Mobility Management (GMM) entity - in charge of all functions related to UE mobility in the CN, for the PS domain

Non-Access Stratum Protocols

- NAS Connection Management (CM)
  - Connection Control (CC) – in charge of handling connections in the CS domain
  - Session Management (SM) – in charge of handling sessions in the PS domain
  - Supplementary Services (SS) – used for the activation of supplementary services
  - Short Message Services (SMS/GSMS) – for sending and receiving text messages

Non-Access Stratum Protocols

- User plane and control plane protocols