



*Master Degree in Telecommunications Engineering*

*“Mobile Radio Networks” Class*

4 – From 2G to 3G (part 3)

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## Mobile Radio Networks

- UMTS (Universal Mobile Telecommunications System)

## Evolution towards UMTS

- The **3G** started its evolution with UMTS that presents **several novelties** with respect to 2G technologies, but also **share with them several elements and features**
- The main **novelties** are in the RAN and include the **new CDMA radio interface, soft-handover, the concepts of bearer services and access and non-access stratum** (later inherited by LTE), etc.
- The main **commonalities** are in the **core network** architecture and functionalities (already mentioned), and **signaling procedures**
- The UMTS is the technology that started the standardization process under the **3GPP organization** that continues for all technologies (from 2G to 5G) under periodic releases (the first Rel.99, then Rel. 4, Rel. 5, ..., Rel. 8 (first of LTE), ..., Rel. 15 (first of 5G), ...)

## Evolution towards UMTS

- Conceived in Europe and standardized as an evolution of GSM
- First studies and research at the beginning of the 90s – funded by the European Community (RACE, ACTS, ... projects)
- In 1998 the CDMA technique was chosen for radio access
  - W-CDMA: FDD with symmetrical bands
  - TD-CDMA: TDD on the same band (for asymmetric and picocell services)

## Evolution towards UMTS

- At the end of 1998, 3GPP was born and standardization moved to this forum ([WWW.3GPP.org](http://WWW.3GPP.org)):
  - ETSI (Europe), ARIB and TTC (Japan), TI (USA), TTA (Korea), CWTS (China).
- 3GPP bases the evolution of UMTS on the GSM core network
- 3GPP specifications are implemented by participants (ETSI in Europe)
- In parallel, a similar forum (3GPP2) takes care of the standardization of CDMA2000, the evolution of UMTS in the U.S.A.
- An attempt is made to make the two systems interoperate

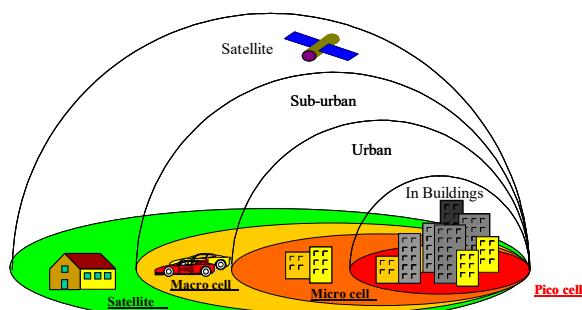
## Key peculiarities of UMTS

- Both W-CDMA and TD-CDMA have a 5 MHz channelization.
  - Chip rate of 3.84 Mchip/s
- In China, there is a narrowband TC-CDMA version (1.6 MHz channels)
  - Chip rate of about 1.2 Mchip/s
- 2 Mbit/s for MS stopped or almost, close to base radio station (not available in the first versions)
- 384 Kbit/s for MS in urban environment with mobility up to 50/60 Km/h
- 144 Kbit/s per MS in rural and automotive speeds (up to 150 km/h)
- The possibility of supporting speeds of up to 500 km/h for high-speed vehicles has also been investigated

## Key peculiarities of UMTS

- introduction of **flexible pricing**, depending not only on the duration of the connection but also on the **amount of data transferred** and the **quality** of service required;
- offer of **new transport speeds** depending on the service environment and mobility characteristics.
- *Channel access*: W-CDMA (profoundly different from previous systems)
- *Terrestrial segment*: it inherits a lot from GSM and GPRS and tends to integrate all existing 2G networks

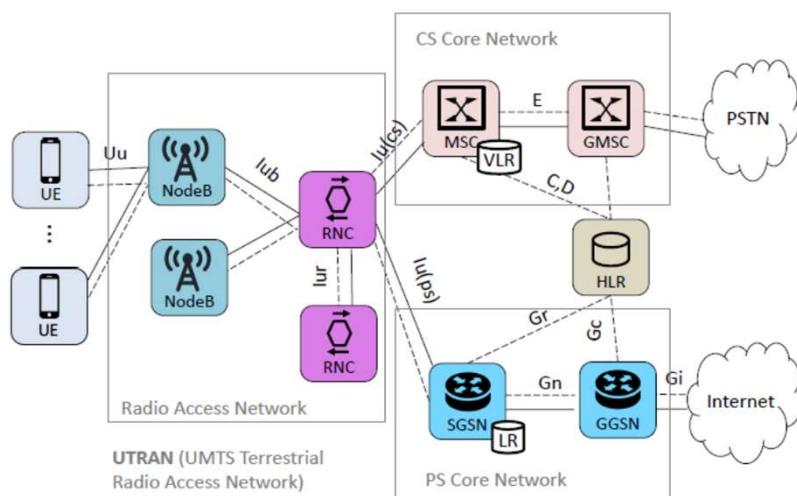
## UMTS coverages



## UMTS architecture

- The UMTS architecture mainly introduces a new RAN, the UTRAN (UMTS Terrestrial Radio Access Network), while it reuses the Core Networks of 2G with minimal modifications
- It also introduces the separation of signaling protocols and procedures related to the **radio access networks (AS – Access Stratum)** e those related to the **core network (NAS – Non-Access Stratum)**, so that to allow future evolutions of the core network independent from the access network

## 3G architecture



## UMTS Network elements

- **USIM** is a SIM-like smart card that stores subscriber information, authenticates, stores authentication and encryption keys
- **User Equipment** allows the use of TLC services
- **Access network (UTRAN)** composed of a set of network nodes that manage system resources and assign them dynamically to whoever requests them
- **Core network** or carrier network includes both a PS and a CS part
- **External networks** can be both CS and PS

## UMTS Network elements

- UTRAN manages the radio functionalities
- Core Network does switching, routing, connection with external networks
- User devices interface with the user and with the radio interface of the access network
- User equipment and UTRAN implement totally new protocols designed for the new WCDMA technology
- The core network, on the other hand, is based on what has been created for GSM so that it can be easily and quickly integrated with what is already widespread and consolidated

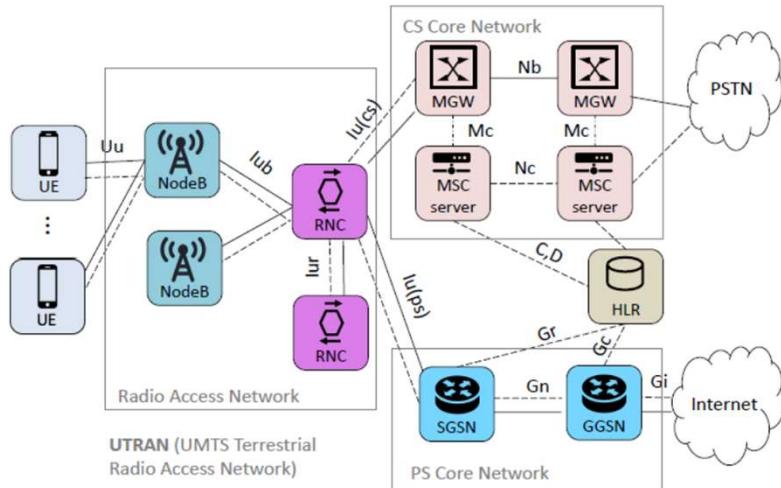
## UMTS architecture: RAN elements

- **Node-B:** it is the UMTS base station, and it is responsible for all functions required for sending and receiving data over the air interface based on CDMA. This includes channel coding, spreading and de-spreading of outgoing and incoming frames, as well as modulation. Node-B is also responsible for the power control of all connections.
- **RNC (Radio Network Controller):** it is the main element of the UTRAN and is responsible for controlling both radio resources of all Node-Bs connected and mobility. Due to additional functionalities, like soft-handover, enabled by the CDMA radio interfaces, it has more functions than the BSC in GSM, and an additional inter-RNC interface.

## UMTS architecture: interfaces

- **Radio interface (Uu):** it is based on CDMA and is the main novelty of UMTS. At the first introduction of UMTS both voice and data services were based on dedicated physical channels (dedicated spreading code). Later, the data services moved to a shared channel approach with HSPA (see later)
- **Iu interfaces:** the other interfaces of the RAN were initially based on telephone trunks E1, but gradually they have been replaced with IP technologies both for voice/data transport and signaling.
- This has required also an architectural change in the CS Core network 

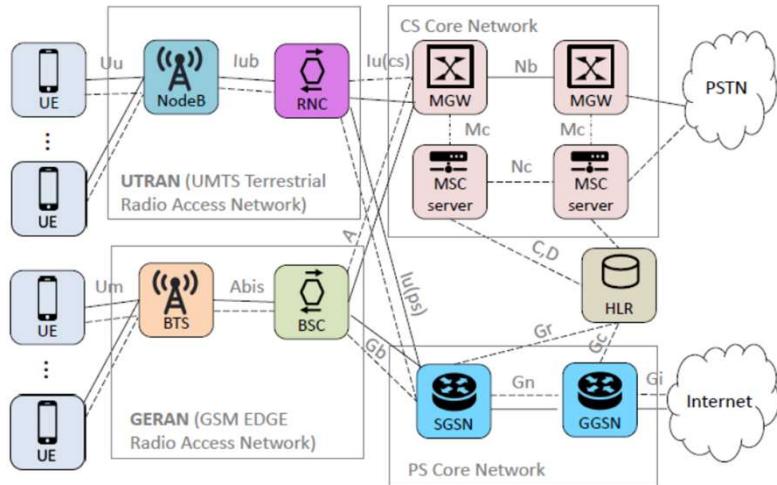
## 3G architecture: all IP transport



## 3G architecture: all IP transport

- **MGW (Media Gateway):** it replaces the circuit-based switching element of the MSC with an element able to transport media on flows of IP packets
- **MSC Server:** it implements all signaling functions of MSC and it also controls the MGW instructing it to create media flows
- **Interfaces:** they are based on IP transport and use adaptation protocols to transport media and signaling
- The final 2G and 3G architectures is fully integrated →

## 2G and 3G integrated architecture



## UMTS bearer services

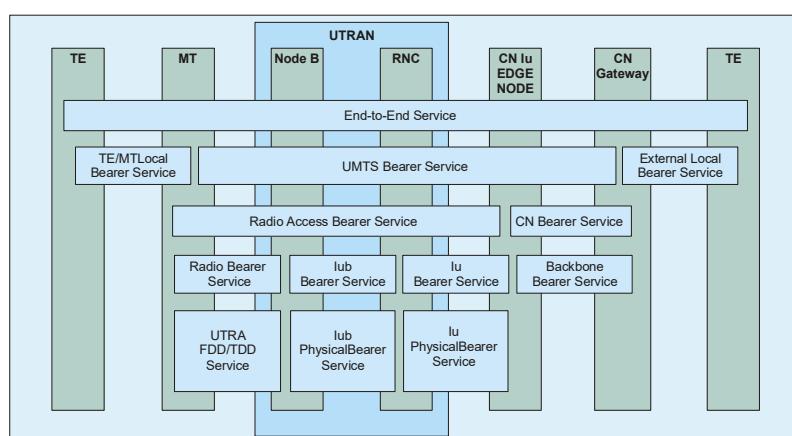
- Services are considered end-to-end when they are guaranteed from one terminal to another. Each end-to-end service is characterized by a certain quality of service (QoS), provided to the user by the network.
- To implement a network level QoS it is necessary to establish a transport service (Bearer Service) from the source to the recipient of the service.
- A Bearer Service includes all aspects necessary to guarantee the required quality of service. These include: signaling, transport of user data, and QoS management features.

## UMTS bearer services (2)

- A UMTS bearer is divided into the radio access bearer (RAB) and the core network bearer
- The RAB is further divided into the radio bearer and the Iu bearer
- Before data can be exchanged between a user and the network it is necessary to establish a RAB between them. This channel is then used for both user and signaling data.
- A RAB is always established by request of the MSC or SGSN.
- In contrast to the establishment of a channel in GSM, the MSC and SGSN do not specify the exact properties of the channel. Instead, the RAB establishment requests contain only a description of the required channel properties.

## UMTS bearer services (3)

- UMTS presents a layered architecture of the transport services: the N-level Radio Bearer offers its service using the services provided by the radio bearers of the (N-1) levels below



## UMTS services and QoS classes

- The end-to-end service used by the user is therefore created as a combination of:
  - a TE/MT local Bearer Service,
  - a UMTS Bearer Service
  - and an External Bearer Service.

**But we are interested in describing the peculiarities of UMTS!**

**So, the focus is only on UMTS Bearer Service which introduces the concept of quality of service (QoS) in UMTS**

- It consists of two elements:
  - **Radio Access Bearer (RAB) service** - guarantees the transport of information on the radio interface ensuring the requested QoS.
  - **Core Network Bearer (CNB) service** - carries the service outside the UMTS system.

## UMTS services and QoS classes

**Four different classes of QoS are defined:**

• **Conversational class:**

- Used to carry **real-time traffic**. Typical services of this class are: voice, voice over IP and videoconferencing.  
Characterized by a very low transfer delay, a limited variation of this delay, the maintenance of temporal relationships between the various entities of the data flow.

• **Streaming class:**

- Used to transport **both audio and video one-way real-time traffic**.  
Characterized by the maintenance of the temporal relationships between the various entities of the data flow and by a limited (but higher than the previous) variation of the delay. However, there are no requirements aimed at keeping the transfer delay low.

• **Interactive class:**

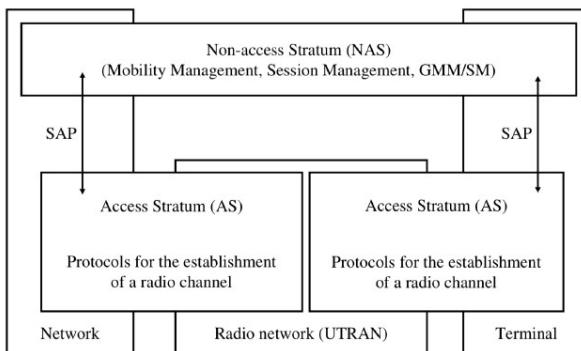
- It is used when a user requests **data from a remote device**.  
Examples are: web browsing, database research and access to a network server.  
Characterized by a low round trip delay and data transfer with a low error rate.

• **Background class:**

- Used when a computer sends or receives **data files in the background**.  
Examples: Email, SMS, downloading information from a database. It is the least sensitive class to delivery time but which requires maximum reliability and integrity on data transmission.

## UMTS access stratum and non-access stratum

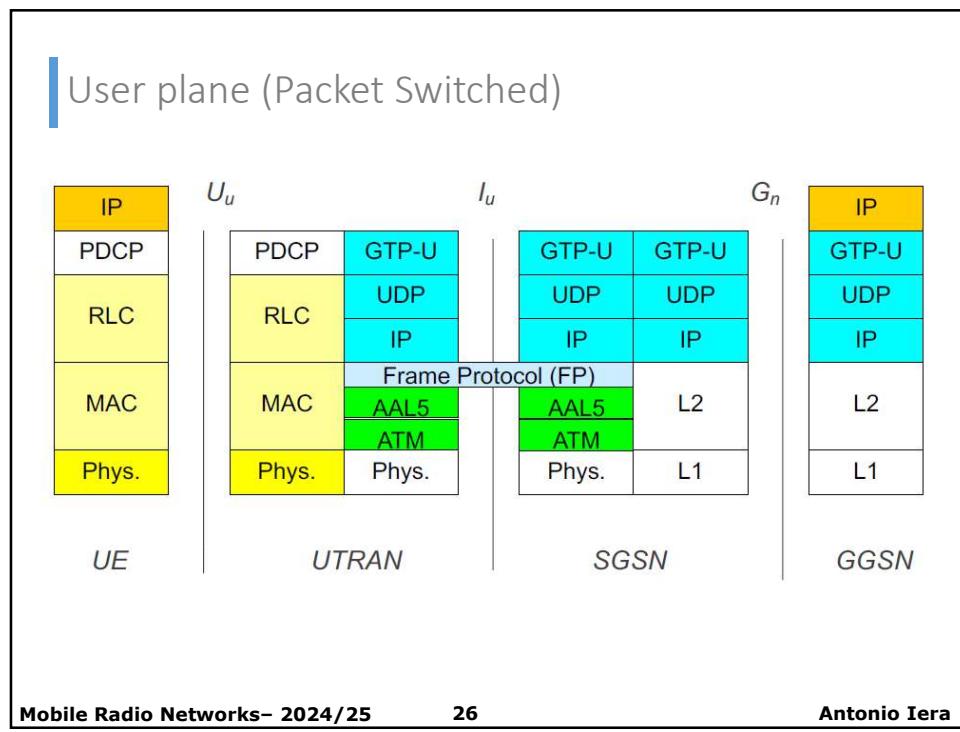
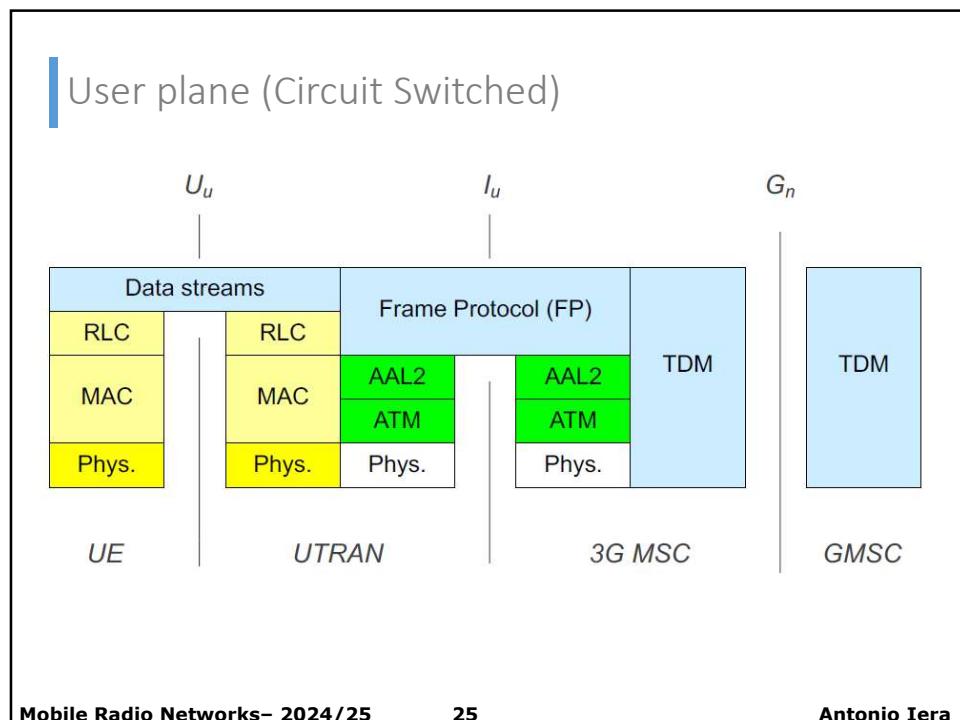
- UMTS separates functionalities of the core network from the access network, so that to **independently evolve** the two parts of the network
- To this purpose, UMTS strictly differentiates between signaling functionalities of the **Access Stratum (AS)** and the **Non-Access Stratum (NAS)**

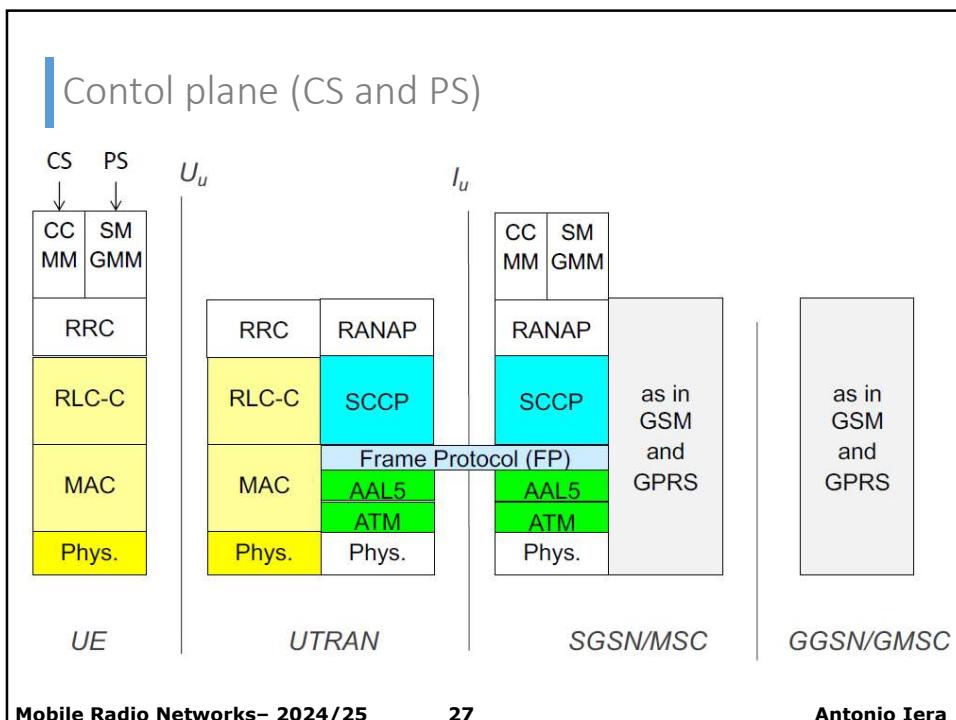


- SAPs between NAS and AS are:
  - notification SAP (e.g. for paging)
  - dedicated control SAP (e.g. for RAB setup)
  - general control SAP (e.g. for modification of broadcast messages, optional).

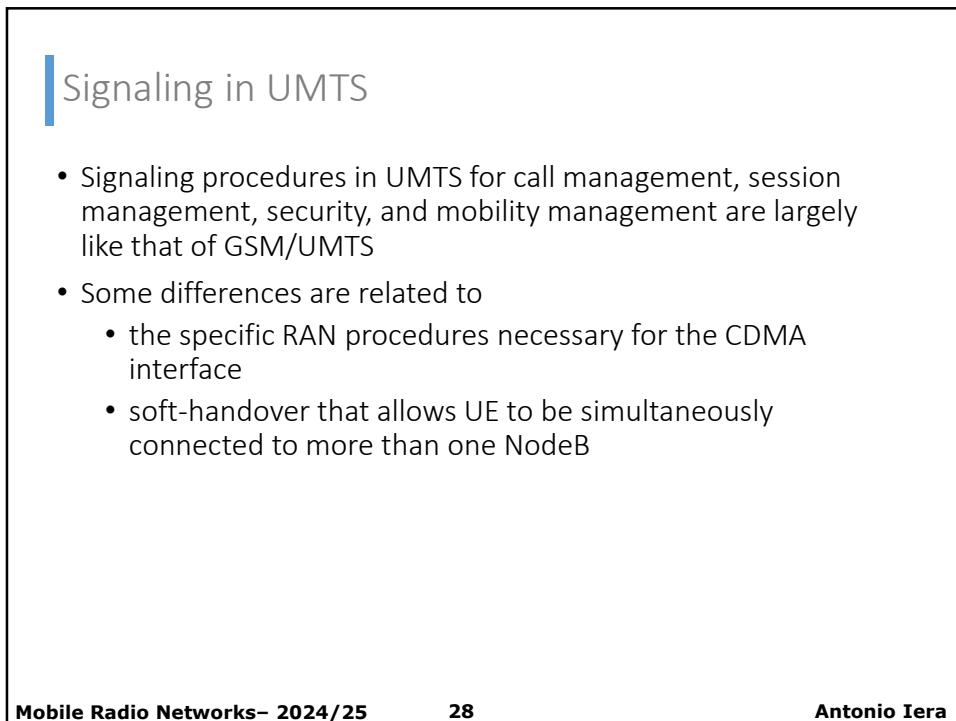
## UMTS Protocols

- Different protocol stacks for user and control plane
- User plane (for transport of user data):
  - Circuit switched domain: data within "bit pipes"
  - Packet switched domain: protocols for implementing various QoS or traffic engineering mechanisms
- Control plane (for signalling):
  - Circuit switched domain: SS7 based (in core network)
  - Packet switched domain: IP based (in core network)
  - Radio access network: UTRAN protocols





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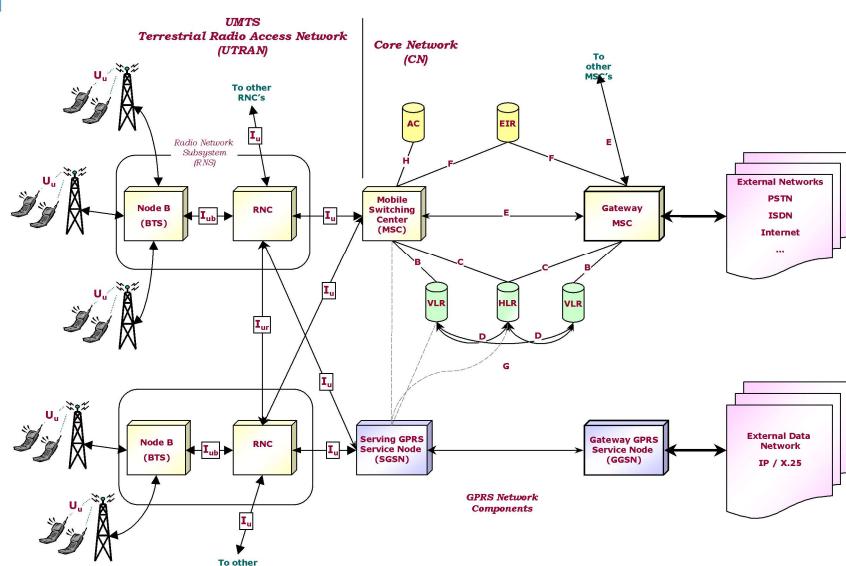


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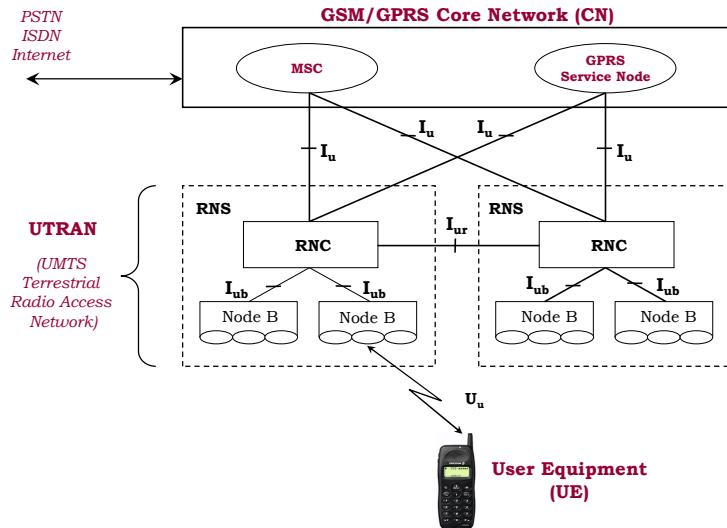
## Mobile Radio Networks

### □ UMTS - UTRAN

## WCDMA/UMTS Architecture



## UMTS Access Network (UTRAN) Architecture



## UMTS Access Network (UTRAN)

### Definitions related to the UTRAN

- **RNS (Radio Network Sub-system)**
  - A subnet that allows the access between UE and Core Network
  - Contains an RNC
- **RNC (Radio Network Controller)**
  - The element of the RNS that controls physical radio resources
- **Node B**
  - Logical node that controls Tx & Rx of traffic from one or more cells
- **U<sub>u</sub> Interface**
  - Interface between UE and Node B
- **I<sub>u</sub> Interface**
  - Interface between CN and RNS
- **I<sub>ur</sub> Interface**
  - Interface between two RNS
- **I<sub>ub</sub> Interface**
  - Interface between RNC and Node B

## UMTS Access Network (UTRAN)

- The UTRAN consists of a set of *Radio Network Subsystems (RNS)* connected to the *Core Network* through the " $I_u$ " interface.
- Functionally, this interface has a double value as it integrates both the interface that connects the UTRAN to the circuit CN (Circuit Service) and the one that connects the UTRAN to the packet CN (Packet Service).
- An RNS comprises a *Radio Network Controller (RNC)* and one or more *Node Bs*.
- A *Node B* is connected to the RNC through the " $I_{ub}$ " interface and supervises a set of cells that can support both transmission modes (FDD and TDD).
- Within the UTRAN, different RNCs can be connected to each other via the " $I_{ur}$ " interface.

## UMTS Access Network (UTRAN)

- This architecture provides the ability to manage mobility within the UTRAN.
- In fact, both *Node B* and the *RNC* are able to manage handover and macrodiversity. These features can be coordinated at the level of:
  - *Node B* (in the case of cells belonging to the same Node B),
  - *RNC* using the " $I_{ub}$ " interface (in the case of cells belonging to different Nodes B but controlled by the same RNC) or the " $I_{ur}$ " (in the case of cells belonging to different RNS).
  - *Between different RNS* the handover can also be performed via the CN (using the " $I_u$ " interface)
- Each RNS is responsible for the resources of its set of cells. For each connection between UE and UTRAN, there is an RNC defined as Serving RNC, whose task is to establish and manage the existing connection.
- In case of a temporary shortage of radio resources it is possible for the *S-RNC* to be supported by another RNC, called Drift RNC. The latter must be able to provide a certain number of resources to the former.

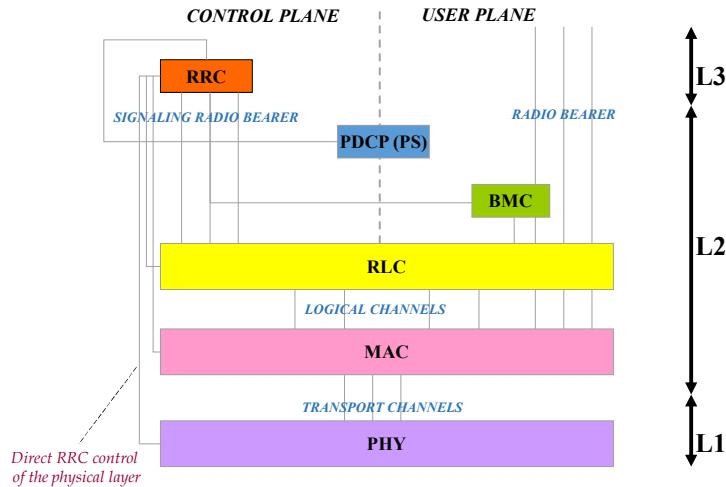
## The functions of UTRAN

- *User data transfer* - this function allows user data to be transferred through the UTRAN between the “I<sub>u</sub>” and “U<sub>u</sub>” interfaces.
- *System access control functions* - allow the user to connect to the UMTS network in order to use the services offered. Access to the system can be done both from the mobile terminal and from the network.
- *Encryption and decryption of radio channels* - must protect transmitted data from unauthorized interceptions. This feature is localized in the EU and UTRAN.
- *Mobility* related features
- Functions related to the *management and control of radio resources*

## Mobile Radio Networks

### ❑ UMTS Radio Interface

## General architecture of the radio interface



## General architecture of the radio interface

- The radio interface can be divided into three levels:
  - the Physical level (or level 1);
  - the Data Link layer (or layer 2);
  - the Network level (or level 3).
- The levels are conceived with a division into two planes: the *control plane* (signaling information) and the *user plane* (information deriving from the user service).
- Since levels 1 and 2 offer a transport basis for both signaling and user information, they are *transversal to both Control and User planes*.

## General architecture of the radio interface

- Level 2 is in turn divided into the following sub-levels:
  - Medium Access Control (MAC),
  - the Radio Link Control (RLC),
  - the Packet Data Convergence Protocol (PDCP)
  - and Broadcast/Multicast Control (BMC).
- The PDCP and BMC levels exist only in the user plan.

## General architecture of the radio interface

- Level 3 is also divided into a control and user plan.
- It is basically responsible for managing signaling, therefore
  - it is placed entirely in the control plane.
- In the control plane the network layer can be divided into sub-layers:
  - The lowest one is called *Radio Resource Control (RRC)* and interfaces with layer 2 and terminates in the UTRAN. Must be able to manage and control lower levels and to obtain input parameters for Radio Resource Management (RRM) procedures.
  - The upper sublevel instead provides "*Duplication avoidance*" functionality and ends in the Core Network. It provides services to higher levels such as:
    - Mobility Management (MM) and Call Control (CC)

## Physical layer of UMTS Radio Interface (CDMA)

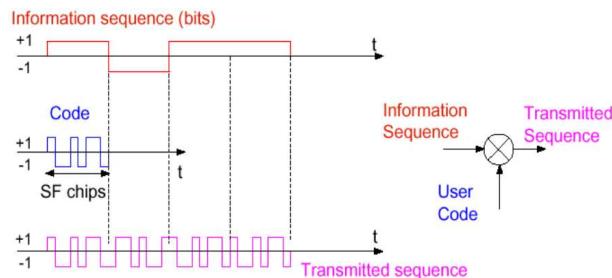
- The radio interface of UMTS is based on CDMA and carriers of 5 MHz bandwidth (much larger than the 200 kHz of GSM, that's why it was called Wideband CDMA)
- The basic principle of UMTS with its first releases was the use of dedicated channels (codes) to users not only during calls but also data sessions (and their inactivity periods)
- Being capacity affected by average interference only this was assumed to be an efficient approach with respect to GSM/GPRS
- Later, due to difficulties in achieving high rates for data sessions in downlink, this approach was abandoned and replaces channel sharing for high-speed services

## Physical layer functionalities: "spreading" and "scrambling"

- With spreading it is possible to separate the various users
- Since the channeling codes are limited in number to be able to reuse them, scrambling is used to separate the various cells from each other
- Scrambling consists in considering suitable pseudo-random sequences long enough and taking only a part of them; taking different pieces of sequence or having random starts will result in unrelated sequences
- Scrambling operations performed after spreading do not change the bandwidth

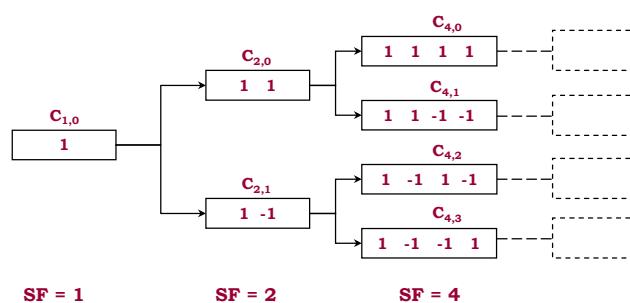
## Physical layer functionalities: "spreading"

- The number of chips in the spreading code is called Spreading Factor (SF). The chip rate in UMTS is 3.84 Mcps.
- Services requiring low transfer speeds will use longer codes, while higher speed users will use shorter codes.



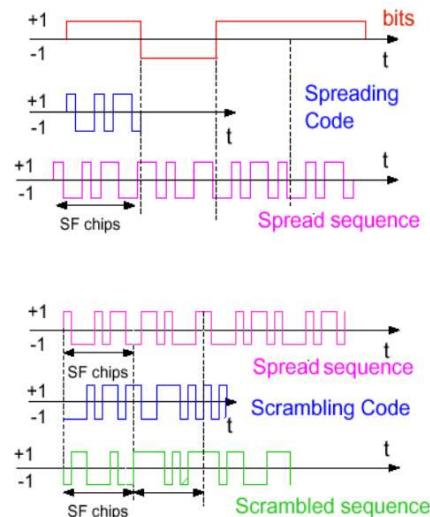
## Physical layer functionalities: "spreading"

- The orthogonal spreading codes are generated with different lengths using the OVSF (Orthogonal Variable Spreading Factor) tree.
- The Spreading Factor (SF) is equal to the number of codes



## Physical layer functionalities: "scrambling"

- Spreading codes of the same transmitter are mutually orthogonal
- Code of different transmitters have low cross correlation regardless of the time offset
- With scrambling I can spread several signals using a single channelization code
- the bit rate of the signal to be transmitted is maintained at 3.84 Mchip/s.



## Relationship between user rate and applied SF

Net user rate (Kbit/s)	Redundancy*	Gross user rate (Kbit/s)	Applied SF	Chip rate (Mchip/s)	Processing Gain (dB)
9,6	1,56	15,0	256	3,84	26,02
12,2	1,23	15,0	256	3,84	24,98
24,4	1,23	30,0	128	3,84	21,97
48,0	1,25	60,0	64	3,84	19,03
96,0	1,25	120,0	32	3,84	16,02
171,0	1,40	240,0	16	3,84	13,51
384,0	1,25	480,0	8	3,84	10,00

(\*): bit rate increase for CRC insertion, convolutional coding for transmission protection, bit rate adaptation

## Procedures envisaged at the physical level

- Closed loop power control (fast power control)
- Paging
- Random Access
- Handover measures
- Transmission diversity

## Fast power control (1/3)

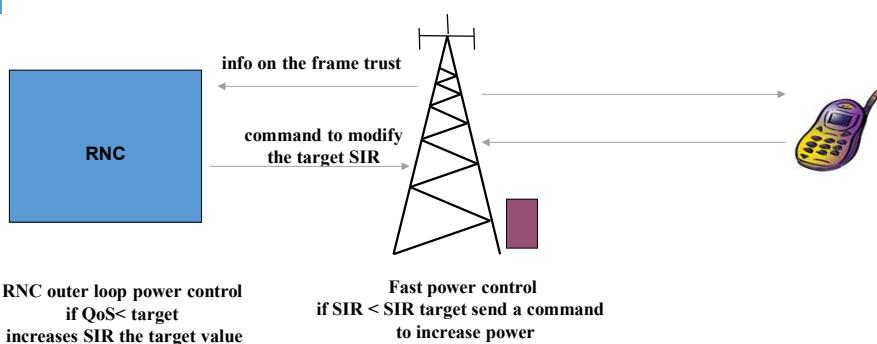
### In UPLINK

- What purpose does it serve? Fixes the near-far effect
- The Serving BS sends a command each slot, after the SIR estimate, at a frequency of 1500 Hz. The granularity of the command is 1dB
- A particular situation is the one in which power control is carried out together with the soft handover (+ stations send commands together to a single terminal)
- With soft handover if the terminal receives multiple commands, combines them, estimates the reliability of each command and then increases or decreases the power accordingly

## Fast power control (2/3)

- Fast power control is also related to the *outer loop power control*
- The *outer loop power control* takes care of choosing the value of the target SIR at the base stations according to the QoS objective in terms of BER or the needs of the particular route also considering the mobile speed

## Outer Loop Power Control



- The Serving BS tags each uplink user frame with a trust indicator
- If the indicator signals the RNC that the quality is decreasing -> RNC orders the SRBs to increase the SIR target

## Fast power control (3/3)

### In DOWNLINK

- It is used not to solve the near-far effect but to adjust the power depending on whether you are transmitting to a mobile located on the edge of the cell or not
- Edge nodes have + interference from adjacent cells as well
- Weaker signals that are more affected by fading must be boosted because otherwise simple error correction methods will not correct the data

## Handover

**Inter-system handover:** *handover between different networks.*

E.g. a UMTS user switches to the GSM/GPRS network when the coverage conditions do not allow maintaining the connection on the UMTS network.

- This type of HO is only possible for services also supported by the 2G/2G+ network and clearly, for data transmissions, the user will be affected by the lower transmission speed that these networks can reach.
- Only possible using multi-standard terminals

**Intra-mode handover:** *handover performed within the UMTS network.*

This feature allows a UMTS user to receive the needed communication resources within the same network. Intra-mode Handover is managed by the UMTS network leveraging the possibility of providing the service using more than one radio link for the same user (Macrodiversity).

In this mode, two main HO procedures are identified that the network can use:

- Soft handovers
- Softer handovers

## Soft and Softer Handover (1/2)

- A UMTS user can be served by multiple cells simultaneously.
- This functionality (*Macrodiversity*) is possible using **Rake Receivers**, which can extract the same signal coming from different sources, since it considers them as different paths of the same signal due to the *multipath* effect, and combine them.

### Soft/Softer handover

- All cells and their respective Nodes-B involved in the Soft/Softer handover form an "Active Set" (AS).
- The maximum size that an AS can have is determined by the parameters fixed on the network, as well as by the maximum number of fingers equipped on the rake receiver.
- With macrodiversity, the user's mobility is ensured in a "soft" way, without therefore having to release the resources of a cell before receiving service from the other adjacent ones.

## Soft and Softer Handover (2/2)

### **Softer Handover:** connection involving two cells of the same Node-B

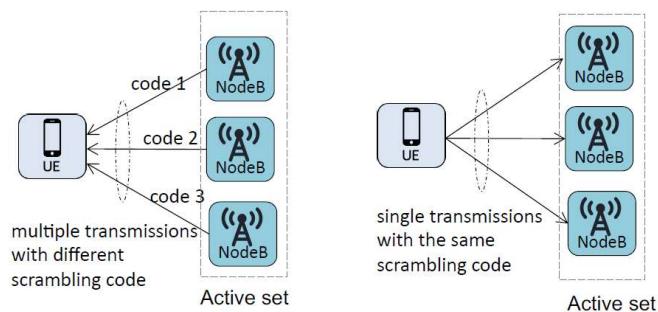
- The communication between mobile and Serving BS uses 2 channels and 2 codes for each interface at the same time
- Typically applies to 5-15% of connections

### **Soft Handover:** the connection uses cells belonging to different Nodes-B.

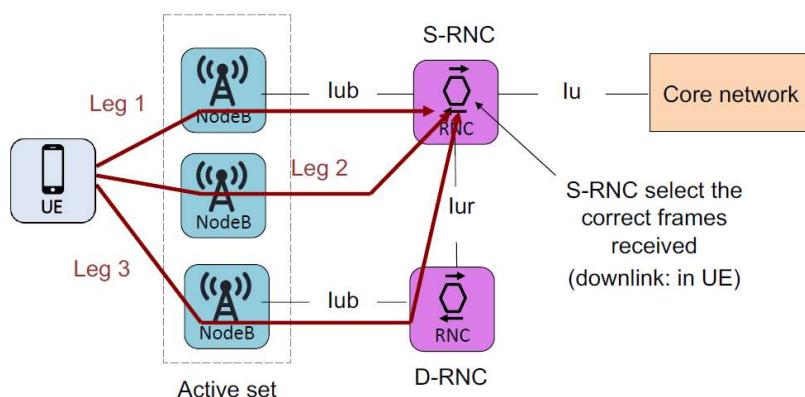
- In uplink data received by the two SBSs are forwarded to the RNC to be suitably combined
- Soft handover applies to 20-40% of connections
- If an Active Set is composed of Nodes-B controlled by different RNCs, the connection can be maintained by exploiting the Iur interface, and only one RNC will have the task of managing the user control (SRNC), while the others (DRNC) will be driven by it

## Soft handover illustrated

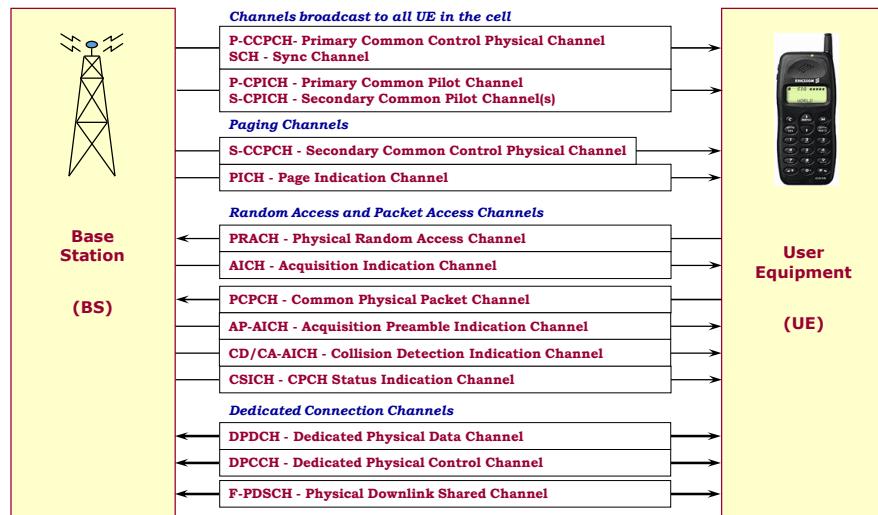
- Soft-handover allows some UEs to stay connected to multiple NodeBs in an Active Set defined by RNC
- In **uplink** transmissions are received by multiple NodeBs and the first correct one is selected
- In **downlink** multiple transmission are performed by NodeBs and the first correct is selected



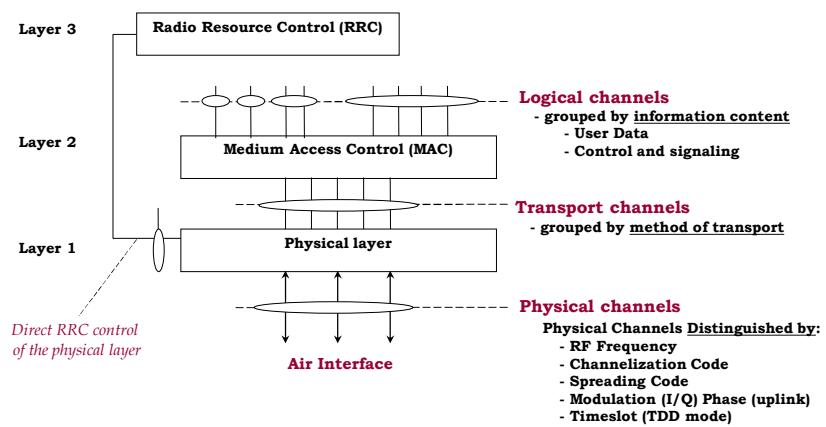
## Soft handover illustrated



## Physical Channels



## Channel mapping



## The physical layer of the Radio Interface: further details

- The data unit of the physical layer is the Transport Block (TB) which corresponds to a certain amount of data and relative coding parameters (code rate, CRC, etc.)
- For some types of channels, sets of TBs called Transport Block Sets (TBS) can be specified
- MAC layer entities exchange TB through transport channels mapped to physical ones

## Transport channels

- Transport channels are the services offered by layer 1 to the higher layers. They can be grouped into two types
  - Common transport channels: the information is transmitted without distinction to all mobile terminals. An identification of the UE is therefore required.
  - Dedicated transport channels: communication takes place towards a single terminal by associating a particular physical channel (code and frequency in FDD mode, frequency code and time slot in TDD mode).

## Transport channels of the “common” type

- *Random Access Channel (RACH)* - It is an uplink contention channel for the transmission of a relatively small amount of control data such as requesting access to the physical medium to initiate a communication. Short data packets can be associated with the transmitted message.
- *Common Packet Channel (CPCH)* - It is an uplink contention channel for the transmission of data traffic with a burst characteristic. It exists only in FDD mode and is shared by all users of a cell.
- *Forward Access Channel (FACH)* - It is used in downlink without closed loop power control for the transmission of a relatively small amount of data. It is characterized by the possibility of quickly changing the transmission speed.

## Transport channels of the “common” type

- *Downlink Shared Channel (DSCH)* - A downlink channel shared by multiple users to carry user or signaling data. Access is regulated by the base station.
- *Uplink Shared Channel (USCH)* - It is an uplink channel shared by several users, used only in TDD mode. It is used to transport user or control data.
- *Broadcast Channel (BCH)* - Used downlink to broadcast system information throughout the cell.
- *Paging Channel (PCH)* - Used to transmit downlink control information to a mobile whose location is not known. Some examples of disseminated messages are those of paging or notification of a change in the information disseminated on the BCH.

## Transport channels of the “dedicated” type

- *Dedicated Channel (DCH)*
- It is a channel used both uplink and downlink to carry user and control information between the mobile and the network. It is characterized by the possibility of changing the transmission speed each time frame

## MAC (Medium Access Control)

- The MAC is a sublayer of layer 2 of the protocol stack under consideration.
- The MAC is made up of several entities:
  - **MAC-b:** it is the entity that manages the BCH transport channel. There is one MAC-b entity in each UE and one for each cell of the UTRAN.
  - **MAC-c/sh:** Identifies the entity that controls the common transport channels listed here: PCH, FACH, RACH, CPCH, DSCH, USCH. There is a MAC-c/sh entity in each UE and one for each cell of the UTRAN.
  - **MAC-d:** is responsible for controlling the DCH logical channels and dedicated transport channels allocated to various users. There is one of these entities in each UE while in the UTRAN there are as many MAC-d as there are users connected to it.

## The Logical Channels

- To ensure data transfer at the higher levels, the MAC defines a series of logical channels, each characterized by the type of information it carries.
- *Control Channels*: For transferring control plan information.
  - *Broadcast Control Channel (BCCH)*
  - *Paging Control Channel (PCCH)*
  - *Common Control Channel (CCCH)*
  - *Dedicated Control Channel (DCCH)*
  - *Shared Control Channel (SHCCH)*
- *Traffic Channels* : For transferring user plan information.
  - *Dedicated Traffic Channel (DTCH)*
  - *Common Traffic Channel (CTCH)*

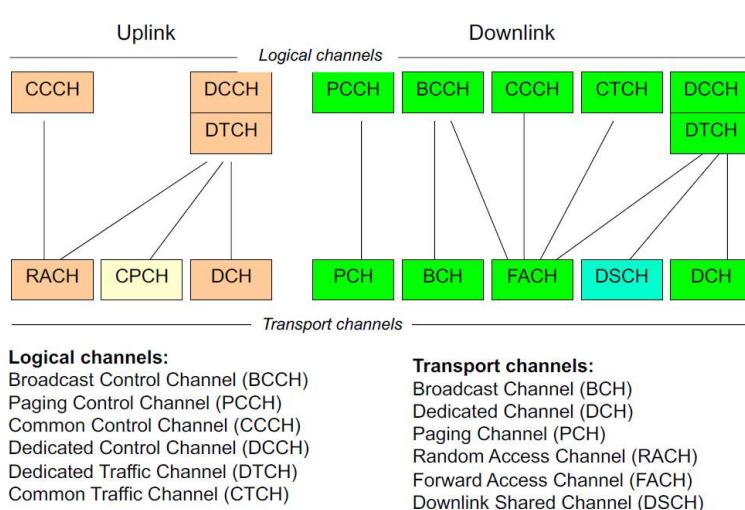
## MAC Functions

- *Mapping between transport channels and logical channels*: The MAC is responsible for **mapping** between logical channels and transport channels.
- *Transport format selection*: Once the Transport Format Combination Set (TFCS) has been assigned by the RRC, **the most appropriate transport format for each transport channel** is chosen based on the speed of the source.
- *Management of priorities between different data flows of the same UE*: the choice of the particular combination of transport formats within a TFCS can be made on the basis of the **priority of the data flow** to be sent on an appropriate transport channel. This allows to adequately assign speeds based on the priorities of the information flows.

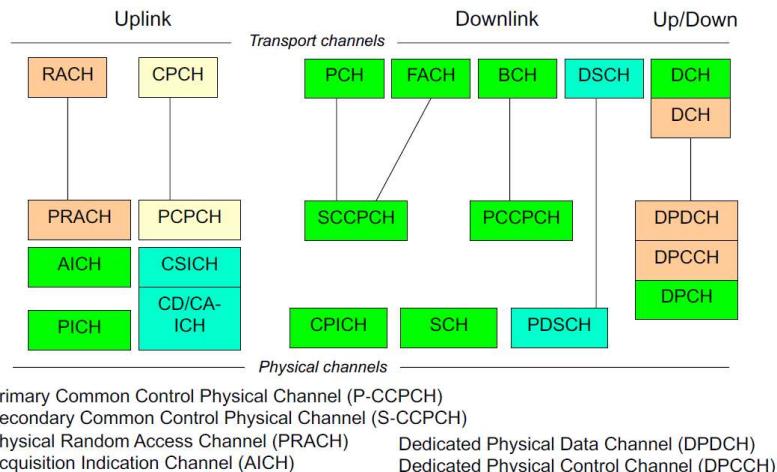
## MAC Functions

- *Switching Transport Channel Type:* This feature implements switching between common and dedicated transport channels based on decisions made by the RRC.
- *Encryption:* must prevent unauthorized acquisition of transmitted data

## Summary: Logical-to-Transport channel mapping



## Summary: Transport-to-Physical channel mapping



## The RRC layer: functions

- Information broadcast:** The RRC layer **broadcasts system information** from the network to UEs.
- RRC connection establishment, maintenance, and release:**
  - The establishment of an RRC connection **begins with a request from the higher levels of the UE to establish the first Signaling Connection** between the UE and the UTRAN.
  - Establishing an RRC connection **optionally includes cell reselection**, checking for connection acceptance and establishing links for layer 2 signaling. **The release of the RRC connection can be requested by higher layers, or by the same RRC** in case of failed connection attempt.
  - When an RRC connection is released, the UE can request the re-establishment of the RRC connection.
- Establishment, reconfiguration and release of Radio Bearers:** the RRC layer can, at the request of higher levels, establish, reconfigure and release Radio Bearers in the user plan.

## The RRC layer: functions

- *Radio resource allocation, reconfiguration, and release:* The RRC layer manages the allocation of radio resources to meet requests in both the user and control planes. This function in particular must allow the RRC to allocate radio resources to multiple Radio Bearers, related to a single RRC connection. Finally, the Radio Resource Control must be able to control the radio resources to achieve asymmetric communications between the UTRAN and the UEs, both uplink and downlink.
- *RRC connection mobility functions:* these functions include handover procedures, preparation for handovers to GSM or other networks, cell reselection and paging area updates.
- *Paging:* The RRC layer can broadcast paging information to interested UEs. These messages can also be sent during the establishment phase of an RRC connection.

## The RRC layer: functions

- *Routing of higher layer PDUs*
- *Required QoS Control:* This function must provide the required quality of service for a given Radio Bearer. Therefore, it must allocate an adequate number of radio resources.
- *Reception and control of measurements:* measurements made by the EU are fully controlled by the RRC level. That is, how, when and what to measure is all fixed by the RRC.
- *External loop power control:* this function defines the power level to be obtained with closed loop power control.
- *Encryption Control:* The RRC layer provides procedures for choosing encryption parameters between the UE and the network.