Universel Mobile Telecommunications System (UMTS)

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Content

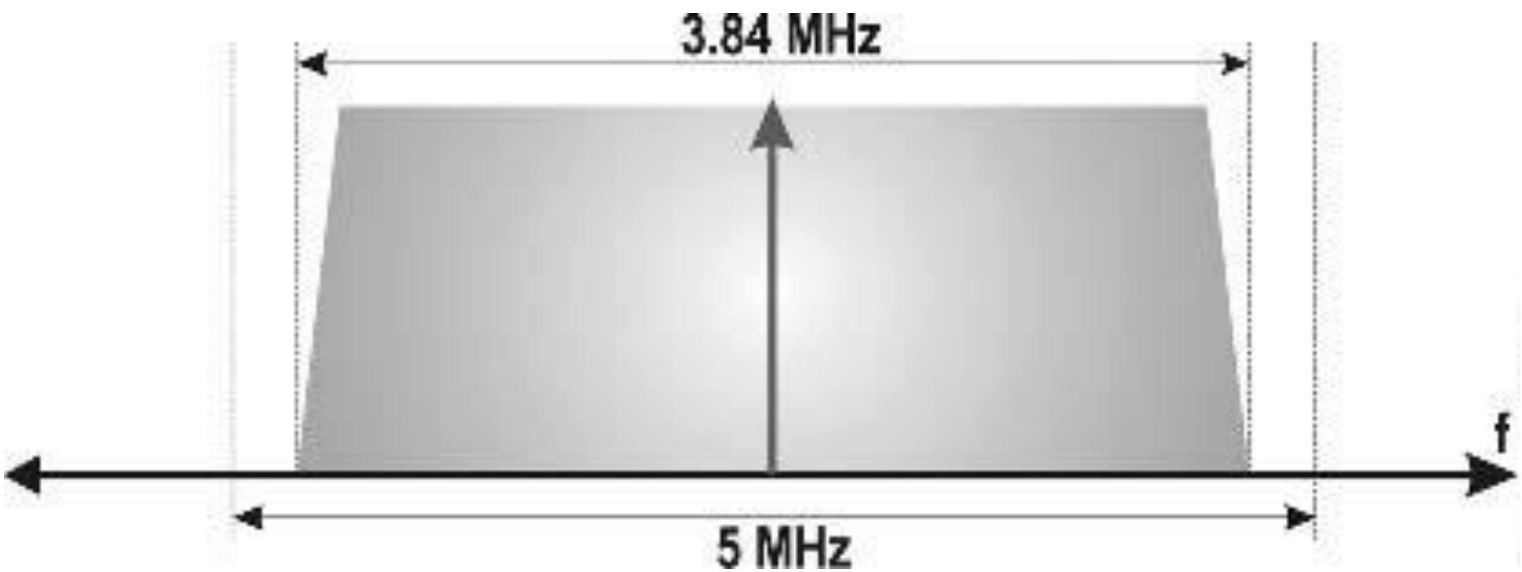
- Basic Requirements
- Network and Domain Architectures
- Core Network Functionality
- UTRAN Functionality
- UTRAN and GERAN
- Channels

Overview of UMTS Radio Access Technologies

- The main radio technology employed in UMTS is WCDMA whose variants FDD and Time Division Duplex (TDD) were selected by the European Telecommunications Institute (ETSI) in 1998.
- just like traditional CDMA, the spread spectrum forms the underlying technique for WCDMA but employing a different control channel and signalling, wider bandwidth, and a set of enhanced futures for fulfilling the requirements of 3G systems.
- The underlying technique utilised in WCDMA is the Direct Sequence Spread Spectrum (DSSS)

- At the BS, the transmitted signal with rate R is spread by combining it with a wideband spreading signal, creating a spread signal with bandwidth W.
- At the mobile, the received signal is multiplied by the same spreading signal.
- Now, if the spreading signal, locally generated at the mobile, is synchronised with the spread code/signal, the result is the original signal plus possibly some trumped-up higher frequency components which are not part of the original signal and, hence, can easily be filtered.
- If there is any undesired signal at the mobile, on the other hand, the spreading signal will affect it just as it did the original signal at the BS, spreading it to the bandwidth of the spreading signal.
- This basic process makes WCDMA more robust, flexible and resistant to interference, and solid against jamming and adversary interception.

- However, to realise its efficiency WCDMA occupies a **wider bandwidth** compared with basic CDMA.
- By benefiting from the wider bandwidth, WCDMA can use several channels in the radio interface (Uu).
- Taking into account that the effective bandwidth for a WCDMA air interface is 3.84MHz and with guard bands the required bandwidth is 5MHz



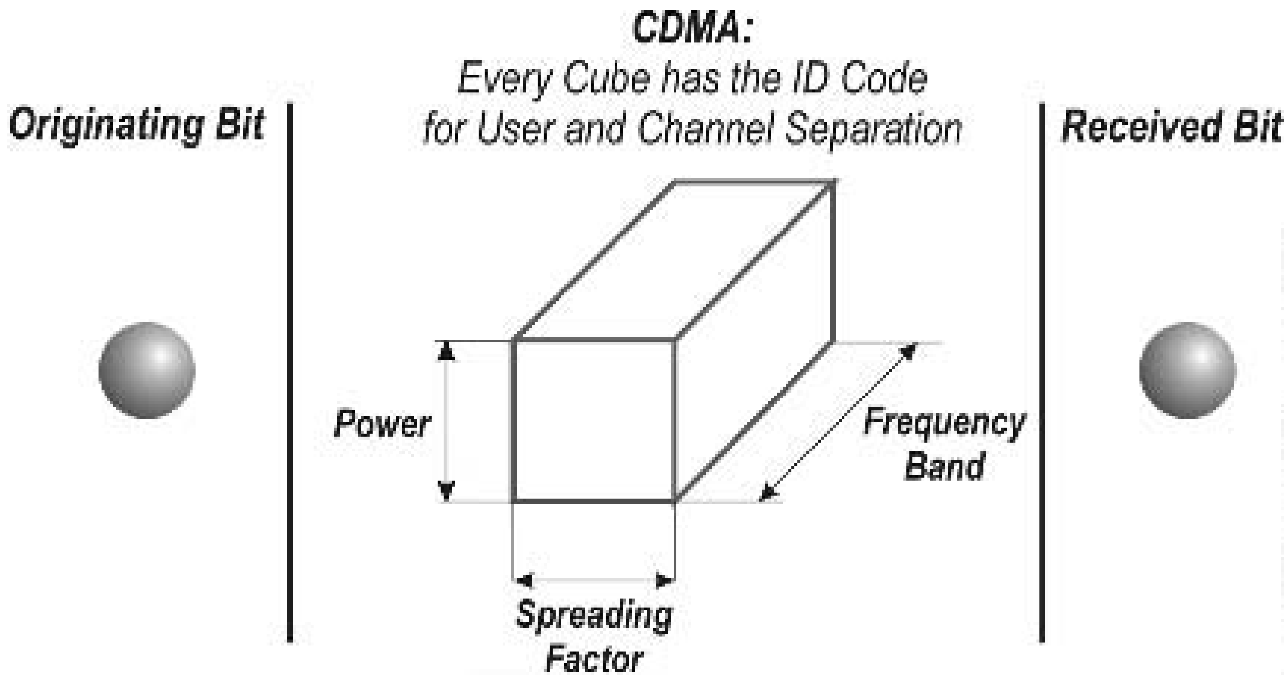
- It is also planned that WCDMA radio should be able to operate in different frequency bands as

Table 4.1 3GPP-planned FDD operating bands

Operating band	UL frequencies (UE transmit, BS receive) (MHz)	DL frequencies (UE receive, BS transmit) (MHz)
WCDMA core band	1,920–1,980	2,110–2,170
1,900 MHz	1,850–1,910	1,930–1,990
1,800 MHz	1,710–1,785	1,805–1,880
1.7/2.1 GHz (USA)	1,710–1,770	2,110–2,170
UMTS850	824–849	869–894
UMTS800 (Japan)	830–840	875–885

- As in the DS-CDMA scheme, the data signal in WCDMA is scrambled by utilising a user-specific pseudo noise (PN) code at the transmitter side to spread the signal over the entire band.
- At the receiver the received signal is extracted by using the same code sequence.
- Thus, following the basic principles of information theory, several simplified conclusions can be reached:
  - The information to be transferred represents a certain power, say P_{inf}
  - The wider the band for information transfer, the smaller the power representing transferred information in a dedicated (small) point within the information transfer band. In other words, the total power P_{inf} is an integral over the information transfer band in this case.

- The more information there is to be transferred, the more power is required. Thus, when power increases briefly P_{inf} , increases too. In this context, the higher the original bit rate to be transferred, the more power required.



- In the air interface, each originating information bit is like a ‘‘box’’ having constant volume but the dimensions of the ‘‘box’’ change depending on the case.

- we can see the depth of the “box” (frequency band) is constant in WCDMA.
- The other two dimensions, power and spreading factor are subject to change. Based on this the following conclusions can be made:
  - The better the signal can be spread, the smaller the required energy per bit (power). This can be applied if the originating bit rate is low. In other words, the spreading factor increases and power decreases
  - The smaller the spreading factor, the greater the energy required per bit (power). This is applied when the originating bit rate is high. In other words, the spreading factor increases and power decreases.

- A confusing issue with WCDMA is that a ‘‘bit’’ is not a ‘‘bit’’ in all cases.
- The term ‘‘bit’’ refers to the information bit, which is the ‘‘bit’’ that occurs in the original user data flow.
- The ‘‘bit’’ occurring in the code used for spreading is called a ‘‘chip’’. Based on this definition, we are able to present some basic items needed in WCDMA.
- The bit rate of the code used for original signal spreading is, as defined, 3.84 Mb/s.
- This value is constant for all WCDMA variants used in 3G networks
- This is called the ‘‘System Chip Rate’’ (SCR) and is expressed as 3.84 Mchip/s (megachips per second).
- With this SCR the size of one chip in time is $1/3840000 = 0.00000026041s$

- In the air interface, information is transmitted as symbols.
- Symbol flow is a result of modulation. Before modulation the user data flow consisting of bits underwent channel coding, convolutional coding and rate matching
- i.e. the cube in the middle of the picture actually represents 1 symbol.
- Depending on the modulation method used 1 symbol represents different numbers of bits

Basic Requirements of UMTS

- UMTS must provide a powerful air interface for the transmission of speech and data
- UMTS is based on an existing network infrastructure
  - Protects network operators’ investments
  - Keeps cost of new equipment as low as possible
- UMTS consists of two main components
  - Independent subnetwork for radio coverage
  - Core network, which provides routing and switching

UMTS Target Transmission Requirements

Environment	Peak Bit Rate	BER/Max Transmission Delay	
		Real-time	Non-real-time
Rural (up to 500 km/h)	144 kb/s preferably 384 kb/s	$10^{-3} – 10^{-7}$ 20-300 ms	$10^{-5} – 10^{-8}$ 150 ms or more
Urban/suburban (up to 120 km/h)	384 kb/s preferably 512 kb/s	$10^{-3} – 10^{-7}$ 20-300 ms	$10^{-5} – 10^{-8}$ 150 ms or more
Buildings/Near Zone (up to 10 km/h)	2 Mb/s	$10^{-3} – 10^{-7}$ 20-300 ms	$10^{-5} – 10^{-8}$ 150 ms or more

UMTS Air Interface

- Air interface is termed UTRA
  - UMTS Terrestrial Radio Access
- Transmission takes place in 1.9-2.2 GHz band
  - CDMA is employed
    - Flexible transmission rate and spectrally efficient
- Two different methods are employed using Wideband CDMA

  - FDD Mode: Pair of frequencies for transmission & reception

    - 1920 – 1980 MHz ↑
    - 2110 – 2170 MHz ↓

    12 channels of 5 MHz

  - TDD Mode: One frequency in both directions at different times

    1900 – 1920 MHz
    2010 – 2025 MHz

    7 Channels of 5 MHz in total

UMTS QoS Classifications

- Conversation
  - Very delay sensitive, e.g. speech, video-telephony
- Streaming
  - Delay less important, e.g. web cast, video-on-demand
- Interactive
  - Data integrity is more important than delay, e.g. On-line gaming, web browsing, database access
- Background Class
  - No specified delay, data integrity is very important, e.g. Downloading, e-mail messages

User Equipment (UE) Types

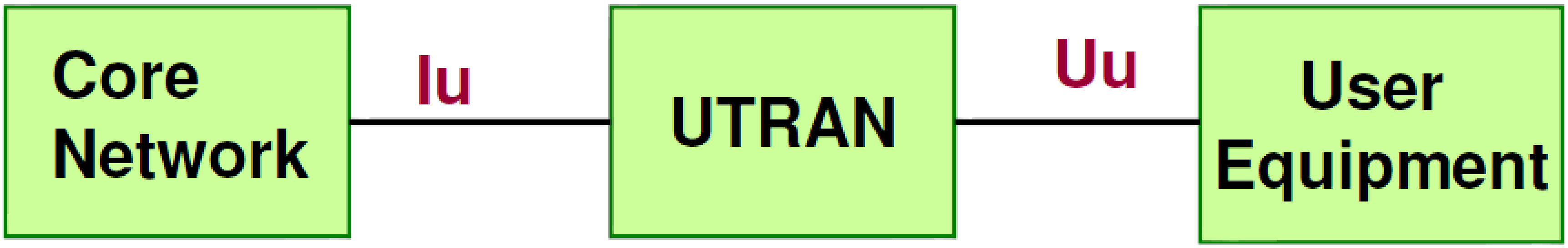
- UMTS terminals are available in a range of modes:
  - Single mode FDD or TDD
  - Dual mode FDD/TDD
  - Dual mode FDD + another radio system (e.g. GSM)
  - Dual mode TDD + another radio system (e.g. GSM)
  - Tri-mode FDD/TDD/GSM

UE Modes of Operation

- The UE can operate in three modes of operation
- Packet-Switched and Circuit-Switched mode
  - The UE is attached to both the PS and CS domains and is capable of operating, simultaneously, services in both
- Packet-Switched Mode
  - The UE is attached to the PS domain only
- Circuit-Switched Mode
  - The UE is attached to the CS domain only

Network and Domain Architectures

UMTS Network Architecture



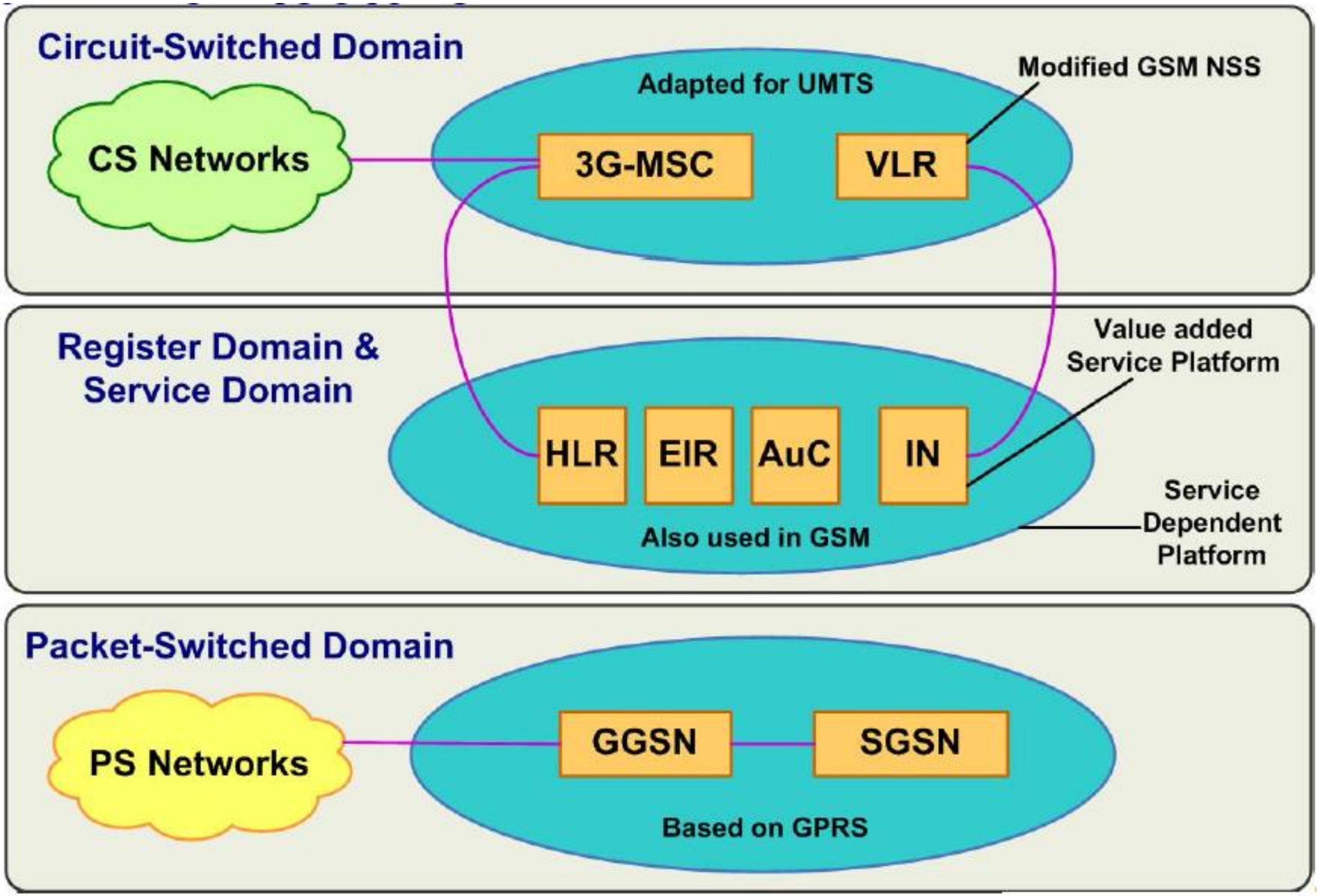
Comprises three interacting domains:

- Core Network (CN)
- UTRAN (UMTS Terrestrial Radio Access Network)
- User Equipment (UE)

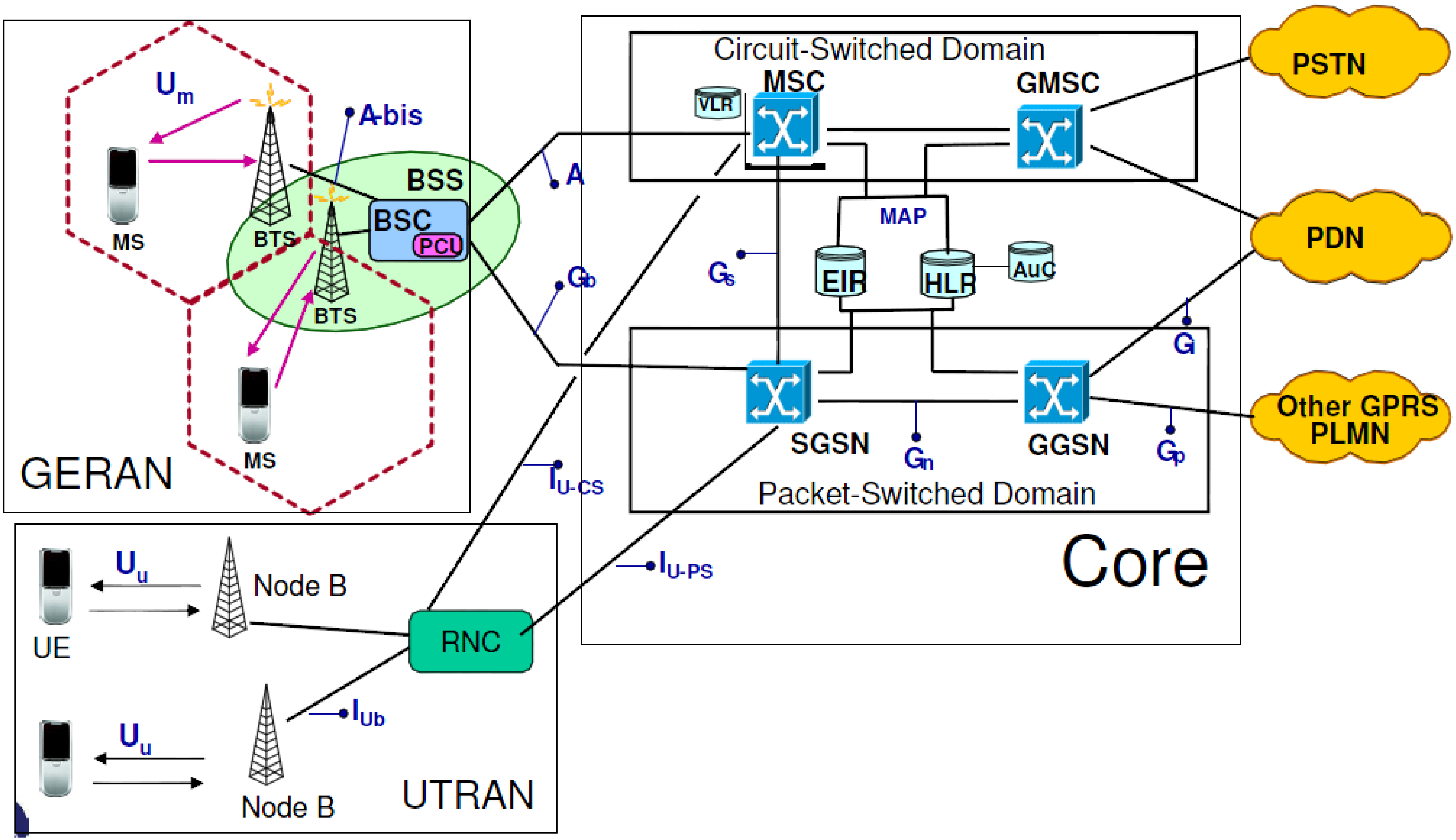
Core Network

- The core network comprises three domains
  - Circuit-Switched Domain
  - Register and Service Domain
  - Packet-Switched Domain

Domain Architecture



Architecture - GSM with GPRS and UMTS



- PLMN (Public Land Mobile Network)
  - operated by a <u>single operator</u>
  - distinguished from each other with <u>unique identities</u>
  - operational either on their own or together with other sub-networks
  - connected to other PLMNs as well as to other types of network, such as ISDN, PSTN, the Internet, etc.

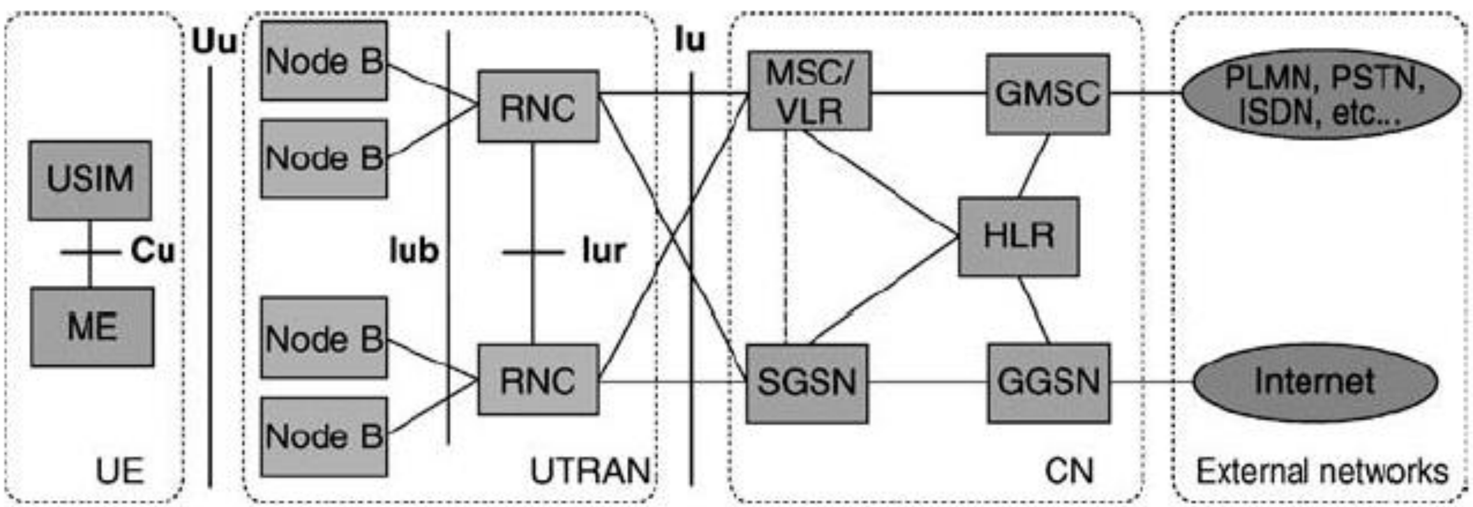


Figure 5.2. Network elements in a PLMN

- UE consists of two parts
  - Mobile Equipment (ME)
    - the radio terminal used for radio communication over Uu interface
  - UMTS Subscriber Identity Module (USIM)
    - a smartcard that holds the subscriber identity
    - performs authentication algorithms
    - stores authentication and encryption keys
    - some subscription information that is needed at the terminal

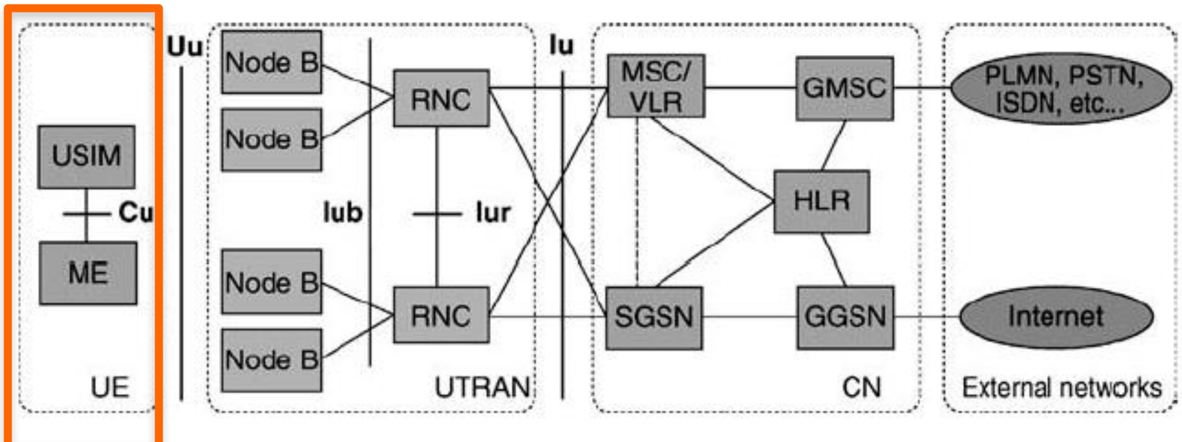


Figure 5.2. Network elements in a PLMN

- UTRAN consists of two elements
  - Node B
    - converts data flow between Iub and Uu interfaces
    - participates in radio resource management
  - Radio Network Controller (RNC)
    - owns and controls radio resources in its domain
    - the service access point (SAP) for all services that UTRAN provides the CN
      - e.g., management of connections to UE

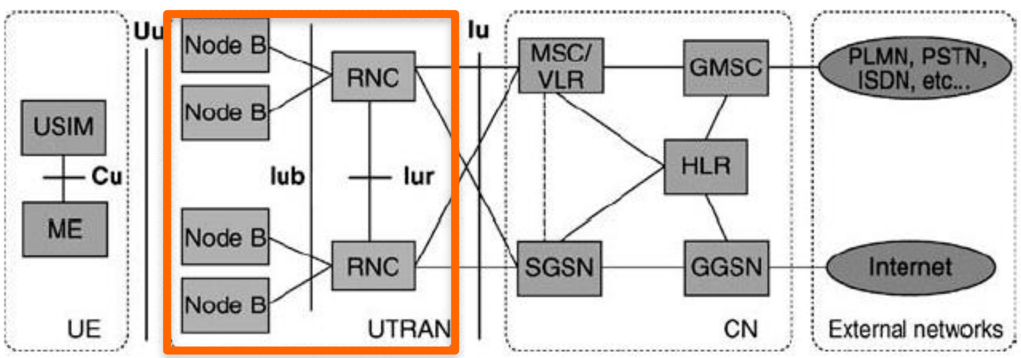


Figure 5.2. Network elements in a PLMN

- Main elements of The Core Network (CN)
  1) HLR (Home Location Register)
  2) MSC/VLR (Mobile Services Switching Centre/Visitor Location Register)
  3) GMSC (Gateway MSC)
  4) SGSN (Serving GPRS (General Packet Radio Service) Support Node)
  5) GGSN (Gateway GPRS Support Node)

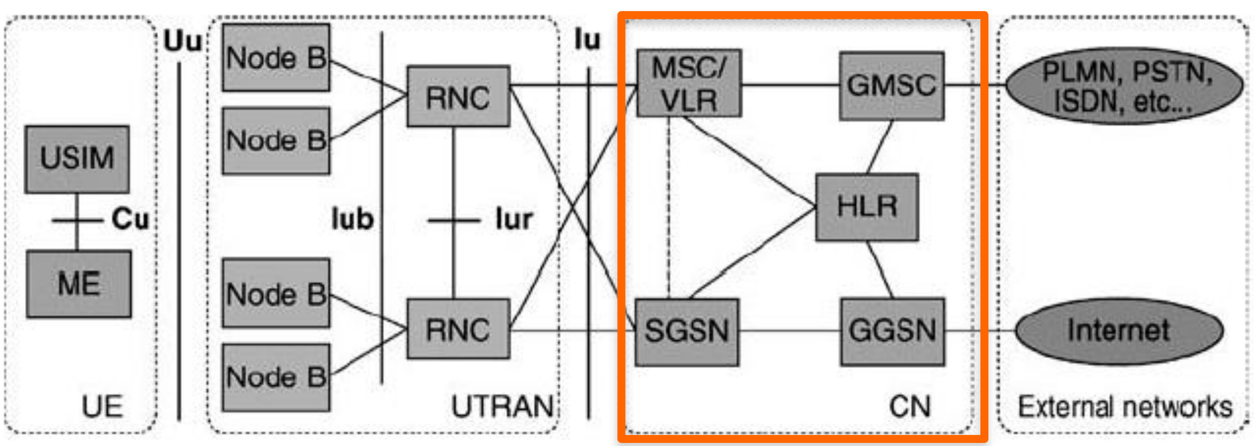


Figure 5.2. Network elements in a PLMN

1) HLR (Home Location Register)

- a database located in user's home system that stores the master copy of user's service profile
- service profile consists of, e.g.,
  - information on allowed services, forbidden roaming areas
  - supplementary service information such as status of call forwarding and the call forwarding number
- it is created when a new user subscribes to the system, and remains stored as long as the subscription is active
- for the purpose of routing incoming transactions to UE (e.g. calls or short messages)
  - HLR also stores the UE location on the level of MSC/VLR and/or SGSN

2) MSC/VLR (Mobile Services Switching Centre/Visitor Location Register)

- the switch (MSC) and database (VLR) that serve the UE in its current location for Circuit Switched (CS) services
- the part of the network that is accessed via MSC/VLR is often referred to as CS domain
- MSC
  - used to switch CS transactions
- VLR
  - holds a copy of the visiting user's service profile, as well as more precise information on the UE's location within the serving system

3) GMSC (Gateway MSC)

- the switch at the point where UMTS PLMN is connected to external CS networks
- all incoming and outgoing CS connections go through GMSC

4) SGSN (Serving GPRS (General Packet Radio Service) Support Node)

- functionality is similar to that of MSC/VLR but is typically used for Packet Switched (PS) services
- the part of the network that is accessed via SGSN is often referred to as PS domain

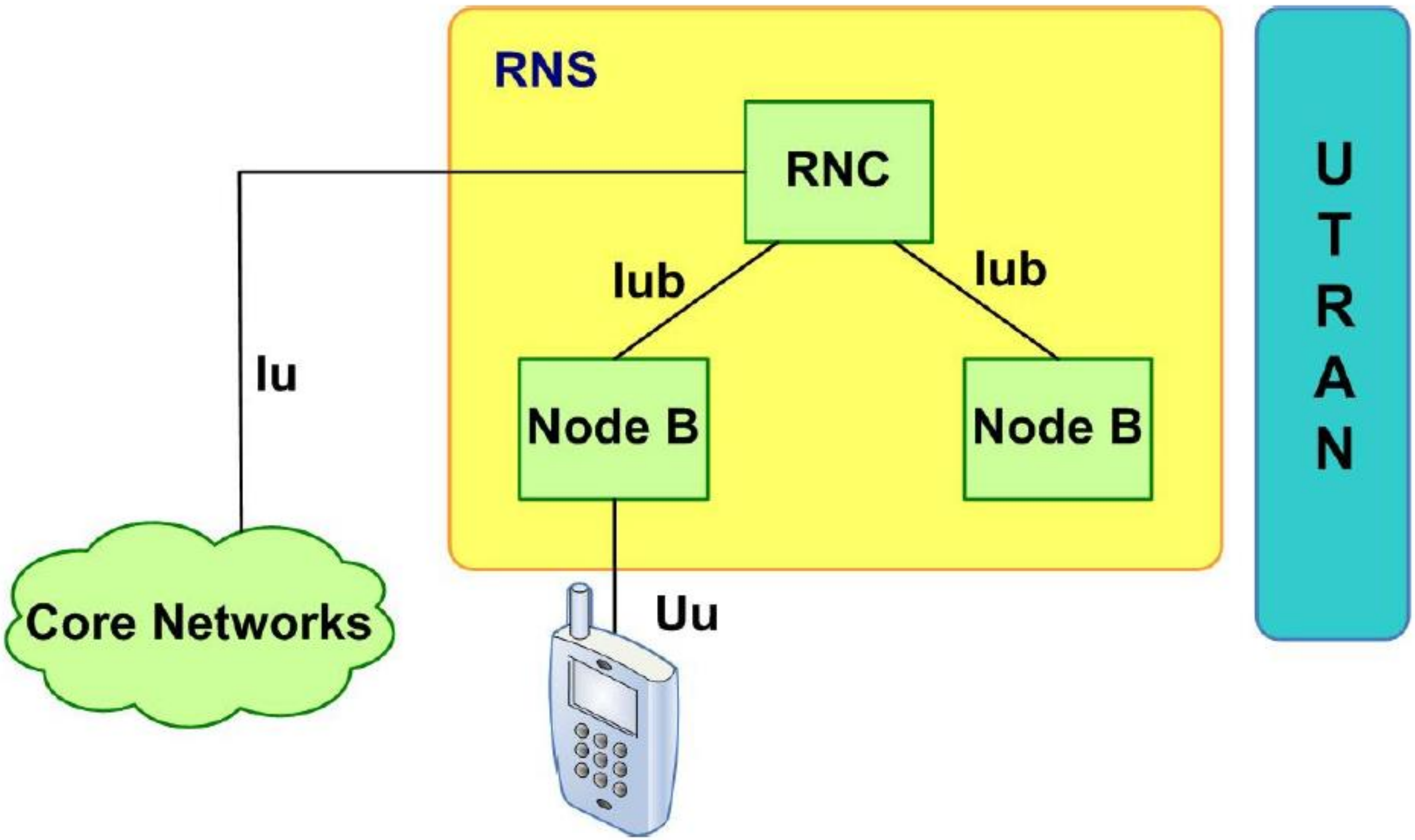
5) GGSN (Gateway GPRS Support Node)

- functionality is close to that of GMSC but is in relation to PS services

- Main open interfaces
  - Uu interface
    - the WCDMA radio interface
    - the interface through which UE accesses the fixed part of the system
    - the most important open interface in UMTS
  - Iu interface
    - connects UTRAN to CN
  - Iur interface
    - allows soft handover between RNCs
  - Iub interface
    - connects a Node B and an RNC

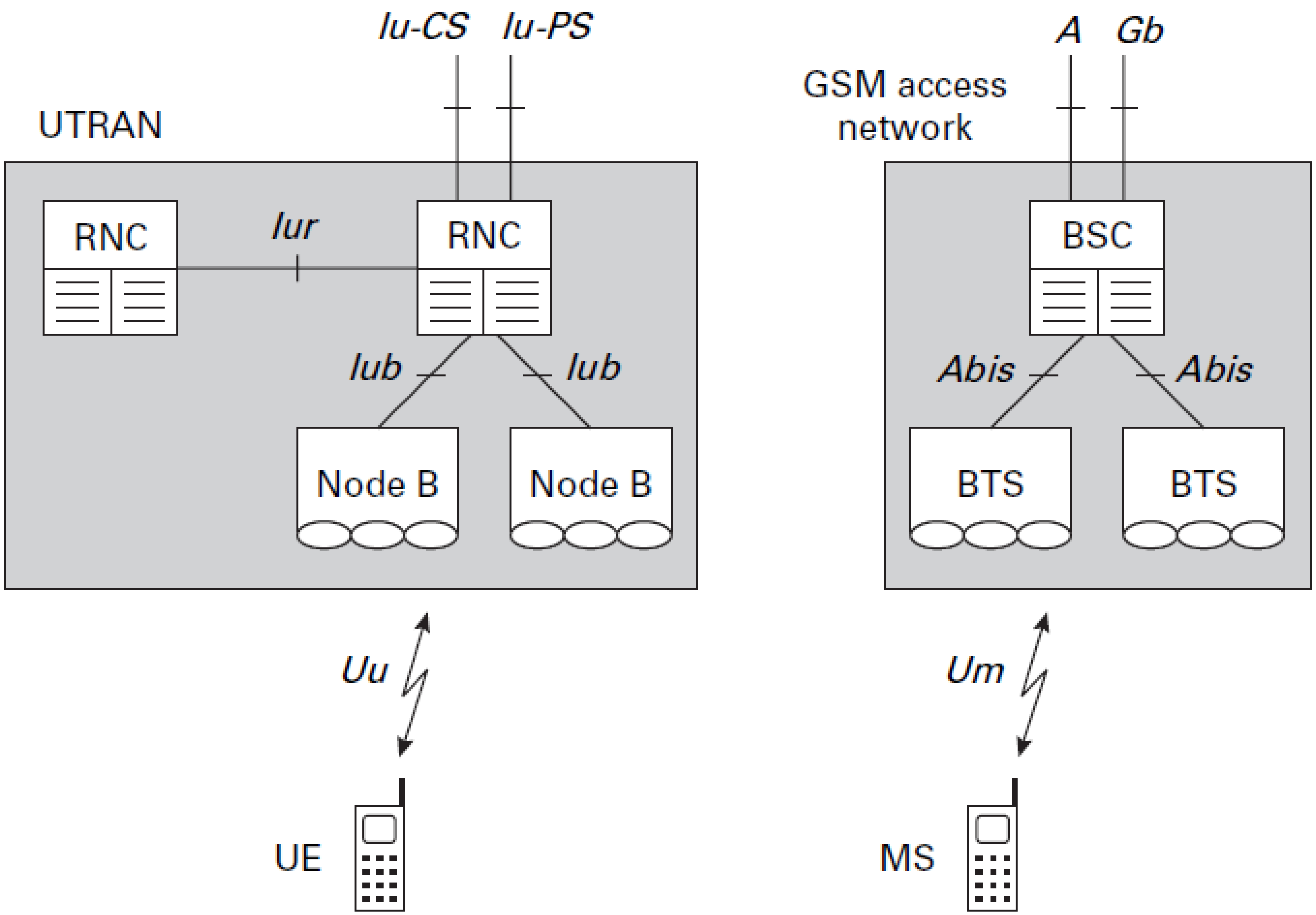
UTRAN Architecture

- UTRAN, similar to BSS in GSM, is responsible for Radio Resource Management
  - consists of one or more Radio Network Sub-systems (RNS)
- Comprises several **R**adio **N**etwork **S**ubsystems (RNS)
  - Connected to the CN via the Iu-interface
- RNS comprises:
  - Radio Network Controller (similar to BSC in GSM)
  - Several Node Bs (similar to BTS in GSM)
- RNC is connected to Node B via Iub-interface


RNS
RNC
Iub
Iub
Iu
Node B
Node B
U T R A N
Core Networks
Uu

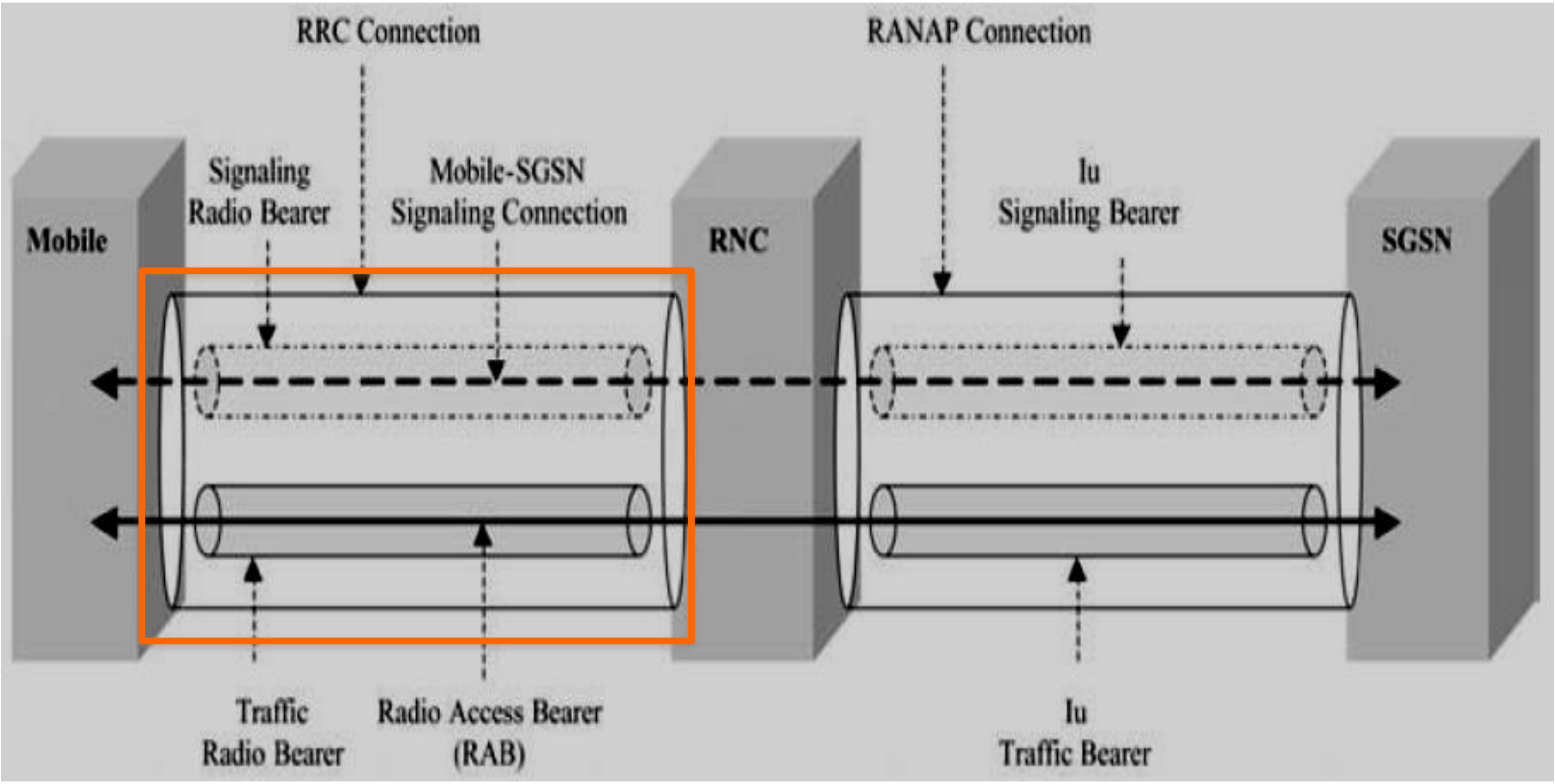
- RNCs
  - may be connected to each other via Iur interface
  - RNCs and Node Bs are connected with Iub interface
- Main characteristics of UTRAN
  - support of UTRA and all related functionality
    - support soft handover and WCDMA-specific Radio Resource Management algorithms
  - use of ATM transport as the main transport mechanism in UTRAN
  - use of IP-based transport as the alternative transport mechanism in UTRAN from Release 5 onwards

Architecture of the radio access network



- RNC (Radio Network Controller)
  - the network element responsible for radio resources control of UTRAN
  - it interfaces CN (normally to one MSC and one SGSN)
  - terminates RRC (Radio Resource Control) protocol that defines the messages and procedures between mobile and UTRAN
  - it logically corresponds to the GSM BSC
- Radio Resource Control (RRC) messages
  - the major part of the control signaling between UE and UTRAN.
  - carry all parameters required to set up, modify and release Layer 2 and Layer 1 protocol entities
- The mobility of user equipment in the connected mode is controlled by RRC signaling
  - measurements, handovers, cell updates, etc.

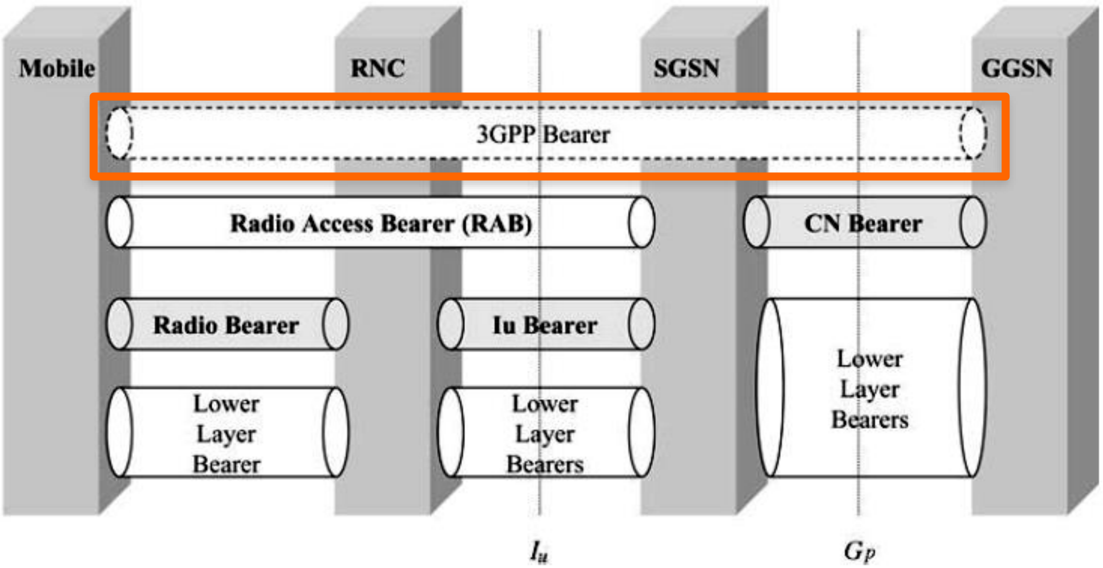
Radio Resource Control (RRC)



Traffic Bearers Structure Supporting Packet-Switched services

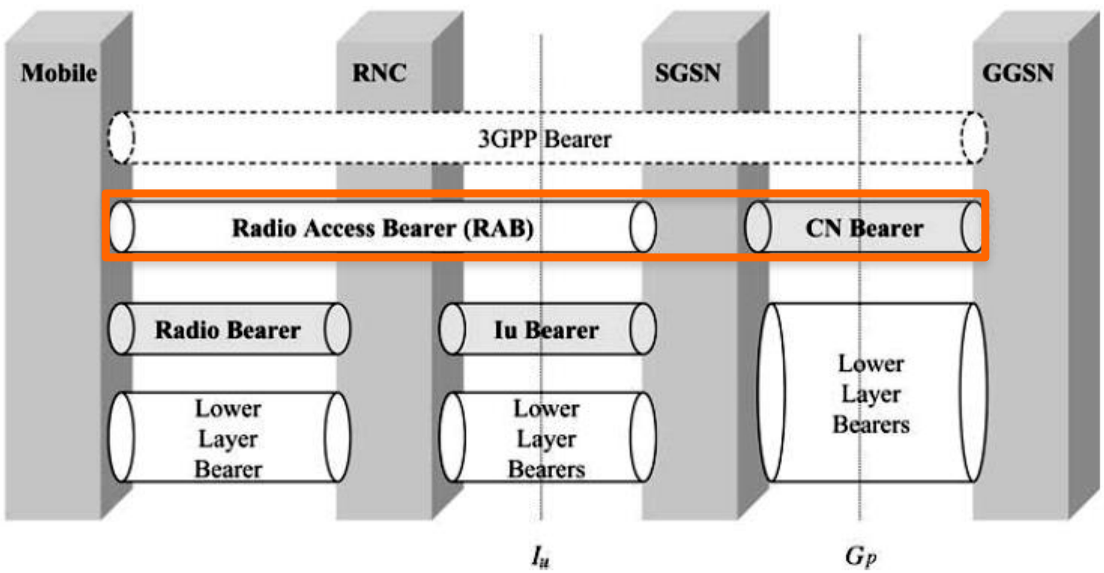
3GPP Bearer

- a dedicated path between mobile and its serving GGSN
- for a mobile to send or receive packets over a 3GPP PS CN
- a 3GPP Bearer in a UMTS network would be a UMTS Bearer



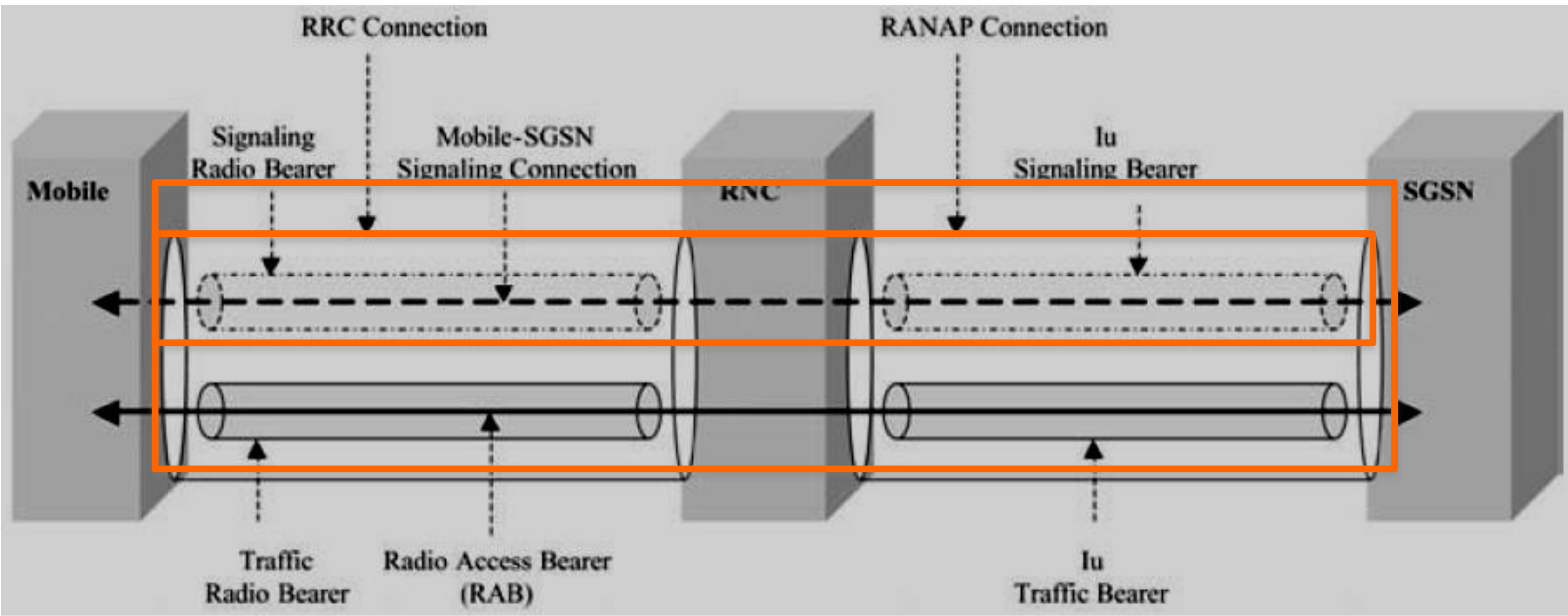
The UMTS Bearer Constructed by concatenating

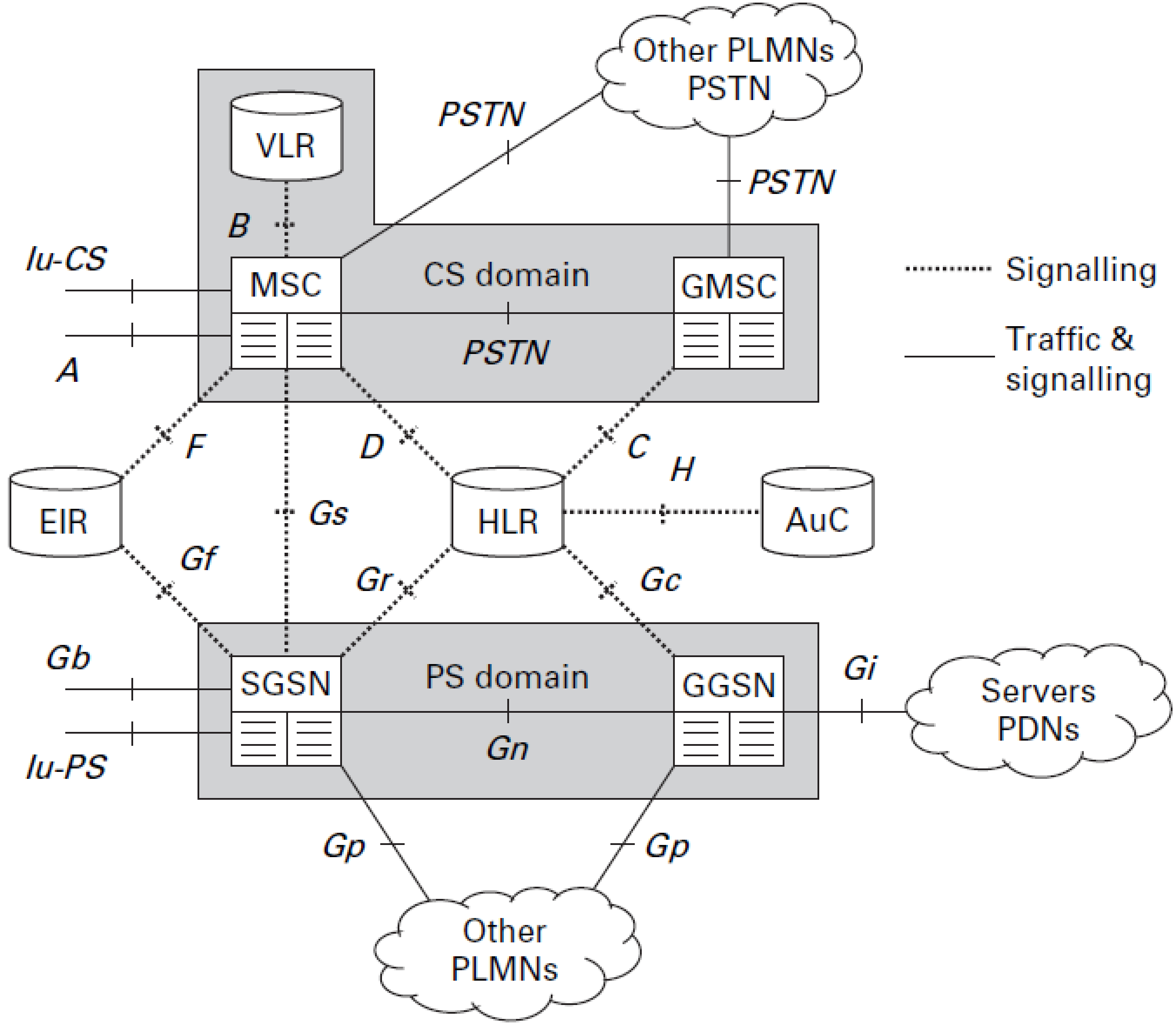
- Radio Access Bearer (RAB)
  - connects a <u>mobile</u> over a RAN to the <u>edge</u> of CN (i.e., a SGSN)
- CN Bearer
  - carries user traffic between the <u>edge</u> of CN and a <u>GGSN</u>



Signaling and traffic connections between mobile and SGSN

- The signaling connection between mobile and SGSN is constructed by concatenating
  - Signaling Radio Bearer
    - between mobile and RAN (e.g., the RNC in UTRAN)
  - I_u Signaling Bearer
    - between RAN and SGSN
- Signaling and traffic connections between mobile and SGSN
  - Radio Resource Control (RRC) connection
  - Radio Access Network Application Part (RANAP) connection


RRC Connection
RANAP Connection
Signaling
Radio Bearer
Mobile-SGSN
Signaling Connection
Iu
Signaling Bearer
Mobile
RNC
SGSN
Traffic
Radio Bearer
Radio Access Bearer
(RAB)
Iu
Traffic Bearer



Architecture of the core network in release 99

Logical role of the RNC

- The RNC controlling one Node B is indicated as the Controlling RNC (CRNC) of Node B
- Controlling RNC
  - responsible for load and congestion control of its own cells
  - executes admission control for new radio links
- In case one mobile–UTRAN connection uses resources from more than one RNS (due to handover), the RNCs involved have two separate logical roles
  - Serving RNC (SRNC)
  - Drift RNC (DRNC)

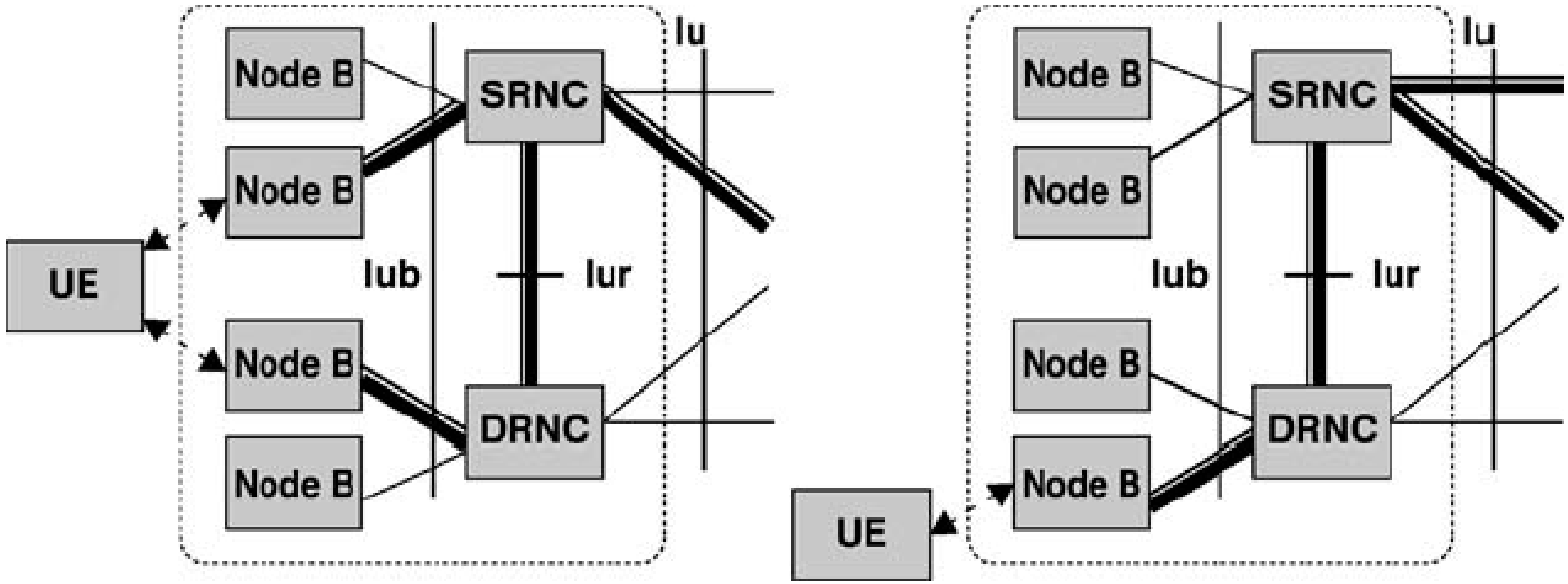


Figure 5.4. Logical role of the RNC for one UE UTRAN connection. The left-hand scenario shows one UE in inter-RNC soft handover (combining is performed in the SRNC). The right-hand scenario represents one UE using resources from one Node B only, controlled by the DRNC

- Each mobile is controlled by a particular RNC, which is known as its **serving** RNC (SRNC).
- A serving RNC exchanges signalling messages with the mobiles that it serves, and acts as their sole point of contact with the core network.
- In some situations, a serving RNC may not actually control the Node B that a mobile is communicating with. This situation is handled by introducing a third function

- <u>**Drift RNC (DRNC),**</u> DRNC is any RNC, other than the SRNC, that controls cells used by the mobile
- DRNC does not perform processing of the user plane data, but <u>routes</u> the data transparently between <u>Iub</u> and <u>Iur</u> interfaces
- one UE may have zero, one or more DRNCs

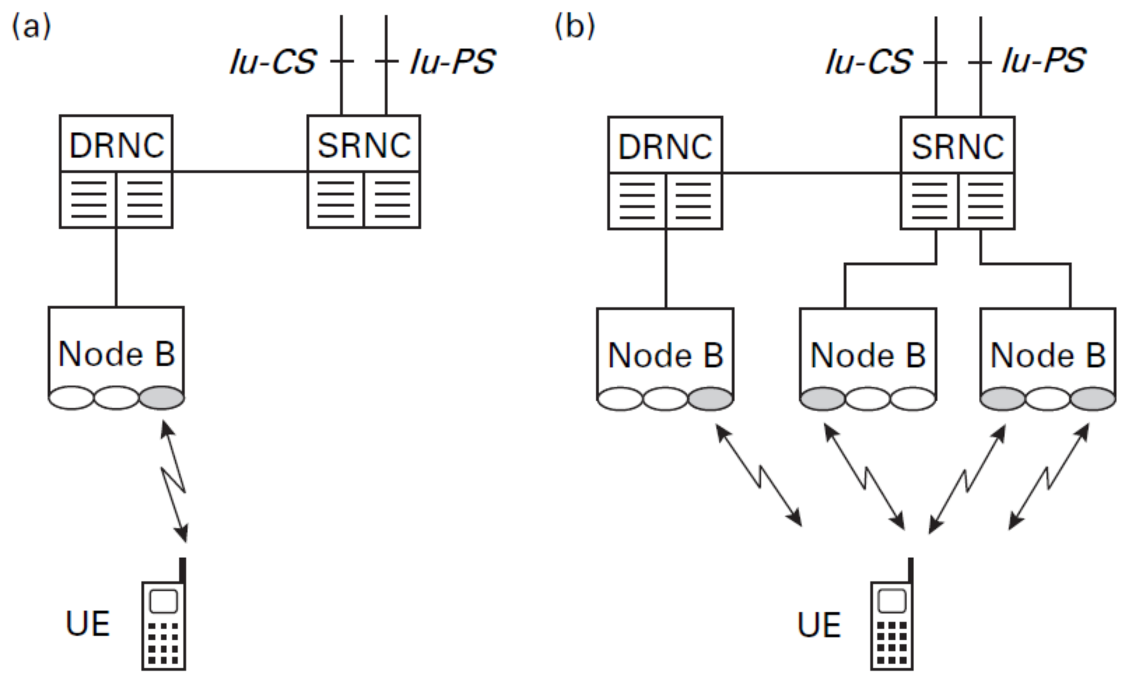


Figure 2.4 Example geometries for the air interface. (a) Use of a drift RNC. (b) Soft handover.

- The cells can be controlled by the same Node B, or by different Node Bs, or even by different RNCs. If more than one RNC is involved, then one acts as the serving RNC, and the others act as drift RNCs.
- The cells used in soft handover are collectively known as the ***active set***

- Main function of Node B
  - perform the air interface processing, e.g.,
    - channel coding and interleaving
    - rate adaptation
    - spreading
  - also performs some basic Radio Resource Management operations, e.g.
    - <u>inner</u> loop power control
- It logically corresponds to the GSM Base Station

Core Network Functionality

Core Network Functions

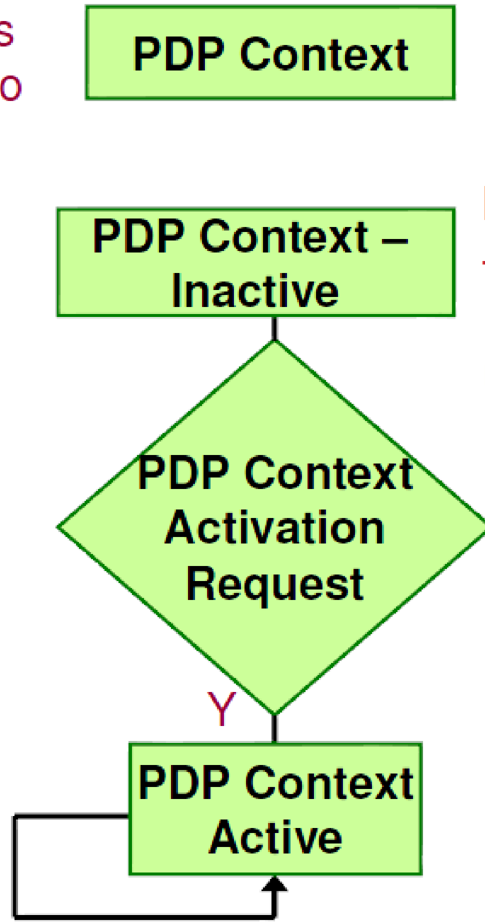
- ❑ The Core Network provides:
- ❖ Connection management
  - ➢ Bearer services and procedures for circuit-switched connection
- ❖ Session management
  - ➢ Set-up, monitoring and release of packet-switched connections
- ❖ Mobility management
  - ➢ Database location of UE

Connection Management

- Real-time services require fixed bit rate
    - Circuit-switched connection
- Radio Access Bearer (RAB)
    - Connection between UE and CN
- Core network performs set-up, modification, monitoring and release of RAB
    - UTRAN performs the function

~~Session Management~~

Includes
QoS info



Defines the set-up, management & release of a packet-switched connection

PDP Context
- modification
- activation of address#
- PDP content
- deactivation

Packet data release
- (last) PDP Context deactivation

Routing & localisation info updated as soon as UE changes Location Area

UE assigned PDP address
- terminal is reachable

Mobility Management

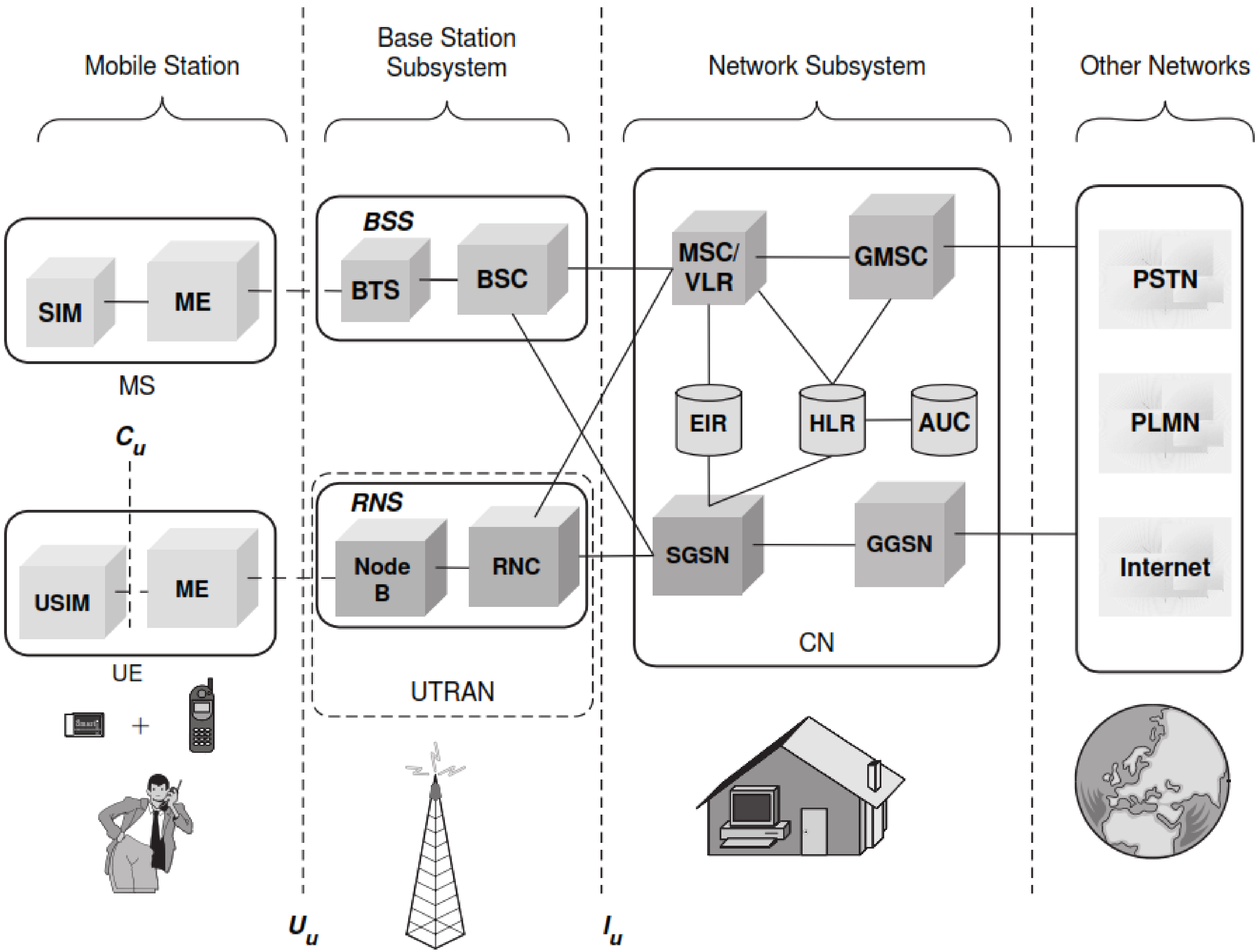
- Mobility Management (MM) is used to locate a UE so that a connection can be set up

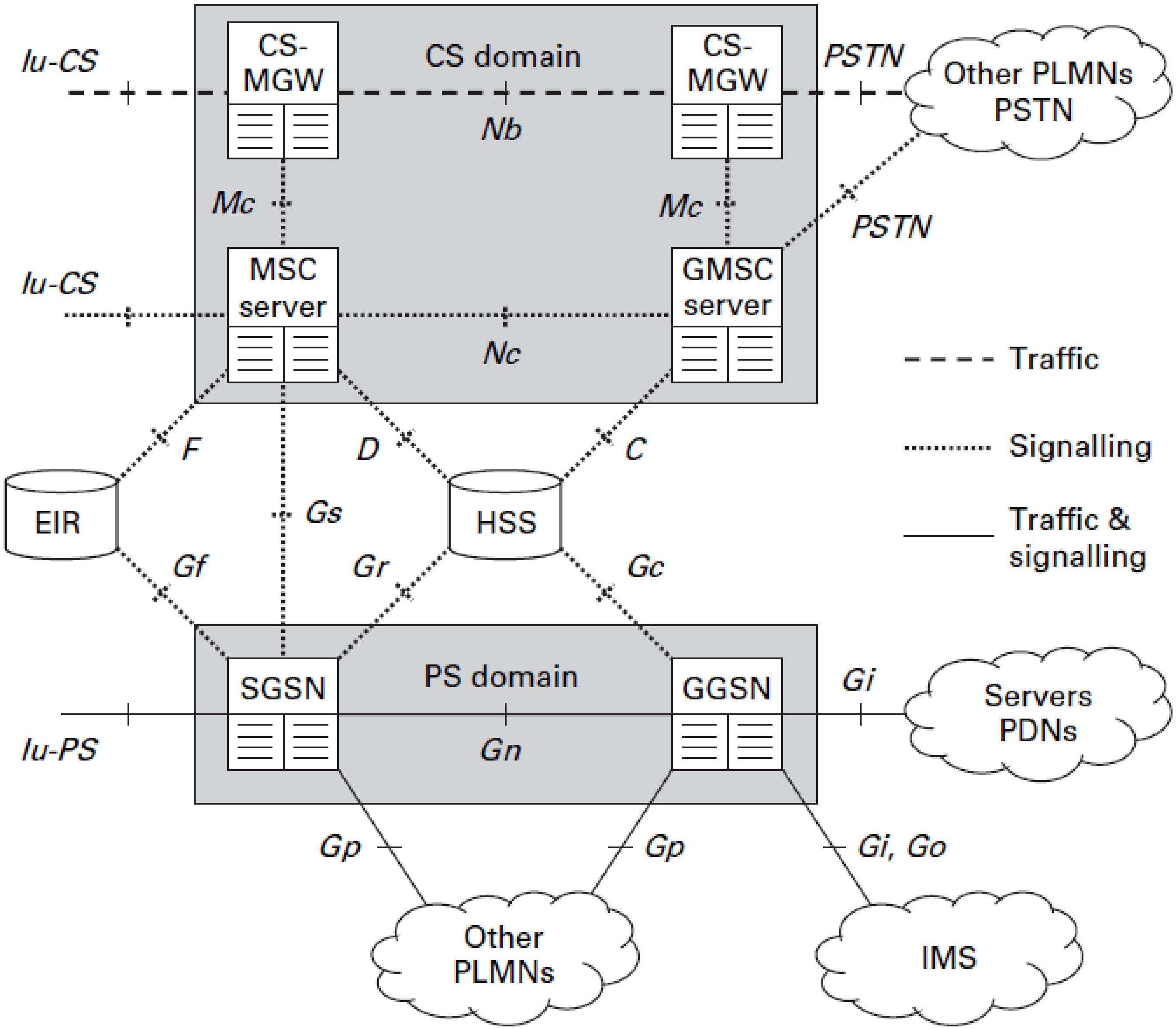
- CN recognises three UE states:
  - MM – Detached:
    - UE is switched off
  - MM – IDLE:
    - UE is not connected but signalling connection can be activated
  - MM – Connected:
    - An active connection exists

Location Update and Handover

- A UE's Location Area is stored in the Register Domain
- HLR and VLR must be updated as soon as a UE changes its location while in Idle mode
  - Called Location Update
- Handover occurs when an active UE changes its cell due to QoS of the radio link

UMTS — 3G reference architecture.



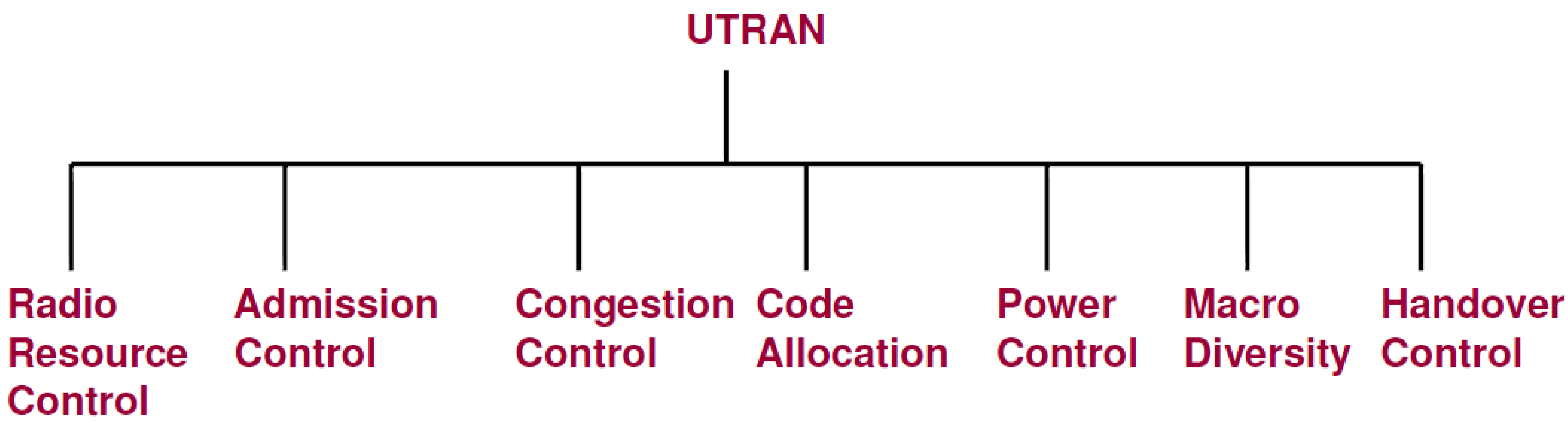


Architecture of the core network in release 7.

- In this architecture, the mobile switching centre is split in two. The circuit switched media gateway (CS-MGW) handles the traffic functions of the MSC, but uses different transport protocols. *(Release 4)*
- It also includes a media conversion function, which allows it to communicate with networks that are using other types of transport protocol.
- The MSC server combines the signalling functions of the MSC with those of the VLR, and also controls the CS-MGW over a signalling interface that lies between them.
- IP multimedia subsystem (IMS). This is an extra network which interfaces with the packet switched domain, and which provides users with real time packet switched services that cannot be supplied using the packet switched domain alone. *(Release 5)*
- The home subscriber server (HSS) combines the functions of the HLR and the AuC. *(Release 5)*

- The main enhancement in ***release 6*** is wireless local area network (WLAN) interworking.
- This allows users to access the network operator's packet switched services using a wireless LAN.
- The services are supplied either by the IMS, or by data servers that are controlled by the network operator and directly connected to a GGSN.
- *The connection uses some extra core network components that are not shown in the figure, known as the WLAN access gateway (WAG) and packet data gateway (PDG).*

UTRAN Functions



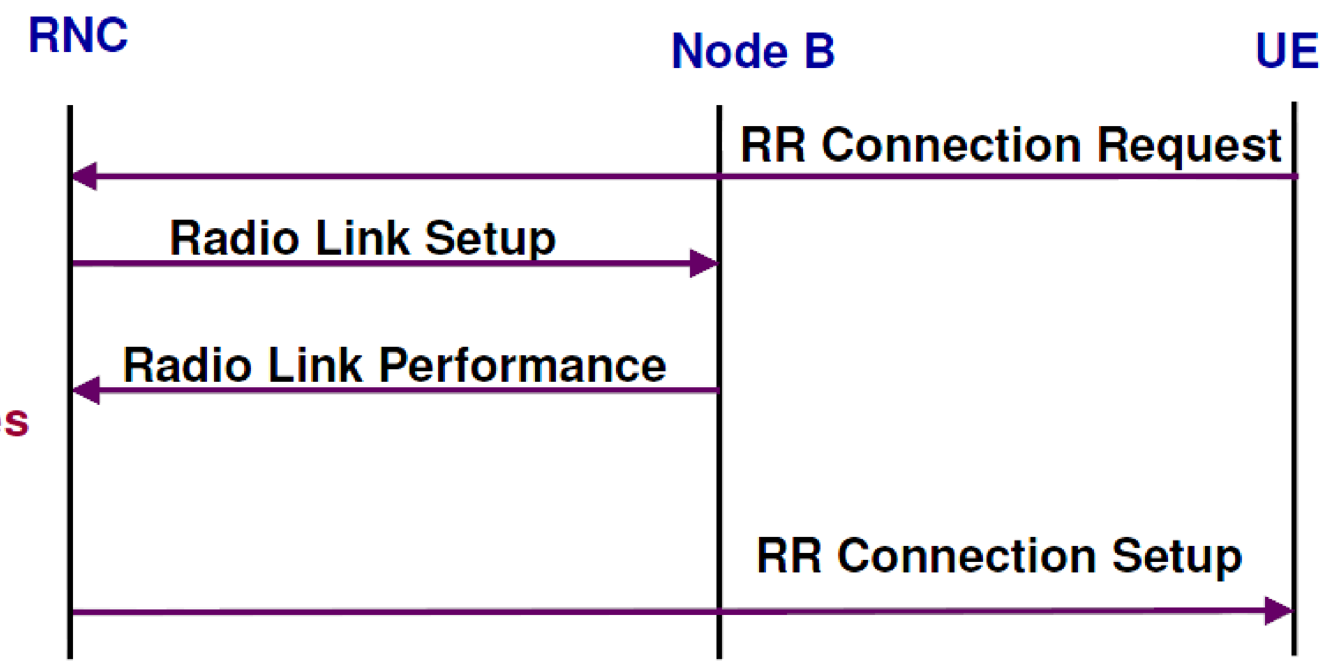
Radio Resource Control

Management & Release of Calls

Function of RNC

Setup of Mobile Originated Call (MOC)

Establish Radio Resources



Mobile Terminated Call (MTC)

Admission Control

- Measurements of interferences and net load within a cell
- RNC decides whether or not to allow further connections
  - Can delay UE access to resources if none available

Congestion Control

- Performs functions to retrieve cell overload situation
  - Force a handover to a different Node B
  - Force a handover to GSM system
  - Reduce data rate of individual active subscribers
  - Perform a controlled tear down of active connections

Code Allocation

- RNC is responsible for code allocation
- RNC constantly monitors the codes used in its Node Bs
- Codes must be unique within a cell and neighbouring cells

Power Control – Near Far Problem

- If two UEs at different distances transmit to a Node B with the equal power, the nearby UE will drown out the distant UE
  - This is near-far problem

- Power control is used to ensure that all UEs transmit with just sufficient power to be received by a Node B
- This is achieved in three ways
  - Open Loop Power Control
  - Closed Loop Power Control
  - Outer Loop Power Control

Open Loop Power Control

- Open loop power control is performed at call set up
- Node B broadcasts information about the transmit power that a UE must use when performing its first network access
- Random access to the network must be performed with lowest possible power to reduce interference

Closed Loop Power Control

- Node B takes over power control once a connection has been established
- Node B makes the UE adapt its transmit power based on:
  - Signal to interference ratio
  - Power received
- This occurs every 0.667 ms, compared with 480 ms in GSM

Outer Loop Power Control

- The RNC adapts the target signal-to-interference ratio (SIR) at Node B
  - Aim is to ensure constant transmission quality with a determined target BER or frame error rate
  - Ensures network performance is maintained
- If RNC detects SIR is worsening.
  - Target SIR is increased in Node B
  - UE gradually increases transmit power until target SIR is achieved
  - Also applies in reverse case

Handover Types

- UMTS supports two types of handover
  - Soft handover
    - Soft
    - Softer
  - Hard Handover
    - Inter-frequency
    - Inter-System

Soft Handover

- Implies that UE is connected to two or more Node Bs using the same frequency
  - This is a form of macro-diversity, where in general, selection combining is applied
- RNC combines all data received via different Nodes
  - The Node B's to which a UE is connected is known as the active set
- In opposite direction, RNC transmits data via different routes to the UE
- This method is used to improve received signal quality

Soft and Softer Handover

- Softer handover is a special type of soft handover
- Softer handover refers to connection in different sectors of the same cell
    - This is a form of macro-diversity, where in general, selection combining is applied

Hard Handover

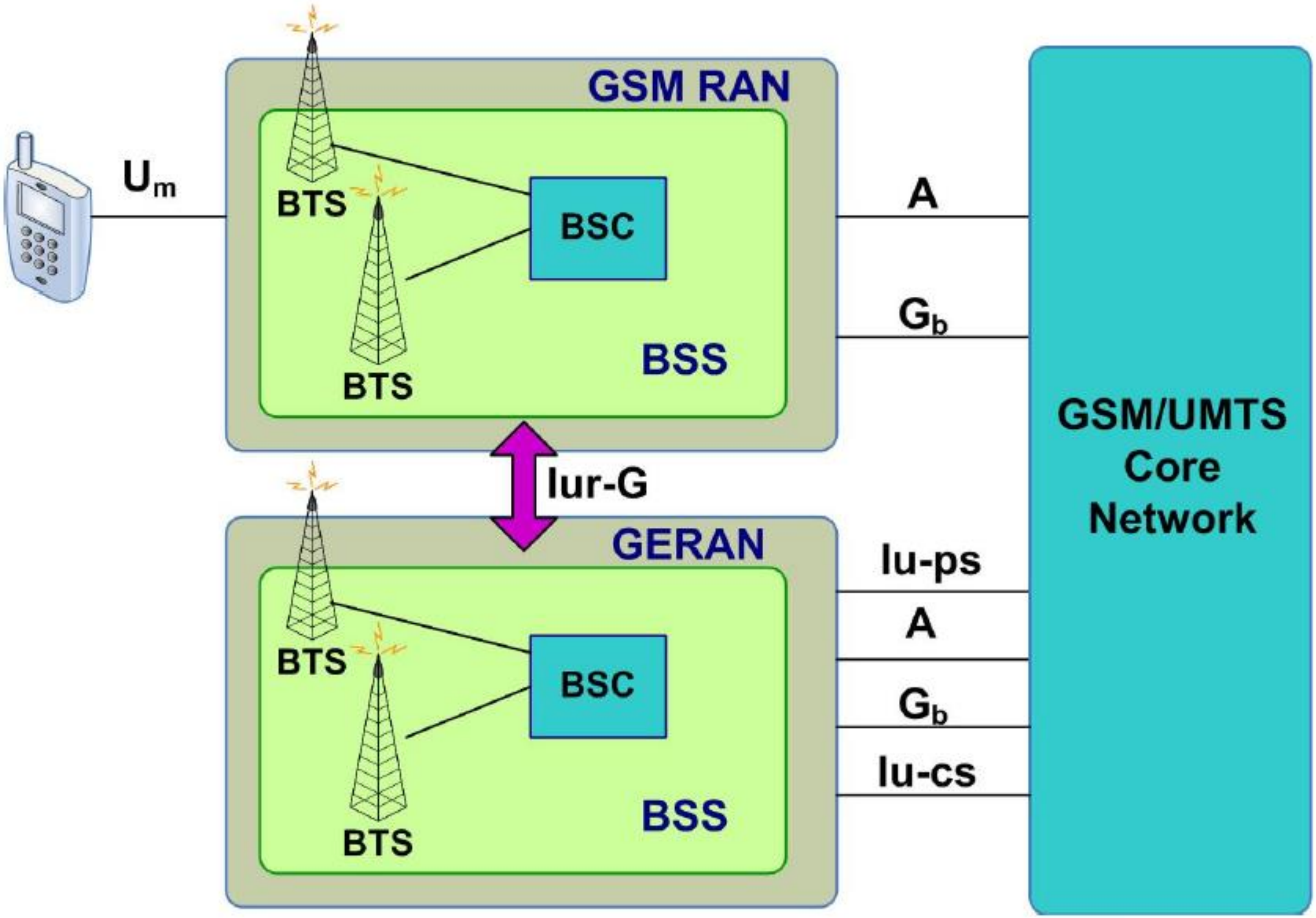
- Performed between two cells of different bearer frequencies
    - Inter-frequency handover
- UE looks for new bearer connection while maintaining existing connection
- Handover implies old radio link is released, while connection is taken over by new cell and frequency
    - No break in transmission during procedure

UTRAN and GERAN

GERAN – GSM EDGE Radio Access Network

- It is a term used to describe a GSM and EDGE (Enhanced Data rates for GSM Evolution) based 200 kHz radio access network
- GERAN is based on GSM/EDGE Release 99
- Separates the related and non-radio related functionalities between the core network and the radio access network
- Provides a common access with the 3G network through the Iu-interface and, hence, provides the same set of services as UTRAN
- GERAN supports both:
  - the Iu-ps interface towards the packet-switched domain
  - and Iu-cs interface towards the circuit-switched domain

GERAN Architecture



Benefits of GERAN

- An operator deploying GERAN and UTRAN radio technologies may operate a single core network
- Both access technologies can provide the same set of services including provision of UMTS service classes
- Network and terminal manufacturers benefit from synergies in protocols and interface implementation
- Simplifies future development and lays foundation for common all IP-Core