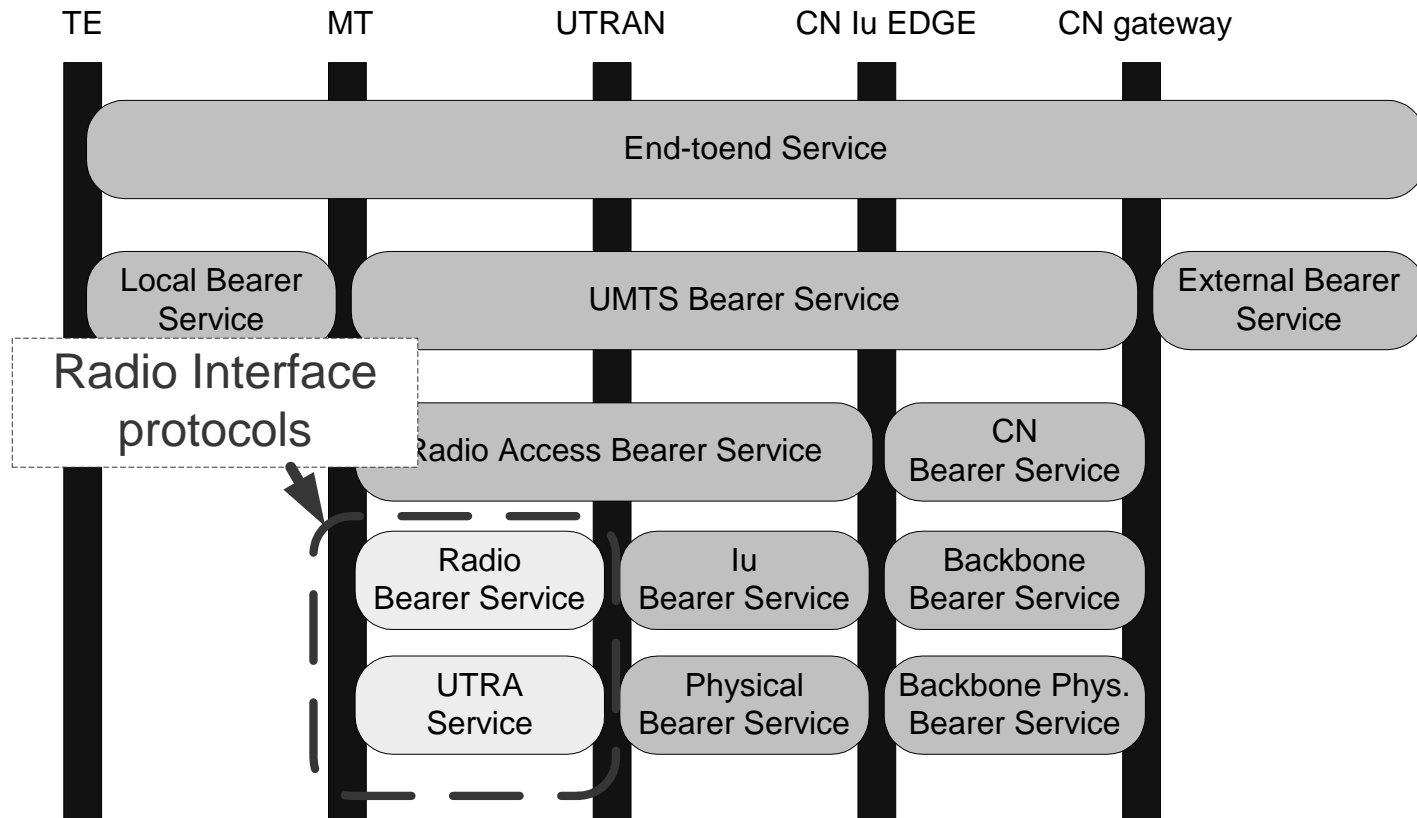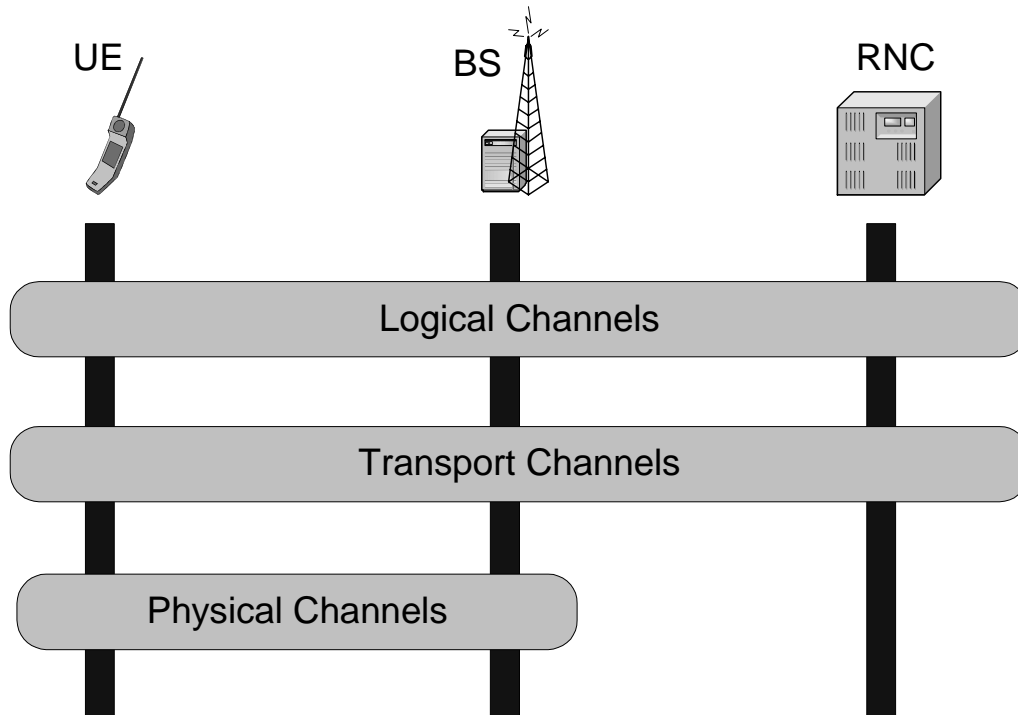# UTRAN Radio Interface protocols

Outline of the lecture

- UTRAN Radio Interface protocol architecture.

- Transport Channels, Logical Channels, Radio Bearers.

- Radio Protocols
  - Medium Access Control (MAC) protocol.
  - Radio Link Control (RLC) protocol.
  - Packet Data Convergence (PDC) protocol.
  - Broadcast/Multicast Control (BMC) protocol.
  - Radio Resource Control (RRC) protocol.

UMTS Bearer services

TE	MT	UTRAN	CN Iu EDGE	CN gateway

End-toend Service

Local Bearer Service | **UMTS Bearer Service** | **External Bearer Service**

Radio Interface protocols

Radio Access Bearer Service | CN Bearer Service

Radio Bearer Service	Iu Bearer Service	Backbone Bearer Service
UTRA Service	Physical Bearer Service	Backbone Phys. Bearer Service

Channel types in UTRAN

UE   BS   RNC

Logical Channels
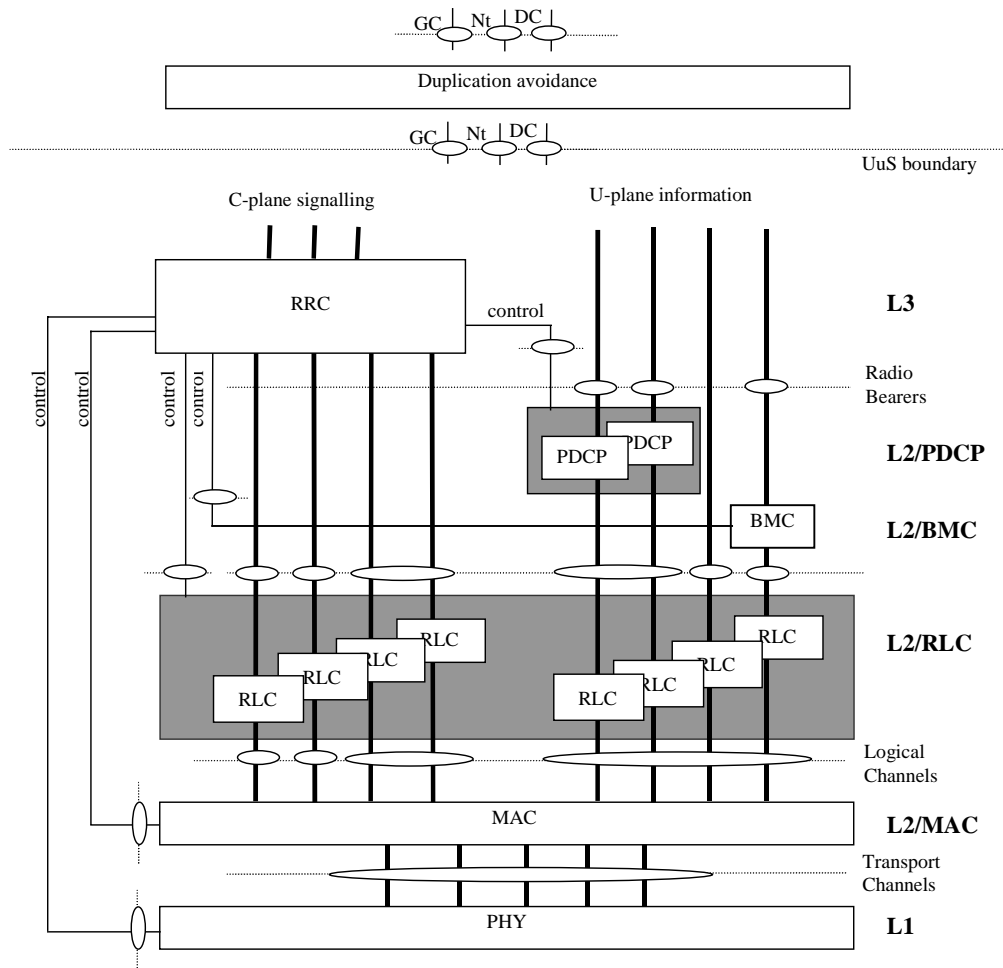
Transport Channels

Physical Channels

- **Physical channel**: form the physical existence of the Uu interface between the UE domain and access domain.
  - Different kind of bandwidth allocated for different purposes.
- RNC deals with **transport channels**: carry different information flows over the Uu interface and the physical elements.
- **Logical channels**: different tasks the network and the terminal should perform in different moments of time.
  - These structures are mapped to transport channels.

Functions using logical different channels

- Network informs the UE about the radio environment. The information is provided through the **Broadcast Control Channel** (BCCH)
  - the code values in the cell and in the neighbouring cells, power levels …
- Paging in order to find out the actual location of the user. Th network request is carried out in the logical channel **Paging Control Channel** (PCH).
- Task common for all UE residing in the cell. **Common Control Channel** (CCCH). Since many users may use CCH simultaneously they are identified by U-RNTI (UTRAN Radio Network Temporary Identity).
- The control information of dedicated and active connection is send in **Dedicated Control Channel** (DCCH).
- The dedicated user traffic in DL is sent through **Dedicated Traffic Channel** (DTCH).
- In DL the information to all UE or a specific group of UE in the cell can be transmitted on **Common Traffic Channel** (CTCH)

UTRAN Radio Interface Protocol Architecture

GC | Nt | DC |

Duplication avoidance

GC | Nt | DC |

UuS boundary

C-plane signalling

U-plane information

RRC

control

L3

Radio Bearers

control

control

control

control

control

PDCP
PDCP

L2/PDCP

BMC

L2/BMC

RLC RLC RLC RLC RLC RLC RLC RLC RLC

L2/RLC

Logical Channels

MAC

L2/MAC

Transport Channels

PHY

L1

- Transport channels: How data is transferred

- Logical channels: what type of data is transferred.

- Measurements reports: measurements and control and configuration.

Transport Channels

- Service provided by L1 to L2 (MAC). Defined how data is transported.
- **Common transport channels** (where there is a need for inband identification of the UEs when particular UEs are addressed);
- **Dedicated transport channels** (where the UEs are identified by the physical channel, i.e. code and frequency for FDD and code, time slot and frequency for TDD).

Dedicated transport channel types are:

- **Dedicated Channel (DCH):**
  A channel dedicated to one UE used in uplink or downlink.

Common transport channel types are:

- **Random Access Channel (RACH):**
  A contention based uplink channel used for transmission of relatively small amounts of data, e.g. for initial access or non-real-time dedicated control or traffic data.

- **Common Packet Channel (CPCH):**
  A contention based channel used for transmission of bursty data traffic. This channel only exists in FDD mode and only in the uplink direction. The common packet channel is shared by the UEs in a cell and therefore, it is a common resource. The CPCH is fast power controlled.

- **Forward Access Channel (FACH):**
  Common downlink channel without closed-loop power control used for transmission of relatively small amount of data.

- **Downlink Shared Channel (DSCH):**
  A downlink channel shared by several UEs carrying dedicated control or traffic data.

- **Uplink Shared Channel (USCH):**
  An uplink channel shared by several UEs carrying dedicated control or traffic data, used in TDD mode only.

- **Broadcast Channel (BCH):**
  A downlink channel used for broadcast of system information into an entire cell.

- **Paging Channel (PCH):**
  A downlink channel used for broadcast of control information into an entire cell allowing efficient UE sleep mode procedures. Currently identified information types are paging and notification. Another use could be UTRAN notification of change of BCCH information.
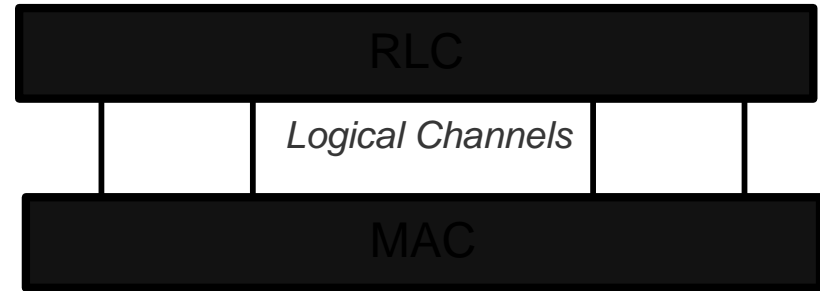
Logical Channels

- Service provided by MAC to higher layers.

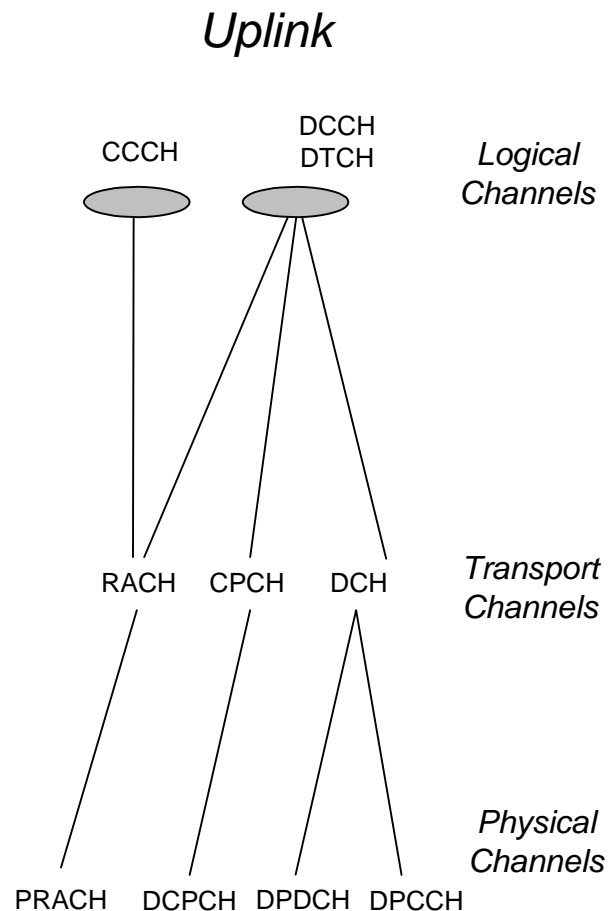- Defined "what type" of data is transferred.

- Control Channels:

  – Broadcast Control Channel (BCCH) (DL)

  – Paging Control Channel (PCCH) (DL)

  – Dedicated Control Channel (DCCH) (UL&DL): a point-to-point bidirectional channel that transmits dedicated control information between a UE and the network. Established during RRC connection establishment procedure.

  – Common Control Channel (CCCH) (UL&DL): a bidirectional channel for transmitting control information between a UE and the network.

- Traffic Channels:

  – Dedicated Traffic Channels (DTCH) (UL&DL)
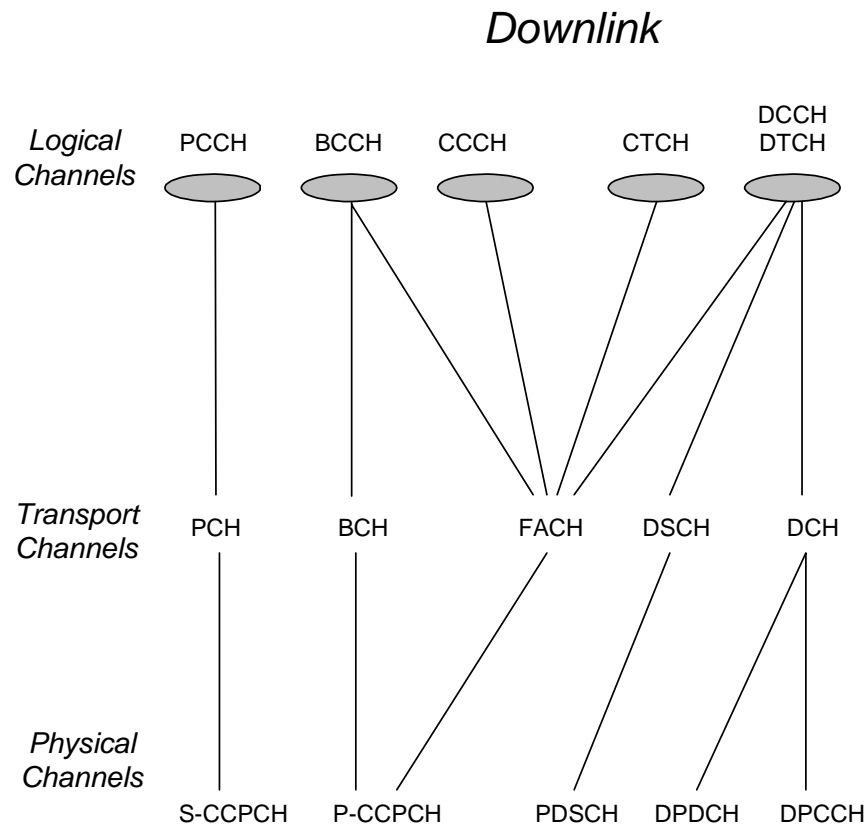
  – Common Traffic Channels (CTCH) (DL)

Mapping between logical and transport channels (Uplink)

Uplink

CCCH

DCCH
DTCH

Logical Channels

RACH   CPCH   DCH

Transport Channels

PRACH   DCPCH   DPDCH   DPCCH

Physical Channels

Examples of carried data:

- RACH: control information from UE to the UTRAN.
  - Connection set-up request.
  - Small amounts of packet data.
- DCH: dedicated traffic and control information. It may contain several DTCH. (Similar to the one in DL)
- CPCH: a common transport channel for packet data transmission. (Extention of RACH)

Mapping between logical and transport channels (Downlink)

Downlink

Logical Channels: PCCH BCCH CCCH CTCH DCCH DTCH

Transport Channels: PCH BCH FACH DSCH DCH

Physical Channels: S-CCPCH P-CCPCH PDSCH DPDCH DPCCH

Examples of carried data:

- BCH: UTRA specific information
  - random access codes, access slot information, …
- PCH: Paging information. Network wishes to initiate connection.
- FACH: Control information to the UE known to be in the cell.
  - Response to the random access message.
- DCH: dedicated traffic and control information. It may contain several DTCH.
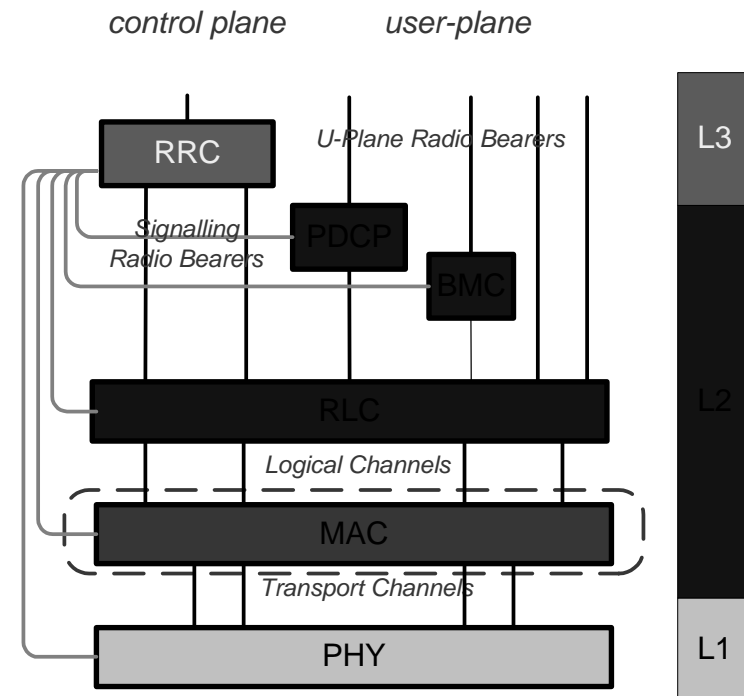- DSCH: Dedicated user information for packet traffic.

Radio Bearers

- Service provided by RLC/PDCP/BMC to higher layers.
- Defined by:
  - RLC/PDCP/BMC parameters.
  - Transport channel parameters.
  - Physical channel parameters??
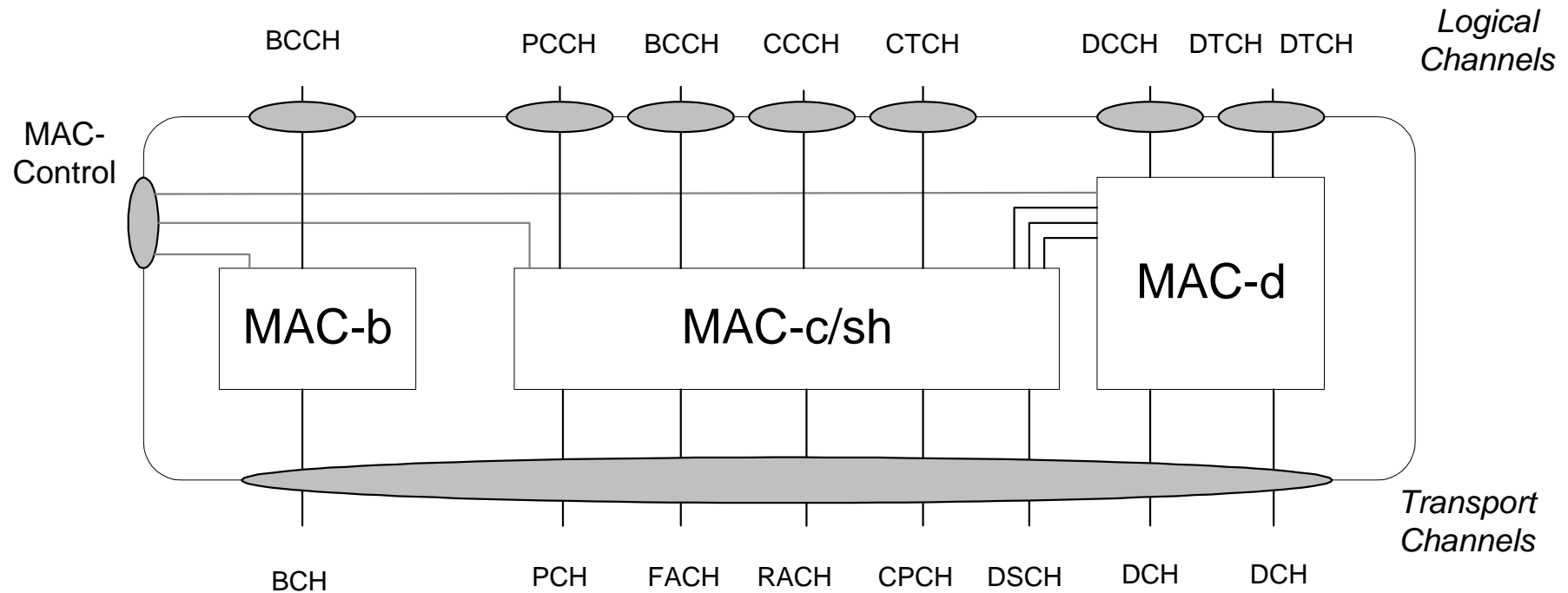 - Mapping between Radio bearer(s) logical channels and transport channels.
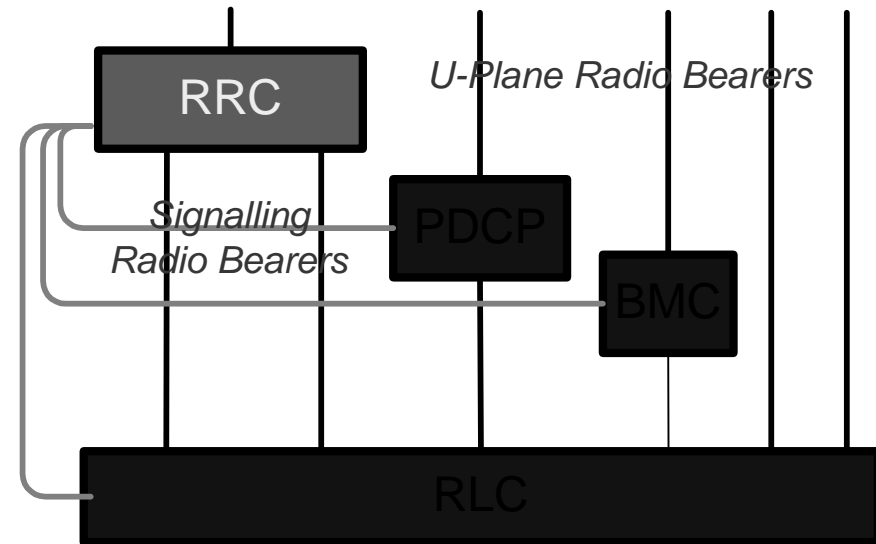
Medium Access Control protocol functions

- Mapping between logical channels and transport channels.
- Selection of appropriate Transport Format for each Transport Channel depending on instantaneous source rate.
- Priority handling between data flows of one UE.
- Priority handling between UEs by means of dynamic scheduling.
- Identification of UEs on common transport channels.
- Multiplexing/demultiplexing of upper layer PDUs into/from transport block sets delivered to/from the physical layer on dedicated transport channels.
- Traffic volume measurement.
- Transport Channel type switching.
- Ciphering for transparent mode RLC.
- Access Service Class selection for RACH and CPCH transmission.

control plane   *user-plane*

RRC   U-Plane Radio Bearers   L3

Signalling Radio Bearers   PDCP

BMC

RLC   L2

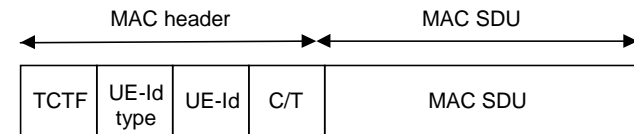*Logical Channels*

MAC

Transport Channels

PHY   L1

MAC layer logical architecture

Services provided to upper layers
- **Data transfer:** This service provides unacknowledged transfer of MAC SDUs between peer MAC entities without data segmentation.
- **Reallocation of radio resources and MAC parameters:** This service performs on request of RRC execution of radio resource reallocation and change of MAC parameters.
- **Reporting of measurements:** Local measurements are reported to RRC.

MAC PDU Format

MAC header				MAC SDU
TCTF	UE-Id type	UE-Id	C/T	MAC SDU

MAC PDU

- MAC header consist of:
- **Target Channel Type field (TCFT):** a flag that provides identification of the logical channel class on FACH and RACH transport channels.

  (BCCH, CCCH, CTCH, SHCCH or dedicated logical channel information).

- **C/T field:** provides identification of the logical channel instance when multiple logical channels are carried on the same transport channel.

- **UE-Id field:** provides an identifier of the UE on common transport channels.
  - UTRAN Radio Network Temporary Identity (U-RNTI) may be used in the MAC header of DCCH when mapped onto common transport channels in downlink direction; the U-RNTI is never used in uplink direction;
  - Cell Radio Network Temporary Identity (C-RNTI) is used on DTCH and DCCH in uplink, and may be used on DCCH in downlink and is used on DTCH in downlink when mapped onto common transport channels;
  - the UE id to be used by MAC is configured through the MAC control SAP.

- **UE-Id Type field:** is needed to ensure correct decoding of the UE-Id field in MAC Headers

MAC c/sh

TCTF MUX: this function represents the handling (insertion for uplink channels and detection and deletion for downlink channels) of the TCTF field in the MAC header, and the respective mapping between logical and transport channels.The TCTF field indicates the common logical channel type, or if a dedicated logical channel is used;

add/read UE Id:

- the UE Id is added for CPCH and RACH transmissions
- the UE Id, when present, identifies data to this UE.

UL: TF selection: in the uplink, the possibility of transport format selection exists. In case of CPCH transmission, a TF is selected based on TF availability determined from status information on the CSICH;

ASC selection: For RACH, MAC indicates the ASC associated with the PDU to the physical layer. For CPCH, MAC may indicate the ASC associated with the PDU to the Physical Layer. This is to ensure that RACH and CPCH messages associated with a given Access Service Class (ASC) are sent on the appropriate signature(s) and time slot(s). MAC also applies the appropriate back-off parameter(s) associated with the given ASC. When sending an RRC CONNECTION REQUEST message, RRC will determine the ASC; in all other cases MAC selects the ASC;

scheduling /priority handling: this functionality is used to transmit the information received from MAC-d on RACH and CPCH based on logical channel priorities. This function is related to TF selection.

TFC selection: transport format and transport format combination selection according to the transport format combination set (or transport format combination subset) configured by RRC is performed,
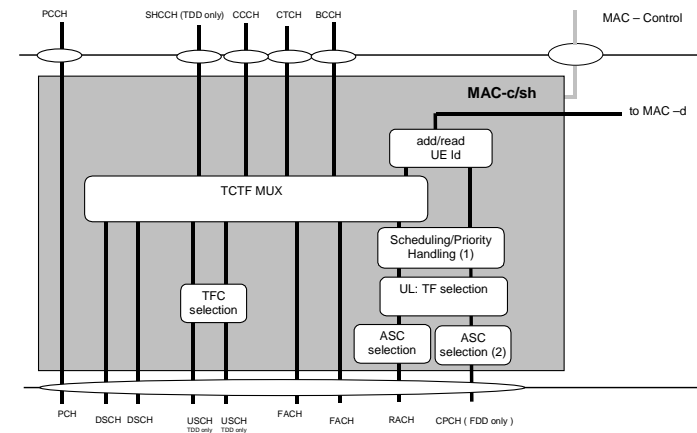
Note 1: Scheduling /Priority handling is applicable for CPCH.
Note 2: In case of CPCH, ASC selection may be applicable for AP preamble.

UE side MAC-c/sh details
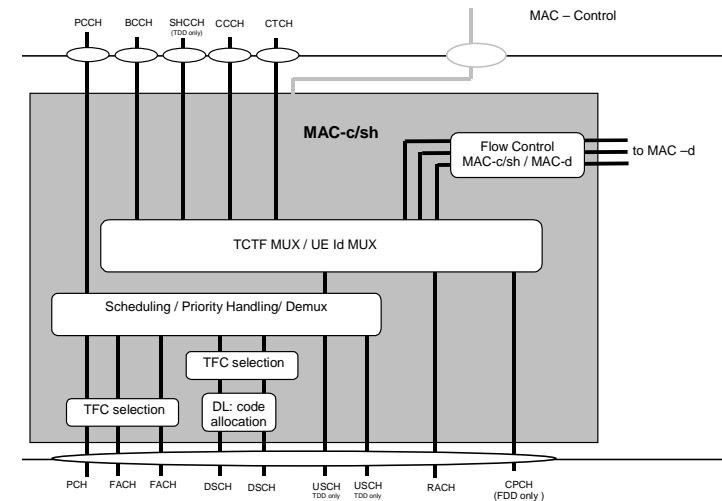
UTRAN side MAC-c/sh details

MAC-d

Transport Channel type switching: performed based on decision taken by RRC. This is related to a change of radio resources. If requested by RRC, MAC shall switch the mapping of one designated logical channel between common and dedicated transport channels.

C/T MUX: The C/T MUX is used when multiplexing of several dedicated logical channels onto one transport channel is used. An unambiguous identification of the logical channel is included.
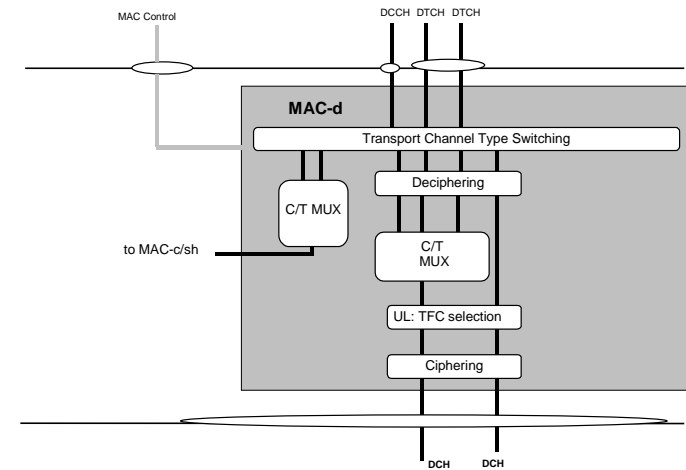
Ciphering: Ciphering for transparent mode data to be ciphered is performed in MAC-d.

Deciphering: Deciphering for ciphered transparent mode data is performed in MAC-d.

UL TFC selection: Transport format and transport format combination selection according to the transport format combination set (or transport format combination subset) configured by RRC is performed.

DL Scheduling/Priority handling: in the downlink, scheduling and priority handling of transport channels is performed within the allowed transport format combinations of the TFCS assigned by the RRC.

Flow Control: a flow control function exists toward MAC-c/sh to limit buffering between MAC-d and MAC-c/sh entities. This function is intended to limit layer 2 signalling latency and reduce discarded and retransmitted data as a result of FACH or DSCH congestion.

Note 1: For DCH and DSCH different scheduling mechanism apply
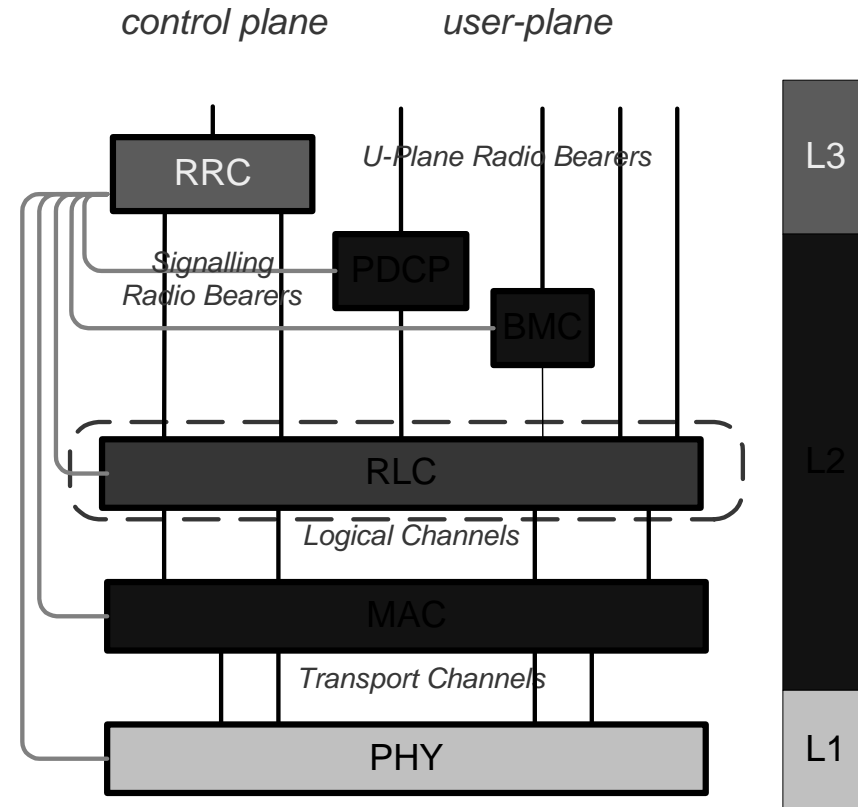Note 2: Ciphering is performed in MAC-d only for transparent RLC mode
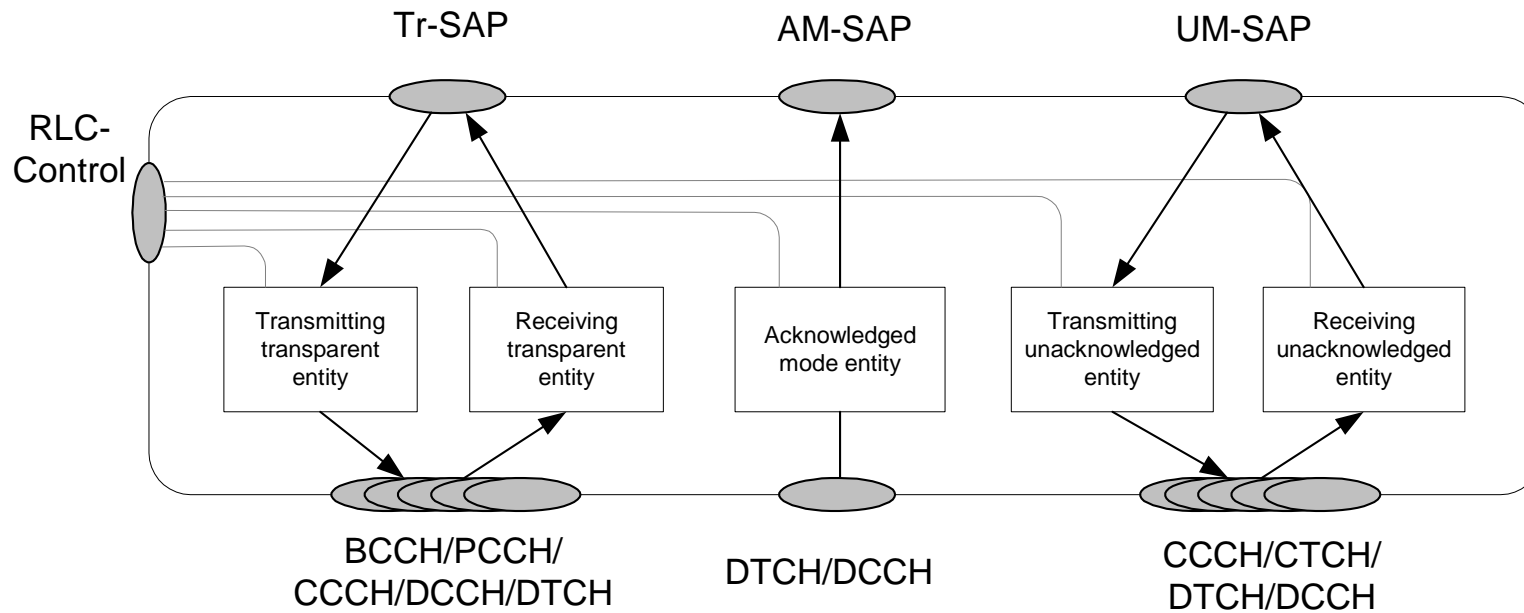
UE side MAC-d details
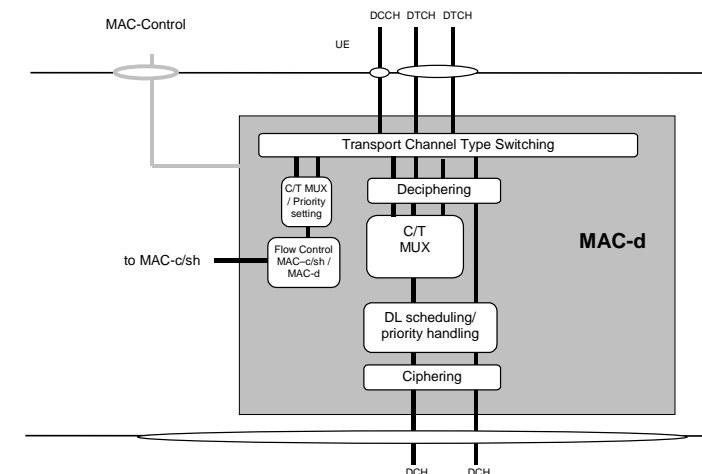
UTRAN side MAC-d details

Radio Link Control protocol

- Segmentation and reassembly.
- Concatenation.
- Padding.
- Transfer of user data.
- Error correction.
- In-sequence delivery of upper layer PDUs.
- Duplicate detection.
- Flow control.
- Sequence number check.
- Protocol error detection and recovery.
- Ciphering.
- SDU discard.

control plane   *user-plane*

RRC

U-Plane Radio Bearers

L3

Signalling Radio Bearers

PDCP

BMC

RLC

L2

Logical Channels

MAC

Transport Channels

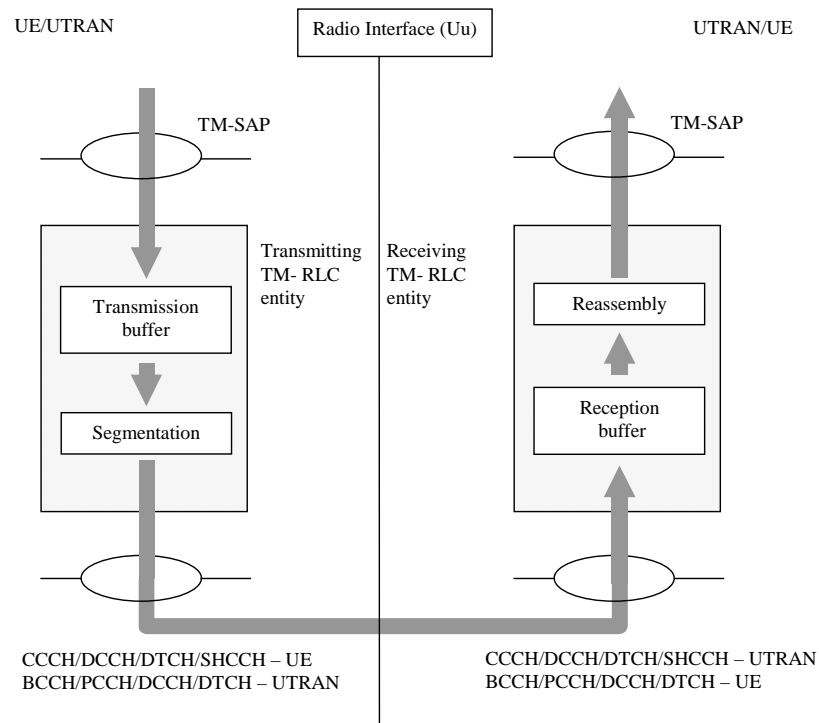PHY

L1

RLC logical architecture

- Provides segmentation/reassembly (payload units, PU) and retransmission service for both user(Radio Bearer) and control data (Signalling Radio bearer).

- **Transparent mode (Tr):** no overhead is added to higher layer data.

- **Unacknowledged mode (UM):** no retransmission protocol is used and data delivery is not guaranteed.

- **Acknowledged mode (AM):** Automatic Repeat reQuest (ARQ) mechanism is used for error correction.

RLC Services provided to upper layers

- **Transparent data transfer Service:**
- The following functions are needed to support transparent data transfer:
  – Segmentation and reassembly.
  – Transfer of user data.
  – SDU discard.
- **Unacknowledged data transfer Service:**
- The following functions are needed to support unacknowledged data transfer:
  – Segmentation and reassembly.
  – Concatenation.
  – Padding.
  – Transfer of user data.
  – Ciphering.
  – Sequence number check.
  – SDU discard.

- **Acknowledged data transfer Service:**
- The following functions are needed to support acknowledged data transfer:
  – Segmentation and reassembly.
  – Concatenation.
  – Padding.
  – Transfer of user data.
  – Error correction.
  – In-sequence delivery of upper layer PDUs.
  – Duplicate detection.
  – Flow Control.
  – Protocol error detection and recovery.
  – Ciphering.
  – SDU discard.
- **Maintenance of QoS as defined by upper layers.**
- **Notification of unrecoverable errors.**

RLC transparent mode (TM) entity (1)

UE/UTRAN   Radio Interface (Uu)   UTRAN/UE

TM-SAP   TM-SAP

Transmitting   Receiving
TM- RLC   TM- RLC
entity   entity

Transmission   Reassembly
buffer

                                                          Reception
Segmentation   buffer

CCCH/DCCH/DTCH/SHCCH – UE   CCCH/DCCH/DTCH/SHCCH – UTRAN
BCCH/PCCH/DCCH/DTCH – UTRAN   BCCH/PCCH/DCCH/DTCH – UE

Receiving TM-RLC entity:
- The receiving TM-RLC entity receives TMD PDUs through the configured logical channels from the lower layer. If segmentation is configured by upper layers, all TMD PDUs received within one TTI are reassembled to form the RLC SDU.
- If segmentation is not configured by upper layers, each TMD PDU is treated as a RLC SDU.
- The receiving TM RLC entity delivers RLC SDUs to upper layers through the TM-SAP.
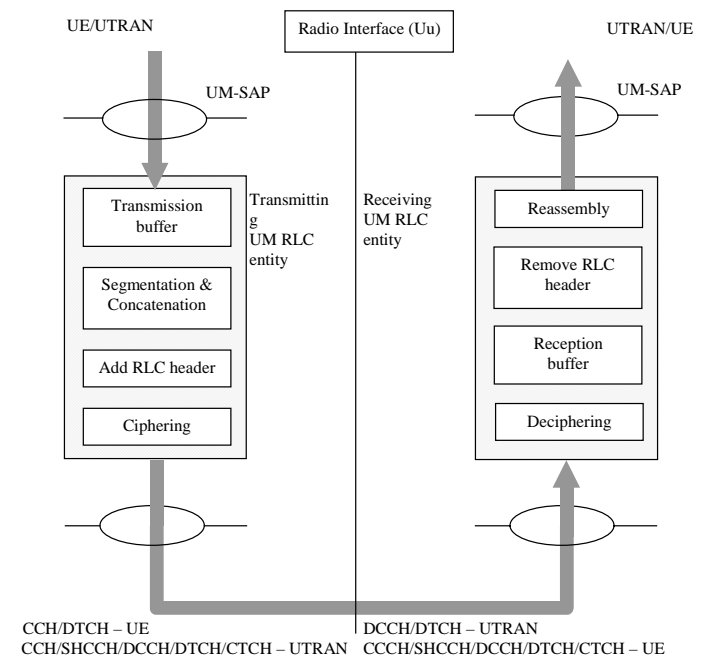
RLC transparent mode (TM) entity (2)

Transmitting TM-RLC entity:
- The transmitting TM-RLC entity receives RLC SDUs from upper layers through the TM-SAP.
- All received RLC SDUs must be of a length that is a multiple of one of the valid TMD PDU lengths.
- If segmentation has been configured by upper layers and a RLC SDU is larger than the TMD PDU size used by the lower layer for that TTI, the transmitting TM RLC entity segments RLC SDUs to fit the TMD PDUs size without adding RLC headers. All the TMD PDUs carrying one RLC SDU are sent in the same TTI, and no segment from another RLC SDU are sent in this TTI.
- If segmentation has not been configured by upper layers, then more than one RLC SDU can be sent in one TTI by placing one RLC SDU in one TMD PDU. All TMD PDUs in one TTI must be of equal length.
- When the processing of a RLC SDU is complete, the resulting one or more TMD PDU(s) are/is submitted to the lower layer through either a BCCH, DCCH, PCCH, CCCH, SHCCH or a DTCH logical channel.

RLC unacknowledged mode entity

Receiving UM-RLC entity:

- The receiving UM-RLC entity receives UMD PDUs through the configured logical channels from the lower layer.
- The receiving UM RLC entity deciphers (if ciphering is configured and started) the received UMD PDUs (except for the UMD PDU header). It removes RLC headers from received UMD PDUs, and reassembles RLC SDUs (if segmentation and/or concatenation has been performed by the transmitting UM RLC entity).
- RLC SDUs are delivered by the receiving UM RLC entity to the upper layers through the UM-SAP.
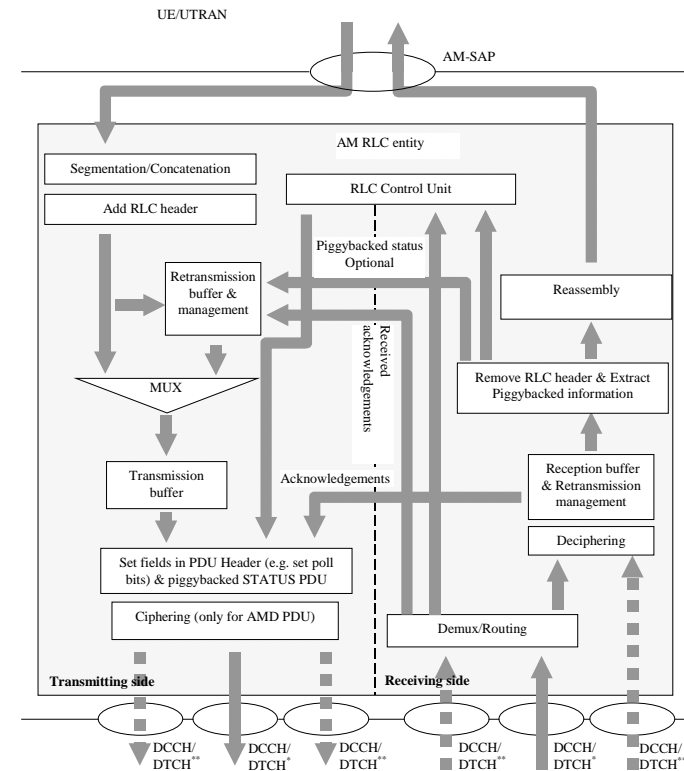
RLC unacknowledged mode entity (2)

Transmitting UM-RLC entity:

- The transmitting UM-RLC entity receives RLC SDUs from upper layers through the UM-SAP.
- The transmitting UM RLC entity segments the RLC SDU into UMD PDUs of appropriate size, if the RLC SDU is larger than the length of available space in the UMD PDU. The UMD PDU may contain segmented and/or concatenated RLC SDUs. UMD PDU may also contain padding to ensure that it is of a valid length. Length Indicators are used to define boundaries between RLC SDUs within UMD PDUs. Length Indicators are also used to define whether Padding is included in the UMD PDU.
- If ciphering is configured and started, an UMD PDU is ciphered (except for the UMD PDU header) before it is submitted to the lower layer.
- The transmitting UM RLC entity submits UMD PDUs to the lower layer through either a CCCH, SHCCH, DCCH, CTCH or a DTCH logical channel.

RLC acknowledged mode entity (1)

- The receiving side of the AM-RLC entity receives AMD and Control PDUs through the configured logical channels from the lower layer.
- AMD PDUs are routed to the Deciphering Unit and then delivered to the Reception buffer.
- The AMD PDUs are placed in the Reception buffer until a complete RLC SDU has been received. The Receiver acknowledges successful reception or requests retransmission of the missing AMD PDUs by sending one or more STATUS PDUs to the AM RLC peer entity, through its transmitting side.

- The associated AMD PDUs are reassembled by the Reassembly Unit and delivered to upper layers through the AM-SAP.
- RESET and RESET ACK PDUs are delivered to the RLC Control Unit for processing. If a response to the peer AM RLC entity is needed, an appropriate Control PDU is delivered, by the RLC Control Unit to the transmitting side of the AM RLC entity.

RLC acknowledged mode entity (2)

- The transmitting side of the AM-RLC entity receives RLC SDUs from upper layers through the AM-SAP.
- RLC SDUs are segmented and/or concatenated into AMD PDUs of a fixed length.
  - The segmentation is performed if the received RLC SDU is larger than the length of available space in the AMD PDU.
  - The PDU size is set during AM-RLC establishment.
  - The packets could be segmented, concatenated, padded.
  - Boundaries between the packets are indicated by a length indicator.
- After the segmentation and/or concatenation are performed, the AMD PDUs are placed in the Retransmission buffer at the MUX.
- AMD PDUs buffered in the Retransmission buffer are deleted or retransmitted.
- The MUX multiplexes AMD PDUs from the Retransmission buffer that need to be retransmitted, and the newly generated AMD PDUs delivered from the Segmentation/Concatenation function.
- The PDUs are delivered to the function that completes the AMD PDU header and potentially replaces padding with piggybacked status information. A Piggybacked STATUS PDUs can be of variable size in order to match the amount of free space in the AMD PDU.
- The ciphering (if configured) is then applied to the AMD PDUs.
  - The AMD PDU header is not ciphered.
  - Control PDUs (i.e. STATUS PDU, RESET PDU, and RESET ACK PDU) are not ciphered.
- AMD PDUs are submitted to either one or two DCCH or DTCH logical channels.

Packet Data Convergence Protocol (PDCP)
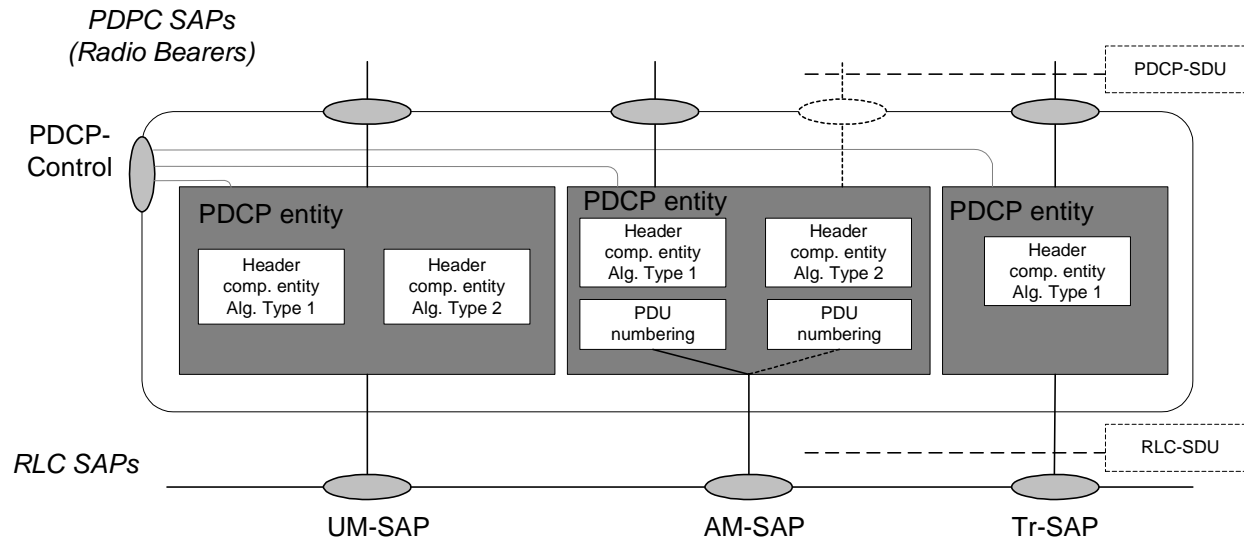
- The Packet Data Convergence Protocol shall perform the following functions:
  - Header compression and decompression of IP data streams (e.g., TCP/IP and RTP/UDP/IP headers for IPv4 and IPv6) at the transmitting and receiving entity, respectively. (In Release 99 compression accordingly RFC 2507).
  - Transfer of user data. This function is used for conveyance of data between users of PDCP services.
  - Maintenance of PDCP sequence numbers for radio bearers that are configured to support lossless SRNS Relocation.
- PDCP uses the services provided by the Radio Link Control (RLC) sublayer.

Broadcast Multicast Control (BMC)
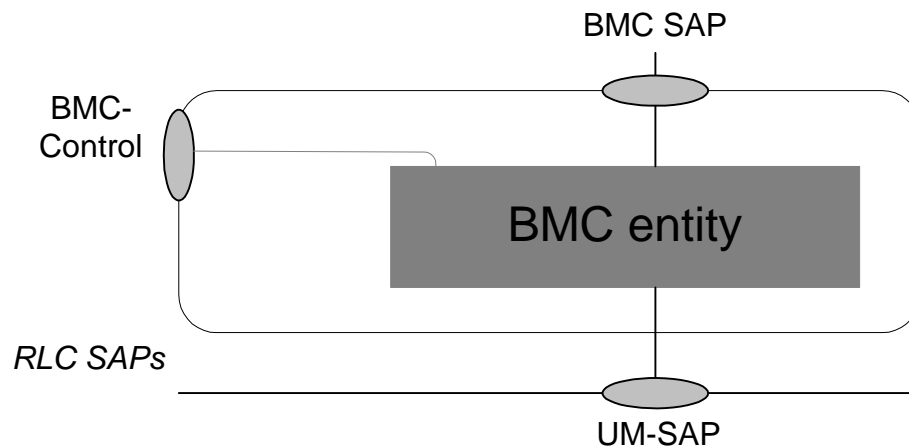
- Storage of Cell Broadcast Messages.
- Traffic volume monitoring and radio resource request for CBS.
- Scheduling of BMC messages.
- Transmission of BMC messages to UE.
- Delivery of Cell Broadcast messages to upper layer.

Radio Resource Control (RRC)

Used for setting up, reconfigure and reestablish radio bearers.

- Cell Broadcast Service (CBS) control.
- Initial cell selection and cell re-selection.
- Paging.
- Broadcast of information:
  - related to the non-access stratum (Core Network).
  - related to the access stratum.
- Establishment, maintenance and release
  - of an RRC connection between the UE and UTRAN.
  - of Radio Bearers.
- Assignment, reconfiguration and release of radio resources for the RRC connection.
- Control of requested QoS.
- UE measurement reporting and control of the reporting.
- RRC message integrity protection.
- Arbitration of radio resources on uplink DCH.
- Slow Dynamic Channel Allocation (DCA) (TDD mode).
- Timing advance (TDD mode).
- RRC connection mobility functions (RNC relocation).
- Outer loop power control.
- Control of ciphering.

RRC logical architecture
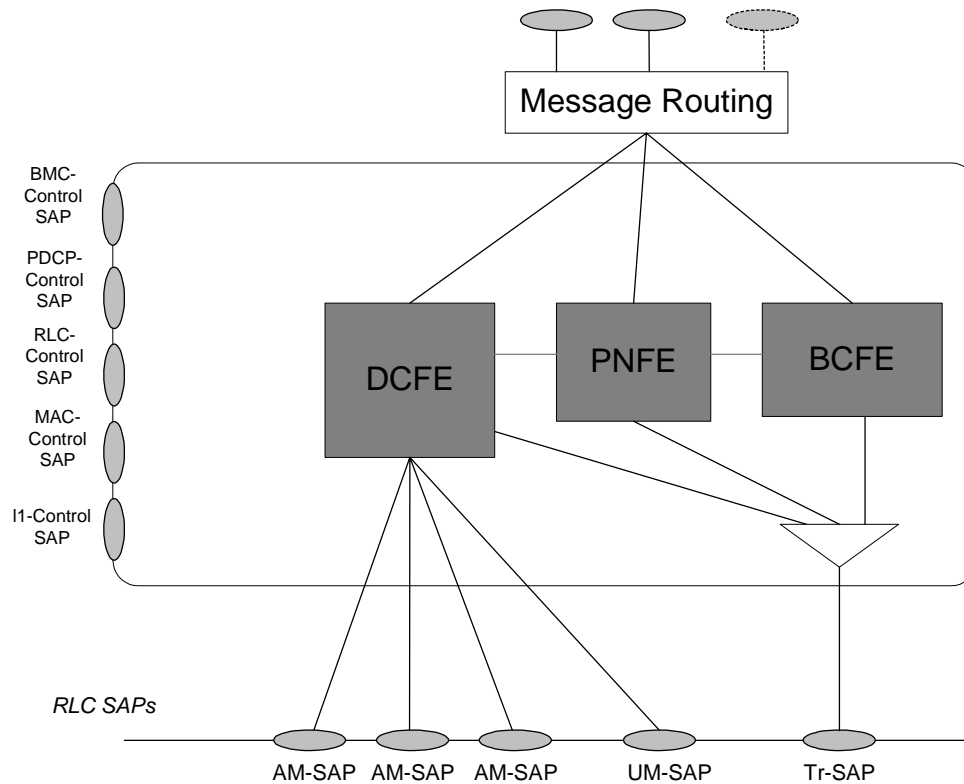
- Dedicated Control Functional Entity (DCFE): Handles functions and signalling specific to UE. One DCFE entity for each UE.

- Paging and Notification control Functional Entity (PNFE): paging of idle mode UE. At least one PNFE in the RNC for each cell.

- Broadcasting Control Functional Entity (BCFE): handles the broadcasting of system information. There is at least one BCFE for each cell in the RNC.

RRC states and state transitions including GSM
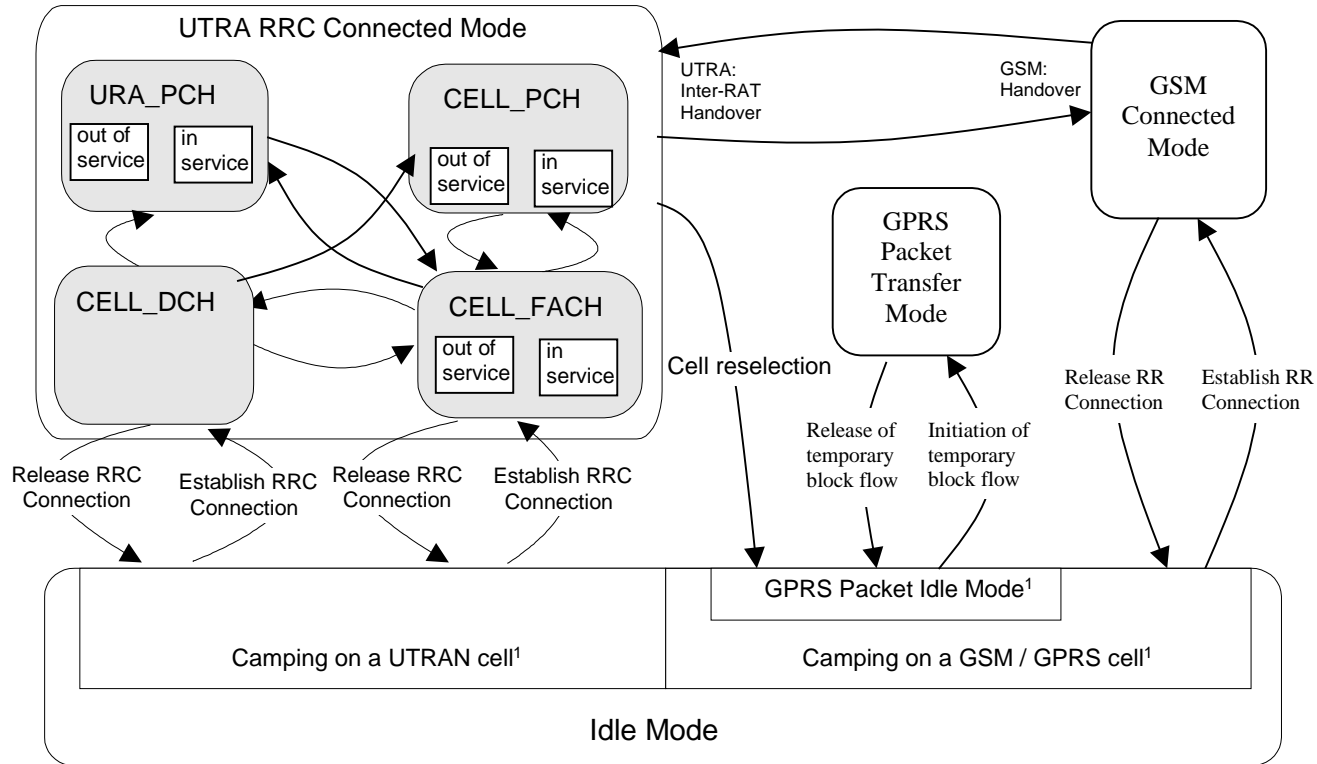
RRC service states

- Idle Mode:
  - After UE is switched on it will camp in the a suitable cell. After camping:
  - User is able to send and receive system and cell broadcasting information.
  - In the idle mode until it transmits a request to establish RRC connection.

- Cell_DCH
  - Entered from Idle Mode or by establishing a DCH from the Cell_FACH state.
  - DPCH and physical downlink shared channel (PDSCH) is allocated to UE.
  - UE is in this mode until explicit signalling for Cell_FACH.

- Cell_FACH
  - No dedicated channel allocated. Data transmitted through RACH and FACH.
  - UE listens BCH.
  - Cell reselection is performed (RNC is informed).

- Cell_PCH
  - UE known at a cell level but can be reached via PCH.
  - Usel listens BCH, some terminals also BMC.
  - In case of Cell reselection automatically moved to Cell_FACH state.

- URA_PCH
  - UE executes the cell update procedure only if the UTRAN Registration Area is changed.
  - DCCH can not be used in this state, all the activities initiated by the network through the PCCH or RACH.