

Mobile Communications

Universal Mobile Telecommunication System

4. Universal Mobile Telecommunication System

4.1 New service paradigms for mobile communication

4.2 Bandwidth and Standard process for UMTS

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4.5 UMTS Core Network – IP integration issues

4. Universal Mobile Telecommunications System

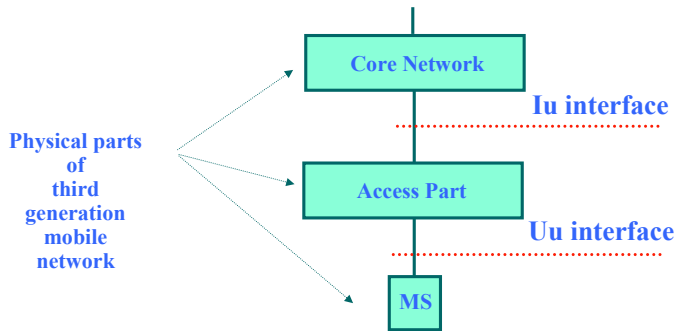
4.4 UMTS signalling and control functions

handover intra, intersystem
active set
mobility functions
access network protocols

extensions:

e4.5 access network protocols

The architecture of the Radio Access Network



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The need of proceeding through a clear splitting between the Radio Access Network (RAN) and the Core Network (CN) is universally accepted. This assumption has been rather important in the definition of the architecture and protocols of third generation mobile.

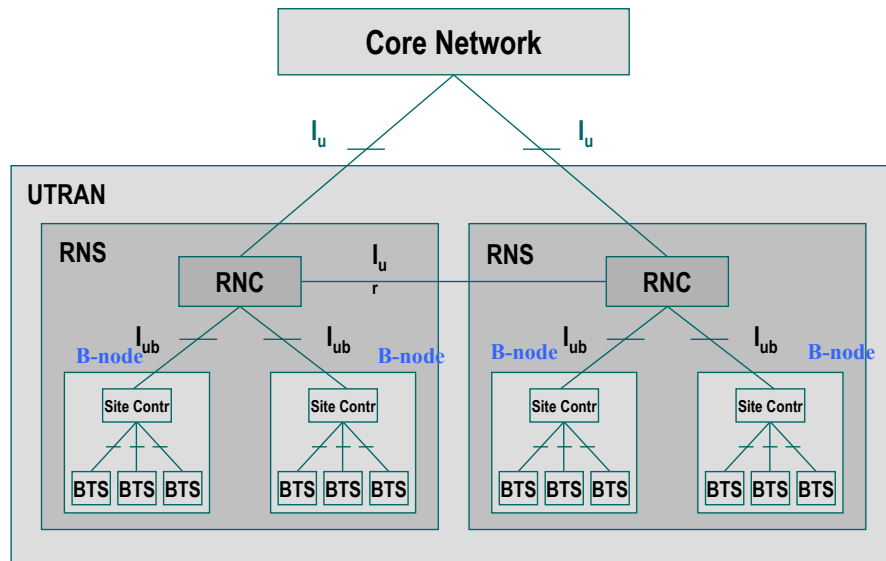
The above parts of the physical system identify the main interfaces: the radio interface (Uu) and the interface (Iu) between the Radio Access Network (RAN) and the Core Network (CN).

Typically, the access part is assigned the role of dealing with the radio resource control and related mobility functions; the control of handover and macro diversity processes is assigned to the access part as well.

The Core Network is taking care of the call control, service related functions and the upper mobility functions like location updating.

Third generation mobile functions associated with the access part and the core network are completely separated from the transport functions; in other words, the transport functions are not considered as a functional part of both RAN and CN.

UTRAN Architecture



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The figure depicts the architectural configuration of the Radio Access Network (RAN). It has been adopted by 3GPP for both the UMTS modes (FDD and TDD) UTRAN= UMTS Terrestrial Radio Access Network).

UTRAN is composed by several Radio Network Subsystems (RNSs) connected to the Core Network through the Iu interface.

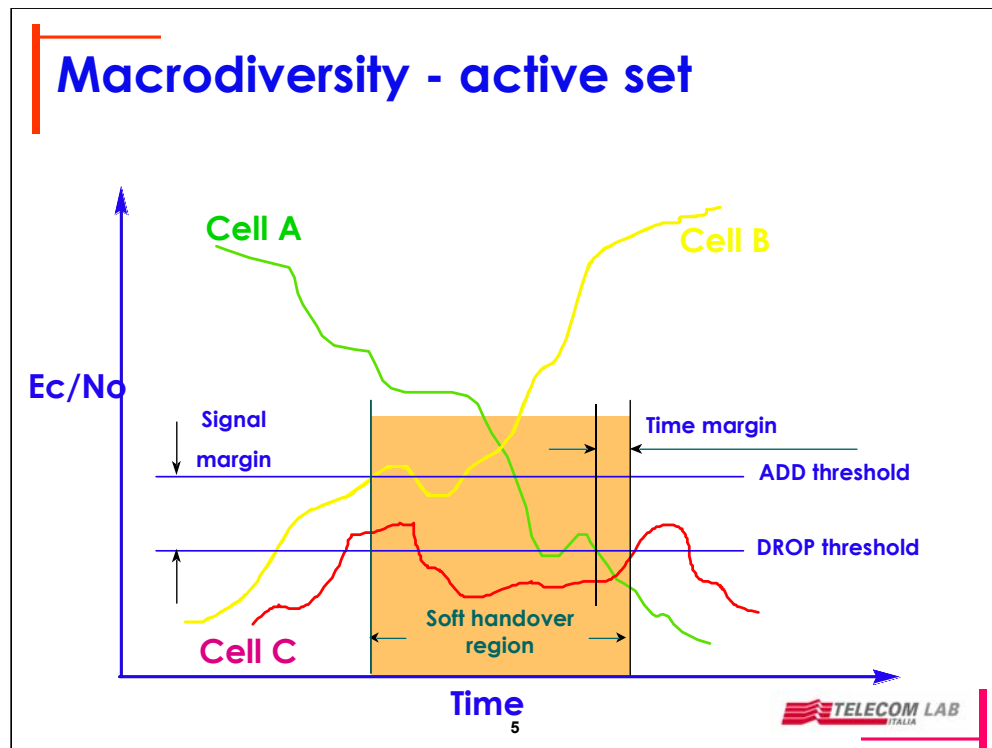
The RNSs can be directly interconnected through the Iur interface.

Every Radio Network Subsystem is composed of a Radio Network Controller (RNC) and one or more “B nodes”. These entities are responsible of the radio resource control of the assigned cells;

A B-node may contain a single BTS or more than one (typically 3) controlled by a site controller. The B node performs the softer handover mechanisms.

RNC is responsible for the local handover process and the combining/multicasting functions related to macro diversity between different B-nodes.

The above architecture is adopted as a model of the radio access segment to analyse how the main function allocation and architectural problems have been solved in third generation mobile systems.



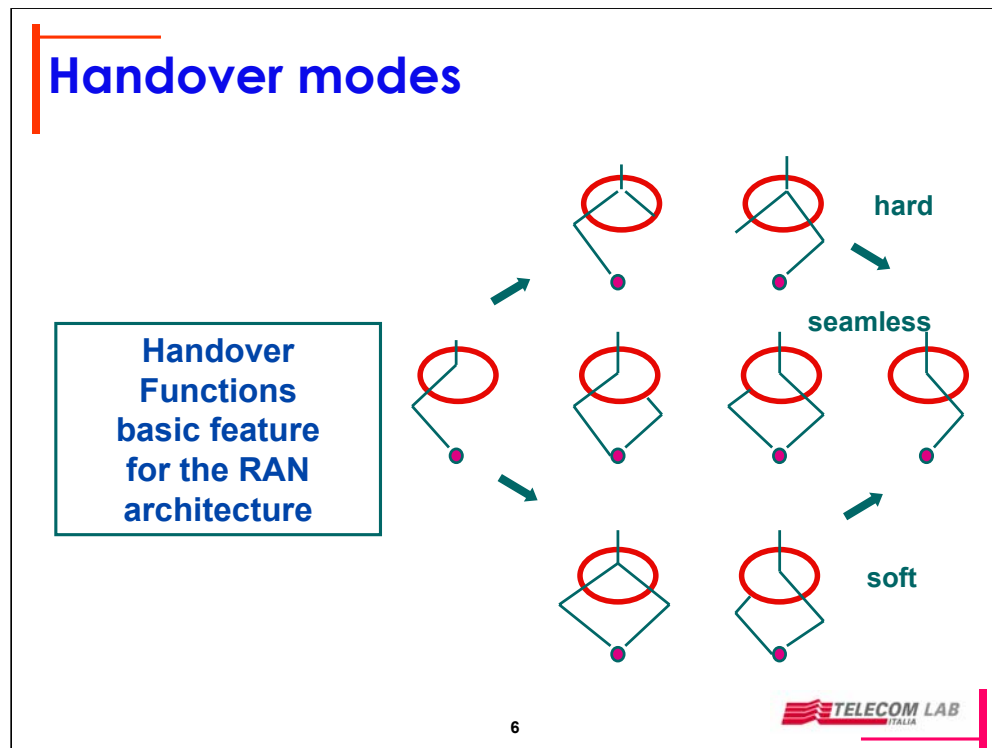
In line with its access characteristics, a CDMA system can implement the handover function in a completely asynchronous way; this “soft handover” functionality is enabled through the macro diversity mechanism.

A given connection which has been set-up between the mobile station and the network, may be active through more than one base station; this means that the same information data are transported on the radio interface through different channels which are activated with different stations.

The figure highlights the mechanism typically adopted to determine the set of stations (the active set) carrying the connection; the activation/de-activation of the parallel paths is done in function of the signal level received by the mobile along its movements.

In the following, the impact of this feature will be further analysed, but something can be argued since now: a single connection is active through more than one path, each routed independently in the network.

Soft handover and macro diversity are strictly linked to each other: in the phase of the “channel change” along the handover process, the connection continuity is implicitly guaranteed through the paths multiplicity realised between the mobile terminal and the “bridging point” in the network. This mechanism relaxes the stringent time constraints that characterise the classical types of handover (e.g. the hard handover of a TDMA system) where the connection continuity is ensured through a change of frequency and time slot and a time disjunction between the activation of the two alternative paths.



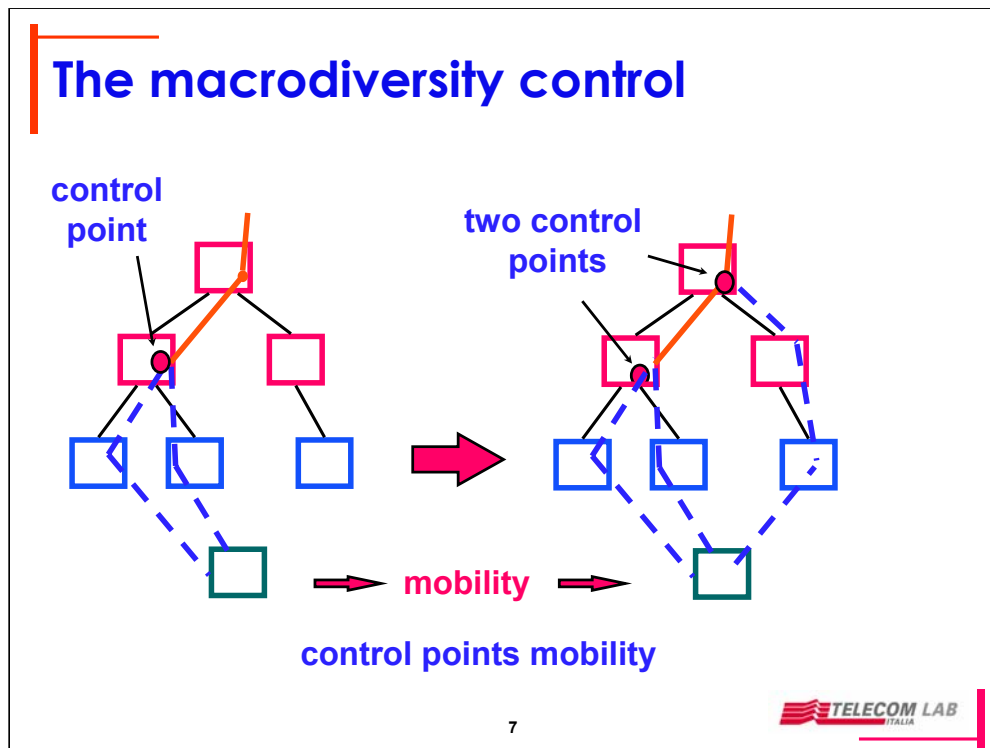
The figure summarises the main kinds of handover.

Hard handover is typically done in second generation mobile like the GSM. It implies a time disjunction between the two alternative paths involved in the handover process.

The seamless handover introduces a level of duplication of the radio resources before switching to the new path. This solution is typically implemented in TDMA systems adopting a Dynamic Channel Allocation scheme (like for instance the DECT system).

The soft handover case is introduced with the CDMA access mode; it is based on the eventuality that a single connection can be simultaneously in progress with more than one base station (macro diversity). The redundancy of the multiple connection paths is possible in CDMA schemes.

The latter kind of handover shows a significant impact on the architecture of the radio access network.



The macro diversity mechanism drives the soft handover process which is typical of the CDMA access. This mechanism guarantees the connection continuity by doubling the the active channels between the mobile terminal and an equivalent bridging point in the network. This multiple path is maintained along the connection, so that the continuity is ensured through an asynchronous acquisition/release process which relaxes the stringent time constraints characterising the handover execution in the present systems.

The set of BTSs involved in a connection which is in the macro diversity status (active set) is changing dynamically with the movements of the mobile station.

In conjunction with a change of the active set, the Radio Access Network must identify the combining/multicasting point recovering in the upper direction a single path from the multiplicity of equivalent paths in progress on the radio interface (combining) and, creating, in the downward direction, the necessary equivalent paths to be directed towards the mobile terminal (multicasting).

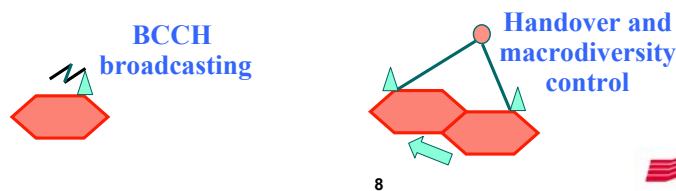
Different combining levels may be in progress along the same connection: they may base on different levels of the quality information associated with the data flow.

The quality information can be either associated

- to any single symbol (soft information) in this case the combining is done in the B-node
- or to a data packet (hard information) in this case the combining is done in the RNC.

Control functions in the Radio Access Network

- system information broadcasting (system knowledge)
- radio resource management (resource availability)
- handover and macrodiversity functions (connection continuity)
- ciphering (security)

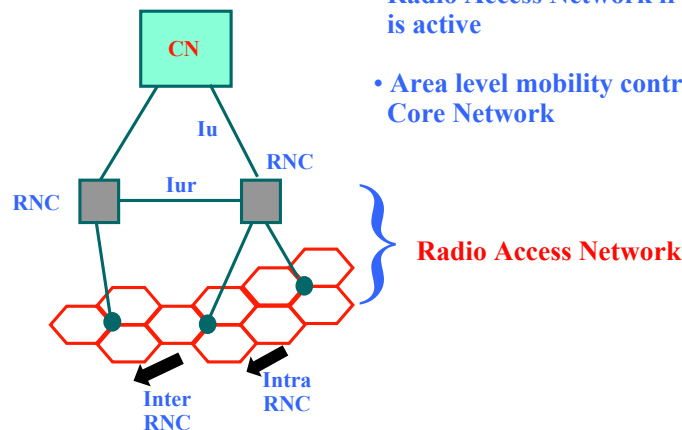


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The figure highlights the basic functions implemented in the Radio Access Network:

- transmission control of the System Information Broadcasting; this function is normally performed through General Control Channels Service Access Points (GCSAP) on the radio interface; through this information, the mobile station can recover all the needed data and parameters when roaming in a cell:
 - channels configuration adopted in the cell (RACH, FACH, PAC)
 - cell identity
 - access rights and admission control information
 - frequency band used in the cell
 - location data (e.g. location area information)
 - rules and criteria for cell selection and re-selection
 - power control data.
- ciphering and de-ciphering function; this function can be performed on the basis of ciphering and de-ciphering keys that are assigned at connection or even at session level.
- handover and macrodiversity function deem a greater attention since they affect directly the radio access network architectural choices.

Mobility handling in the Radio Access Network



- cell level mobility control within the Radio Access Network if a Dedicated Channel is active
- Area level mobility control between MS and Core Network

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In case a dedicated connection between a CN DC-SAP and the MS is in progress, the mobility can totally be managed at the Radio Access Network level and the location of MS can be temporary controlled within the Radio Network Subsystem.

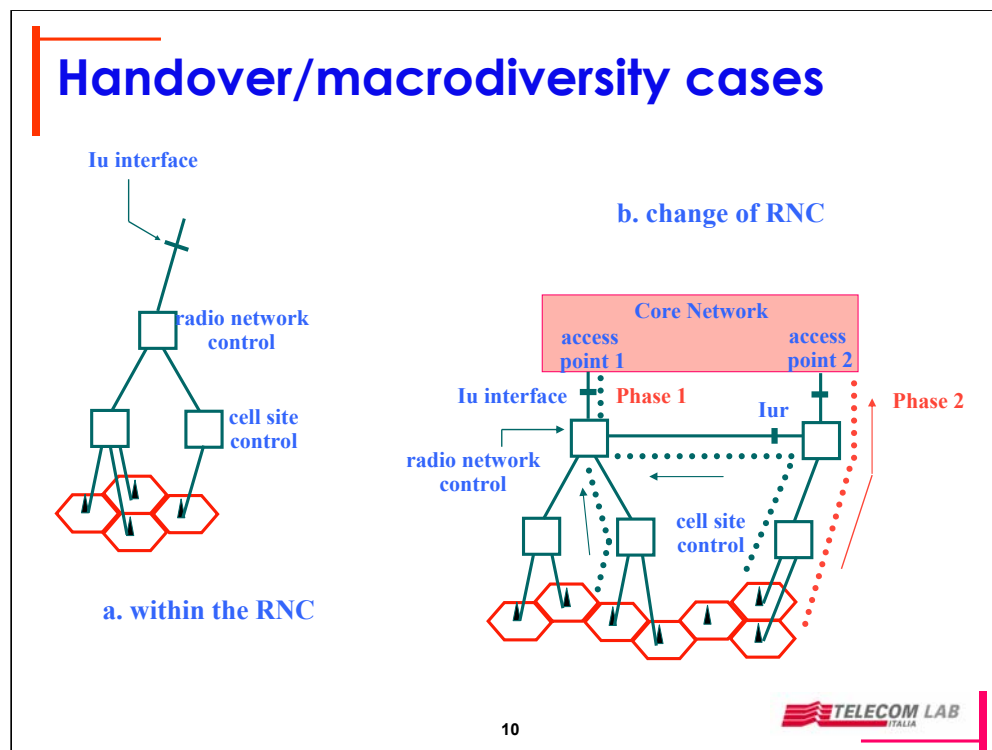
This means that a Radio Network Temporary Identifier (RNTI) must be used to identify the MS; this identifier may be used at the MAC level of the protocol.

Mobility management refers mainly to handover and macrodiversity processes; the interface Iur allows to deal with these events within the Radio Access Network even when they are involving different Radio Network Controllers.

As soon as the Dedicated Channel is released, the MS location process is passed to the Core Network, where the MS can re-register according to its present situation; mobility control remains assigned to the Core Network until MS has no connection in progress.

The above considerations assign to the RAN physical entities the handover and macro diversity related functions and the related protocols.

Handover/macrodiversity cases



In case **a.** the handover/macro diversity status involves B-nodes belonging to the same radio network controller, hence all can be solved at RNC level: a single network access point (Iu interface) with the Core Network is used along the handover/macro diversity process.

In case **b.** the handover/macro diversity status is including cells belonging to different RNCs; two phases can be envisaged in the connection control procedure between the involved RNCs:

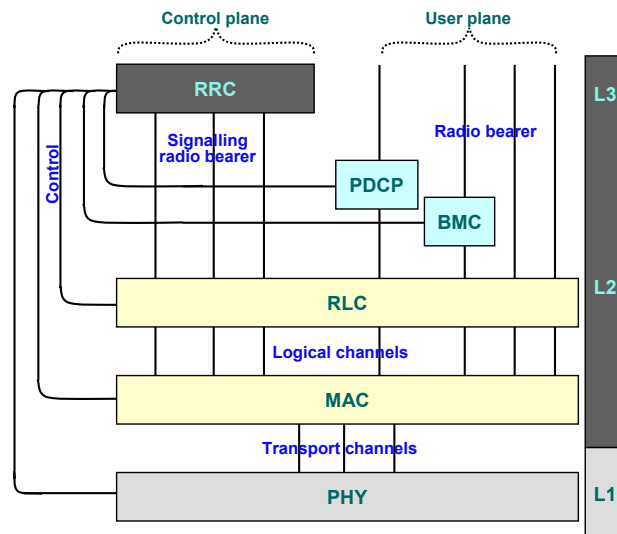
- in phase 1 the control is under the sub-network with access point 1 and the Iur interface is used to recover the secondary branch carried through the secondary sub-network (streamlining function)
- in phase 2 the control is completely passed to the access point 2, being the active branches completely under the control of the new RNC

The change of the access point implies a routing modification in the Core Network which may or may not correspond to a re-location of the call control point.

In case of re-location of the call control point, the change of the access point may trigger a routing optimisation on the fixed network side.

In the cases described in the figure, again, most of the handover/macro diversity control functions are belonging to the access part of the network.

Architecture of the UTRA FDD radio protocols



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The radio interface is composed by several protocol layers.

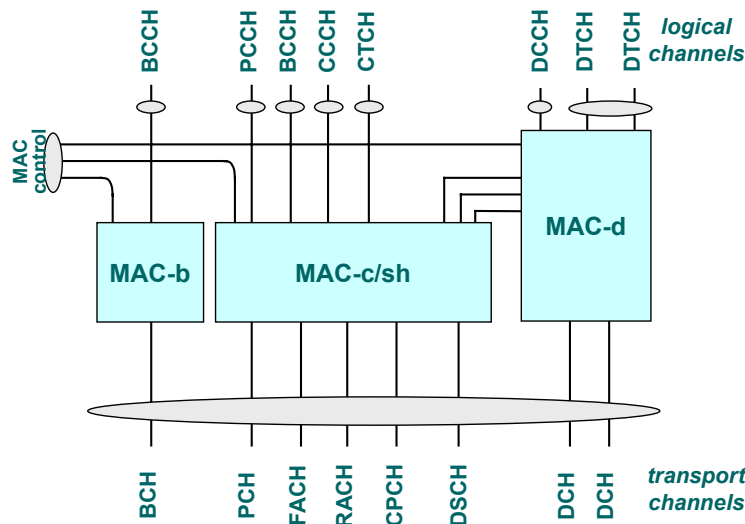
Layer 2 is the Data Link, by turn split into the Medium Access Control (MAC) and the Radio Link Control (RLC).

The Packet Data Convergence Protocol (PDCP) and the Broadcast/Multicast Control protocol (BMC) are still included in the layer 2. The former deals with the compression of the packet headers. The latter manages those messages that require either to be broadcast at the cell level or to be multicast at the same level.

Layer 3 is composed by the Radio Resource Control (RRC).

Call control, mobility management are all implemented at the upper layers and are totally independent from the radio access.

MAC architecture



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The MAC is mapping the logical channels onto the physical channels, as previously seen. Moreover, the MAC selects the transport configuration (TFI) in function of the transport requirements posed by the stream source.

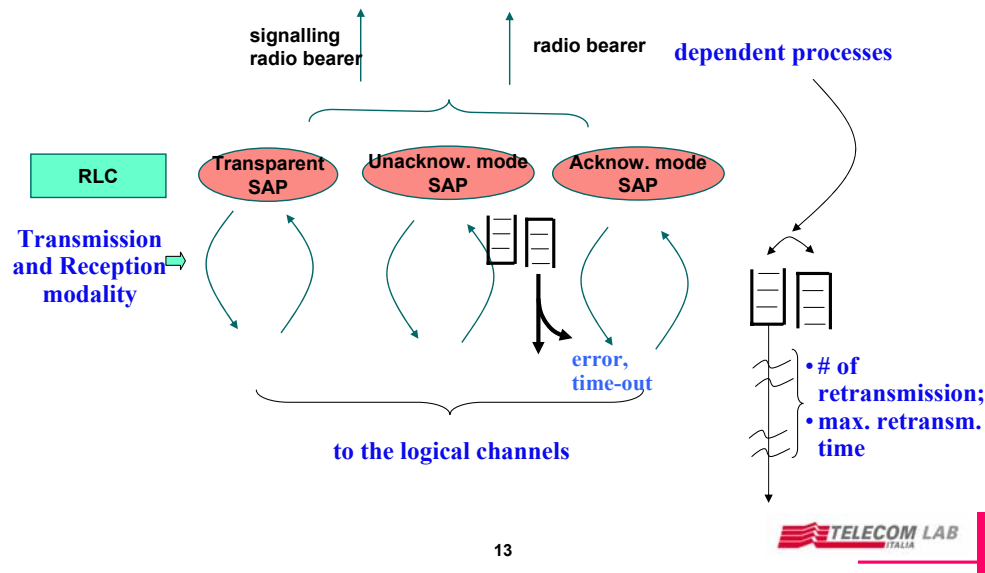
The MAC layer are respectively controlling:

- MAC-b the broadcast channel. A MAC-b instance for each cell is located in the B-node.
- MAC-c/sh the common control channels and the shared channels. The MAC-c/sh is located in the RNC. There is an instance of MAC-b/sh per each of the cells controlled by the RNC.
- MAC-d manages the dedicated channels. In the serving RNC there is an instance of MAC-b/sh per each controlled cell.

The MAC is in addition executing:

- the channel mapping
- the format choice
- the priority management among the terminal flows
- the priority management of the flows activated by different terminals
- the terminal identification on the common control channels
- the ciphering in the transparent RRC mode
- the traffic control on the transport channels and the mailing of the measures to the RRC (the latter can, as a consequence, send a radio bearer reconfiguration command).

RLC role and architecture



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The RLC level is devoted to the data and control flow retransmission.

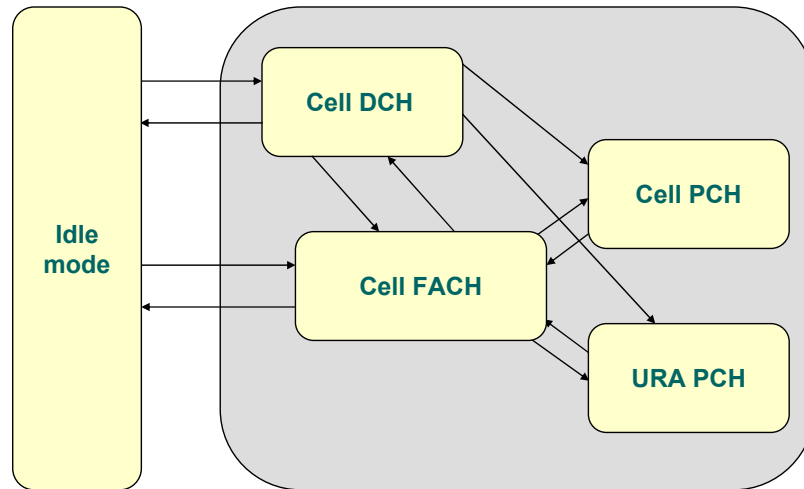
To improve the efficiency of this retransmission, a segmentation/re-assembling of the elementary flow blocks is needed.

The transmission modes that can be used by the RLS (under the RRC command) are:

- Transparent. RLC is not adding any overhead for the control/retransmission of the flow PDU
- Not acknowledged. Tx and Rx flows are dealt with independently. In both directions, RLC puts in sequence the PDUs (order #) and simply discards those that cannot be transmitted within a give time. The RLC either drops or labels the wrong PDUs (e.g *cell broadcast* service)
- Acknowledged. An ARQ mechanism is defined by RRL by specifying:
 - the Selective/non selective character
 - maximum number of retransmissions; maximum retransmission time.

The *Packet Data Convergence Protocol* and the *Broadcast/Multicast Control* are governing respectively the *header* compression for the packet traffic and the *broadcast* functions at the cell level. Both are applied at the user plane only.

States within the connected mode



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The RRC protocol implements the following functions:

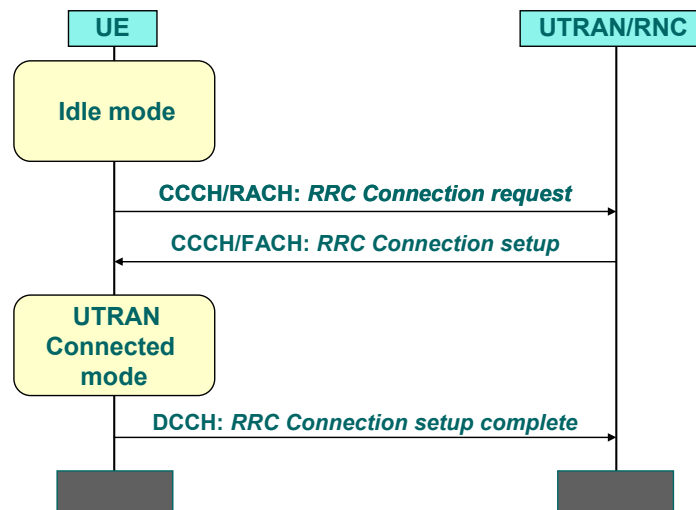
- Signalling towards the MS
- Paging and notification towards the MS
- *Broadcasting* of the system information functions (through BCCH or FACH)
- Routing of the upper layers messages (e.g. *call control*) towards the network entities governing the relevant features.

RRC can work according to two modalities: *idle* o *connected*.

In the *idle* mode, the terminal is camping over a given cell and listening to the broadcast channel over which it receives the system data. In the *idle* mode, the network ignores where the terminal is: just the paging sequence is able to trigger the relationship. Paging is performed through the MS permanent addresses (IMSI) or temporary addresses (TMSI):

- In *cell DCH* the terminal is assigned the dedicated channel (either cell specific or within an *active set*)
- In *cell-FACH* the terminal can just use RACH and FACH channels (the latter for brief messages). MS listens to the *broadcast* channel
- In *cell-PCH* listens to the PCH and the *broadcast* channel. In *cell-PCH* MS saves energy with respect to the *cell-FACH* state (*discontinuous reception*). For the cell re-selection MS must pass to the *cell-FACH* state to execute the relevant procedure.
- In *cell-URA* (Utran Registration Area) the terminal updates its position at each registration area (no cell re-selection).

RRC Connection Establishment



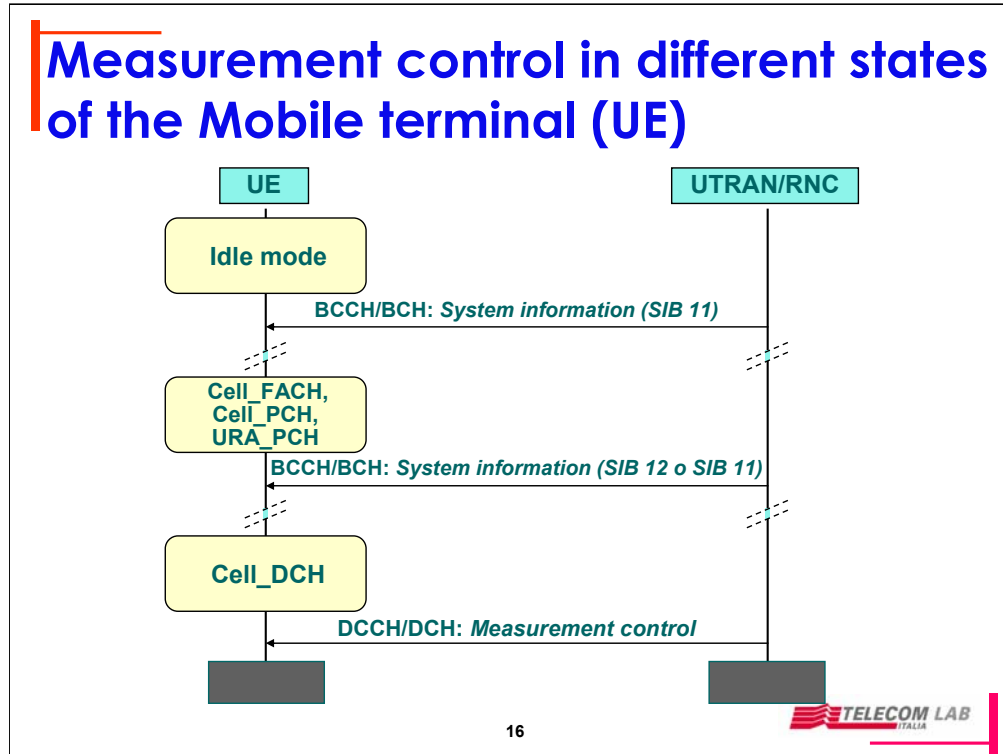
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The RRC connection is performed by the application level (through a paging if network-activated)

MS makes a random access whose outcome is the creation of a *Signalling Radio Bearer* that may be of 4 types:

- *Signalling Radio Bearer* for messages over the DCCH in non-acknowledged mode
- *Signalling Radio Bearer* for messages over the DCCH in acknowledged mode
- *Signalling Radio Bearer* for *direct transfer* messages in acknowledged mode (the distinction with respect to the previous case allows to give priority to the UE – UTRAN relation compared to the messages transported in the UE – Core Network relation (the latter being transfer through a *direct transfer*)
- *Signalling Radio Bearer* for messages (*cell update*; *UTRAN Registration Area Update*) using CCCH in a transparent mode.

Measurement control in different states of the Mobile terminal (UE)



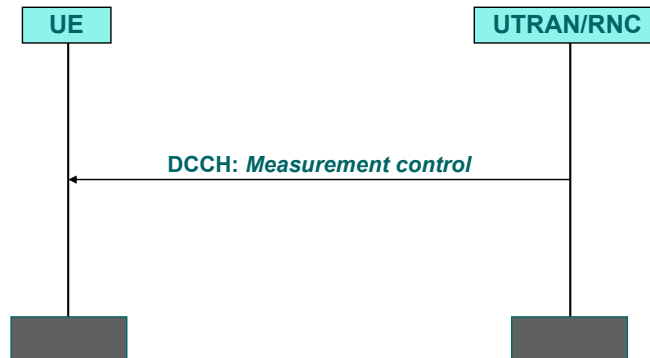
The measurement modalities are fixed by the RNC (# of contemporary measures and what measures; *reporting* mode).

The 3 cases depicted in the figure correspond to 3 terminal states. The utilized logical channels are also shown.

The measures are:

- Intra frequency (*down link* physical channels on the same *active set* frequency)
- Inter frequency (*down link* channels on frequencies different from the *active set* frequency)
- Localisation measures (e.g.: times for the *Observed Time Difference* system).

Measurement report

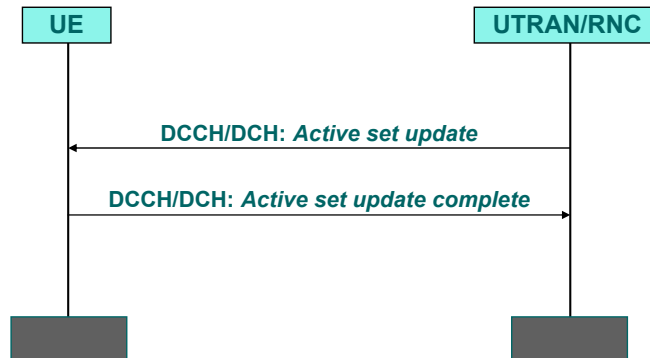


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Also the *measurement report* is activated through an RNC command.
A DCCH channel must be active.

Active Set Update



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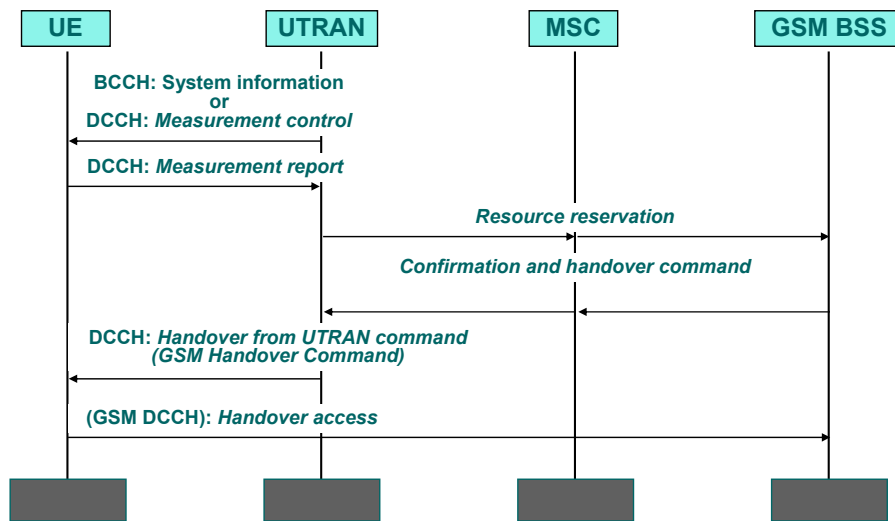
Some of the RRC procedures are strictly tied to the terminal mobility.

The figure shows the active set update procedure. It applies when the terminal is in the *cell-DCH* status.

The *Active set update* command may concern:

- a dropping of a link from the *active set*
- the insertion of a link in the *active set*
- both actions at the same time.

Inter-system Handover from UTRAN to GSM



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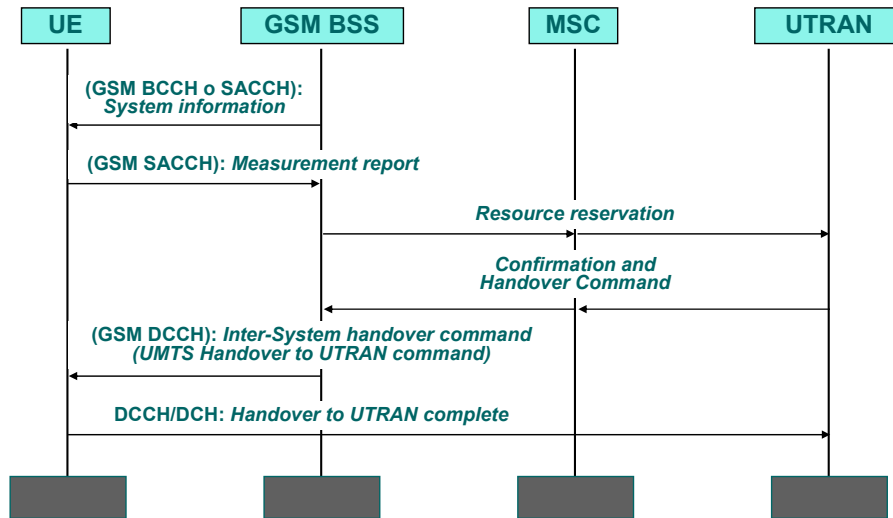
GSM and UMTS systems are strictly tied by the service transparency concept (at least until this is allowed by the service characteristics). This transparency is guaranteed up to the inter-system handover, which is applied just for the circuit-based connections.

The UTRAN-GSM handover can be executed if UE is in either of the states *cell-DCH*; *cell-FACH*.

The procedure is done through a *System information* or a *Measurement control* message informing UE about the GSM candidate cells. There is a report and a booking of the GSM resources driver by the RNC. In this phase the terminal works in *compressed mode*.

When the GSM has completed the resource booking, on the DCH UTRAN and handover execution command is sent to the UE.

Inter-system handover from GSM to UTRAN



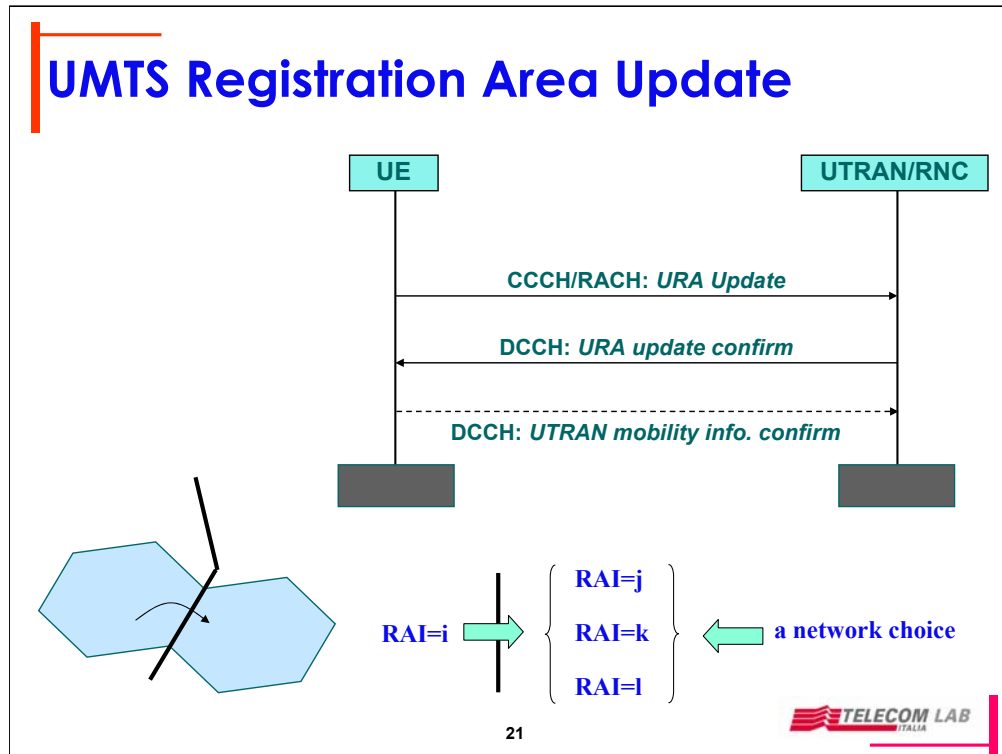
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The dual procedure (from GSM to UTRAN) is activated by a request to the dual mode terminal. It is asked to perform measurements on the UMTS interference. The request is generated by the BSC (GSM).

To this purpose, the *System information* message notified the terminal all the necessary parameters needed to measure the *broadcast* channels of the UMTS cells bordering the GSM cell hosting the MS.

Once the measures have been transported to the GSM network, the procedure follows steps that resembles those described for the dual case.



The location updating procedure is conceptually the same as the one described for the GSM.

The terminal starts the procedure over the CCCH/RACH channels whenever it recognizes that the cell it is entering belongs to a new location area (*Registration Area*).

There is for the UMTS an important improvement: the network can adopt different *Registration Area* dimensions, in function of the mobility needs of each user class (the term *class* refers to the level of mobility).

To realise this mechanism, UTRAN sends to the UE (through the BCCH of the new cell in which the UE is entering) the list of the *Registration Area* identifiers. If the list includes a single element, the terminal accepts the new *Registration Area* identifier. If, conversely, the list reports more than one identifier, the new one is specified to the UE in the *URA update confirm* message (in this case UE must confirm by turn).

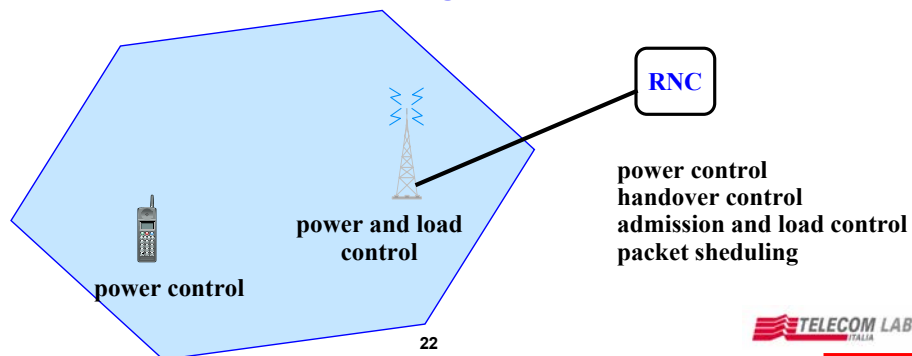
In chapter 5 it will be shown how this mechanism is important to *optimally* dimension the registration areas.

The same sequence takes place for the cell update (it may be run in correspondence to a cell re-selection and the data sending start on the up-link. Here the UTRAN can simply modify in UE the *Radio Network Temporary Identity*).

W-CDMA – Radio Resource Management

RRM – role

- Quality of Service control
- Call Admission Control and Traffic measurement
- Handover
- Power control
- Packet scheduling



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The *Radio Resource Management* functions are governing all those processes that make use in a dynamic way of the radio channels, such as defined in the previous chapters.

They are allocated in the network entities as depicted in the figure.

The interested functions, from the service quality control up to the packet management are described in greater detail in the appropriate extension sections.